

CAN
Fo
46-10
CC-X
110
c. 1
ASEK

file copy - do not remove

LABORATORY TESTS AND FIELD TRIALS OF
LOW VOLUME AERIAL APPLICATIONS OF *Bacillus thuringiensis*
ORTHENE (R) COMBINATIONS AGAINST THE SPRUCE BUDWORM
Choristoneura fumiferana (Clem.)

by

O.N. Morris, J.A. Armstrong and M.J. Hildebrand

Chemical Control Research Institute
Ottawa, Ontario

Report CC-X-110

December 1975



ABSTRACT

Mixtures of Dipel 36B, a highly concentrated commercial formulation of *Bacillus thuringiensis* (B.t.), and Orthene^(R) (O,S-dimethyl phosphoramido-thioate), an organophosphorus insecticide, were applied by aircraft at volume rates varying from 2.35 l/ha to 14 l/ha (0.25 to 1.5 U.S. gallons/acre) to white spruce and balsam fir trees infested with spruce budworm, *Choristoneura fumiferana* (Clem.). All plots received 20 Billion International Units of B.t./ha (8 BIU/acre) with or without 420 g active ingredient of Orthene/ha (0.6 oz/acre). The trees on all test plots except one which had been sprayed with B.t. the previous year, were in the same state of vigor in relation to budworm density.

Drop density in the plot sprayed at 14 l/ha was 3-6 times higher than in those sprayed at 2.35 to 4.7 l/ha. Foliage protection generally increased with drop density in all formulations tested. The number of spores and crystals per drop and standard error increased linearly with drop size. An analysis of 16 B.t. aerial spray applications over a 4 year period indicated that coverage is also related to formulation used, air mass stability and relative humidity at spray time. B.t. deposits varied markedly on the 4 quadrants of the trees indicating that branch samples for population reduction and defoliation assessments should be taken from the 4 sides.

The viability of B.t. spores on white spruce foliage was drastically reduced after 1 day of weathering but a high level of biological activity by the spore crystal-complex was maintained up to 20 days post-spray probably due to the maintenance of crystal activity. The addition of about 10% of the operational rate of Orthene (i.e. 6-8 oz

AI/acre) to B.t. suspension, significantly increased budworm mortality, and reduced emergence and oviposition in the field. The B.t.-Orthene treatments did not deleteriously affect spruce budworm larval, pupal or egg parasites (mainly *Glypta fumiferanae*, *Phaogenes hariolus* and *Trichogramma* sp., respectively). The volume rate of 2.35 l/ha (0.25 GPA) was generally less effective than the higher volume rates. The 14 l/ha rate of B.t.-Orthene gave 59% protection of current growth on white spruce and balsam fir carrying low to moderate levels of budworm density. The formulation containing Dowanol TPM and Orthene applied at 2.35 l/ha gave 61% protection to current growth on heavily infested balsam fir trees, due in part to the toxicity of Dowanol. Viable egg mass density in the spray plots indicated low budworm populations for the following year.

Because of the characteristically delayed effects of B.t. and B.t.-Orthene, applications should be made in two consecutive years, particularly where populations are high.

CAN/Fo/46-10/CC-X/110
Morris, O.N. (Oswald N.)

Laboratory tests and field
trials of low volume
ASEK c. 1

LABORATORY TESTS AND FIELD TRIALS OF
LOW VOLUME AERIAL APPLICATION OF *Bacillus thuringiensis* -
ORTHENE^(R) COMBINATIONS AGAINST THE SPRUCE BUDWORM
Choristoneura fumiferana (Clem.)

by

O.N. Morris, J.A. Armstrong and M.J. Hildebrand

INTRODUCTION

The spruce budworm, *Choristoneura fumiferana* (Clem.) is known to be highly susceptible to commercial preparations of *Bacillus thuringiensis* (B.t.) (Yamvias and Angus 1970, Morris 1973a) and even more so to mixtures of B.t. and low or sublethal concentrations of chemical pesticides (Morris and Armstrong 1973, 1974; Hopewell 1974; Morris 1975a). Aerial application rates of the combinations used so far with appreciable efficiency in spruce budworm control trials range from 4.7 l/ha to 21.1 l/ha (0.5 to 2.25 U.S. gallons/acre). If B.t. is to be used economically over large areas of forests, it would be advantageous to apply even lower volume rates if the appropriate formulations and spray technology were available. The currently available commercial formulations of B.t. are not effective enough to allow this.

This report presents the results of aerial spray trials with a new highly concentrated B.t. formulation, at application rates of 2.35 l/ha to 14.0 l/ha of B.t.-Orthene^(R) (O,S-dimethyl phosphoramidothioate)

mixtures against spruce budworm on white spruce (*Picea glauca* (Moench) Voss) and balsam fir (*Abies balsamea* (L.)) at the Petawawa Forest Experiment Station, Ontario. The project was jointly supported by C.C.R.I., P.F.E.S. and Abbott Laboratories, Chicago.

MATERIALS AND METHODS

Laboratory Tests

Prior to field testing, the high potency B.t. formulation (Dipel^(R) 36B, Abbott Laboratories, Chicago, Illinois) which was to be used in the field was bioassayed in the laboratory to determine how its potency compared with the wettable powder formulation previously used. The additives to be used, viz. Sorbo (Atlas Chemical Industries, Montreal) and Dowanol TPM* (Dow Chemical Co., Midland, Michigan) were also tested for their effect on B.t. spore germination and vegetative cell replication (Morris 1975 b) and mortality of 4th instar budworm larvae when applied with or without B.t. All bioassays were done by incorporating the materials into artificial diet as previously described (Morris 1975b); see Tables 1-7).

Field Tests

The five test plots consisted of mixed white spruce and balsam fir stands varying in height from 9 to 15 m. The trees had been infested with spruce budworm for the previous 5 years but the population densities on one of the plots had been brought to a moderate level by the application of B.t. or B.t. + Orthene during the previous year (Morris and Armstrong, 1974). In that year, 20 BIU of Dipel WP + 42 g

* Tripropylene glycol methyl ether.

Orthene/ha, gave 45% defoliation on white spruce and 19% on balsam fir trees carrying pre-spray larval budworm populations of 10 and 4 per 45 cm branch tip, respectively. This treatment was used as a comparison standard in the 1975 trials.

The spray formulations and application logistics used in the present trials are summarized in Table 8. The Cessna Agtruck used was equipped with 4 AU3000 Micronair emission units calibrated to deliver droplet sizes ranging in diameter from 40-180 microns. Pre-spray budworm density and larval development were assessed one day before spray application and estimates of expected tree conditions were made, based primarily on the ratio of the number of current year's buds per m² of foliage to larval density. The method of recording meteorological conditions at spray time and during the biological assessment periods was similar to that already reported (Morris and Hildebrand, 1974). Meteorological data for the present trials are summarized in Tables 11 and 12. Deposit samples were recorded at ground level using the sample unit earlier described (Morris and Hildebrand, 1974).

The residual activity of B.t. on two open grown white spruce trees in one of the spray blocks was determined by rearing 4th instar spruce budworm larvae on branches collected from the four cardinal sides of the trees at 0 (immediately after spray), 1, 5, 10, 20 and 30 days post-spray. Three to 4 replicates of 50 larvae each were used per weathering period except for the checks in which 2 replicates of 50 were used.

Residual activity was also determined by a spore viability test. Four 10g samples of needles were stripped from the branches

collected at each sample time. To each sample was added 100 ml phosphate buffered saline plus 0.025% Tween 80 and this was shaken on a wrist action shaker for 15 min. A calibrated loop full (0.01 ml) of each wash was streaked on 3 brain heart infusion agar plates and incubated at 29°C overnight. The number of colonies developing on the media was used as an estimate of the number of viable spores per unit weight of foliage.

Estimates of budworm and non-target Lepidoptera population reduction due to treatments were based on number of larvae collected from two 45 cm branch tips per sample station (1 tree per station) within treated and untreated plots. The number of current year's buds on all sample branches were counted and corrected percent population reductions were calculated on the basis of larvae per branch, per m² of foliage and per bud. The drum method of DeBoo et al (1973) and Martineau and Benoit (1973) was used to remove larvae from the branches at all sampling times except at pre-spray when larvae were hand-picked. All dead larvae collected were diagnosed for the incidence of *B. thuringiensis*, nuclear polyhedrosis virus, microsporidia and fungus infections.

To determine the effects of the treatments on feeding activity, canvas mats 0.9 m² in area were placed under 3 white spruce trees per plot. Frass collected at the first post-spray assessment and at the end of pupation was cleaned, air-dried and weighed. The frass drop rate was calculated in mg/m²/day and related to the mean plot deposit of active ingredient and to defoliation. Fettes' (1951) branch sampling method supported by aerial color photography were used to estimate defoliation. Effects of the treatments were observed on emergence of field collected

pupae and on oviposition rate as indicated by an egg mass survey conducted at the end of the test season.

Larval parasitism was recorded at the time of budworm density assessments of all plots. In addition, a special study was conducted along the lines suggested by I.W. Varty (Maritimes Forest Research Centre N.B.) in which ten L₄ larvae collected from each of 20 white spruce trees per plot were reared on artificial diet at room temperature at 5 larvae per rearing cup. Larvae were reared to adult and all emerging parasites were identified. Percent parasitism was related to pre-spray spruce budworm density. The densities of *Apanteles* sp. and *Glypta* sp. cocoon on foliage samples used for defoliation estimates were also recorded and related to budworm population densities occurring at the pre-spray and two post-spray sampling periods.

Finally, a cost analysis of materials used and aircraft rental was made to compare cost per hectare of applying each formulation.

RESULTS AND DISCUSSION

Laboratory Tests

Results of the bioassay of Dipel 36B incorporated in artificial diet (Table 1, Fig. 1) indicated that the potency of this formulation was about the same as that of the wettable powder when compared at equivalent active ingredient (international units of potency) application rates. At 6 hr incubation time, 10% Sorbo substantially reduced B.t. replication in trypticase soy agar liquid culture but when the broth suspension was smeared on solid media, growth was normal indicating that the effect was bacteriostatic rather than bacteriocidal (Table 2). Sorbo

at 35 to 50% concentration apparently killed the vegetative cells since negligible growth occurred both in broth and on solid media (Table 2). Dowanol TPM at all concentrations tested were decidedly bacteriostatic but not bacteriocidal (Table 3). Sorbo at concentrations above 25% and 10-30% Dowanol TPM in liquid culture inhibited spore germination (Table 4). This was apparently a combination of delayed and concentration effects since 0.01 ml of broth culture spread over petri dish agar surfaces resulted in normal germination and growth.

Results of a bioassay of B.t. + Sorbo in artificial diet (Table 5) suggested a certain incompatibility of the two in terms of budworm mortality, with 50% concentration of Sorbo resulting in lower mortality than 10%. Sorbo alone, however, was not insecticidal. In a second experiment, (Table 6), 30% Sorbo, at least with the higher B.t. concentration (6400 IU/l of diet) also appeared to be slightly incompatible. A 25% concentration of Dowanol alone in diet killed 96% of the test larvae. No vegetative cells were found in larvae killed by B.t.-Dowanol combinations, indicating that the observed mortality may have been due entirely to the adjuvant or a combination of toxic crystal protein and adjuvant.

The apparent incompatibilities noted with B.t.-Sorbo and B.t.-Dowanol were shown to be at least partly due to interaction of the materials with the diet. When foliage was dipped in the combinations and fed to budworm larvae (Table 7) neither of the two adjuvants decreased B.t. potency and both reduced feeding activity when compared with B.t. alone.

Field Tests

Results of the spray plane calibration (Fig. 2) indicated that the mean number of drops/cm² for Dipel 36B + Sorbo, Dipel 36B + Dowanol TPM

and Dipel wettable powder + molasses, were 52.5 (range 11.8 to 136.0) over a distance of 60 m, 35.8 (6.2 to 159.0) over 93 m and 23.1 (0.4 to 47.0) over 39 m. Difficulty was encountered with the operation of the two outboard Micronairs during the Dipel-TPM calibration tests at 2.35 l/ha (0.25 gallons/acre) which would at least partly account for the reduced coverage. Drop sizes as indicated by mean spot sizes generally decreased with distance from the flight line.

Development of untreated budworm over the entire test period is summarized in Table 9 and development in treated areas at each population assessment period is given in the appendix. In general, larvae were mainly L₃ and L₄ at time of application.

Estimates of tree vigor based on the number of current year buds per m² of foliage indicated that with the possible exception of the Dipel WP + Orthene plot, the pre-spray tree conditions in all the test plots were similar (Table 10). The ratio of bud density to pre-spray larval density anticipated a relatively lower defoliation on the Dipel WP treatment plot than on other plots even without treatment.

Meteorological conditions at spray time were satisfactory for all spray applications (Table 11). All were done under conditions of stable air mass, temperature inversion, low windspeed, high humidity and low turbulence. Meteorological records for the two post-spray assessment periods indicated normal climatic conditions at Petawawa at that time of year (Table 12).

Deposit rates at ground level in spray plots are given in Table 13. Dipel WP + molasses applied at 14 l/ha gave the smallest average drop size and best coverage (40 drops/cm²) even with the lowest

deposit rate of active ingredient (2.47 BIU/ha). The good break-up of this spray was probably partly due to characteristics of the spray mixture. Studies on the physical behavioral characteristics of the droplets on Kromekote cards in the laboratory by W. Haliburton (C.C.R.I.) indicated that spread factor was approximately 2 at high relative humidity. The drops appeared to exhibit primary and secondary spreads, the latter due to the presence of Orthene or molasses or both. Dipel 36B + Orthene formulation gave a higher active ingredient deposit rate but poorer coverage than the wettable powder formulation. The spread factor for both Dipel-Sorbo formulations was approximately 2 at 55-57% R.H. for drops above 170 μ m diameter. There was only a slight increase in drop spread due to the presence of Orthene. The deposit rates of active ingredient and coverage rates in the Dipel-Dowanol formulation were the lowest with or without Orthene present. The physical characteristics of this latter formulation were such that it was not possible to generate small uniform drops with the rotary drop generator used for the other formulations. Small drops produced via a pneumatic nozzle and injected into a winnowing tunnel at 60% R.H. dried to non-adhering spheres if airborne for more than 2 to 3 seconds so that only a few of the larger ones made discrete spots on paper and their original sizes could not be determined because of unknown degree of evaporation. Rough data indicated a strong effect of evaporation on drops between 60 and 70 μ m diameter at 60% R.H. The spread factor of larger drops (115 μ m diameter) was about 2 with or without Orthene. Less than half as many viable spores deposited with this formulation than with Dipel-Sorbo even though the emitted rate was the same.

An analysis of the relationship between drop size and the number

of spores and crystals (Morris 1973b) indicated a linear relationship for sizes between 20 and 94 μm (Table 14). It was not possible to count spores and crystals in larger drops due to heavy concentration of the tracer dye used in the tank mixes. A comparison of all the B.t. formulations applied by us since 1973 (Table 15) showed that even under unstable spray conditions B.t.-molasses formulations deposited at ground level with greater efficiency than B.t.-Sorbo or B.t.-Dowanol.

Data on the survival of spores on white spruce (Fig. 3) showed a significant reduction in spore viability with only one day of weathering. Viability decreased steadily with time. It is known that 1 day of direct sunlight in May can inactivate over 90% of Dipel 36B spores and white spruce trees themselves (in the dark) can inactivate 78% in 14 days, (Morris and Moore 1975). A combination of the two could understandably cause rapid inactivation in the field. This phenomena is further supported by the data on spore survival on the cardinal sides of the trees (Table 16). These data also show differential deposits on the 4 sides with the north side receiving considerably heavier deposit than the others with the wind blowing in a W.N.W. direction. These results indicate that samples for determining population density and defoliation should be taken from 4 quadrants of the sprayed trees. Results of residual activity studies by spruce budworm bioassay (Table 17) did not entirely reflect foliage deposits inactivation for the reason that both spores and crystals are ingested by the larvae and ultra violet radiation does not appear to affect the crystals (Burgess et al 1975, Cantwell 1967, Morris and Moore 1975). Note however, that while substantial mortality occurred over the 30 day weathering period, a significant decrease in the incidence of B.t.

infection occurred after day 1, indicating a decline in spore activity.

Larval population reductions were generally greater on combination treatment plots than on B.t.-alone plots (Tables 18, 19, 20; Fig. 4). When pupal mortalities due to treatments were included, the total budworm mortality due to treatment was low on the Dipel WP plot probably due to very low pre-spray population densities and ranged from a low of 41% on balsam fir to 98.9% on white spruce in the other treatment plots. The three highest reductions (98.9 and 97.2 and 90.0) were on trees carrying budworm populations ranging from 0.60 to 0.89 larvae per bud (25 to 46 larvae per branch) which may have accounted in part for the high larval mortality. Orthene alone applied at 10 times the rate (420 g/ha) of that used in the combination resulted in 92.6% larval mortality on white spruce with pre-spray populations of 0.26 / bud compared with 51.5% by Dipel alone on white spruce with 0.27 larvae/bud (Table 21). Changes in actual budworm density on B.t. plots as the season progressed are presented in Fig. 4. B.t. + Orthene apparently caused high mortality of the associated species, *Dioryctria reniculella* (Table 22).

The incidence of B.t. and NPV among dead larvae collected in the test plots was generally lower than expected (Table 23). This corroborates the data on residual activity where B.t. incidence was low in spite of high larval mortality. The incidence of microsporidia was high in all plots (average 63.6%) and indicated a general increase in the Petawawa budworm population since the incidence during the previous year on 5 test plots averaged only 26%, (Morris and Armstrong 1974).

Feeding activity was lowest on the Dipel-Sorbo-Orthene plot based on the ratios of frass drop rate to larval density and to spray

deposit rate (Table 24) but this was not reflected in foliage protection probably due to high larval density. Protection on the Dipel WP + Orthene and Dipel 36B alone treatment plots carrying low population (0.25 to 0.27/bud) were 59% and 52%, respectively, and were significantly different from untreated checks (Table 25). Seventy five percent of balsam fir foliage was saved on Dipel WP + Orthene plot and 61% on the Dipel-Dowanol-Orthene plot. Note that the percentage defoliation on the check plots I and II were not significantly different. Protection of 50% or more of the current year's growth is generally considered not to seriously affect continued tree survival.

No consistent difference was observed between defoliation at the upper and middle thirds of sample tree crowns on the basis of branch sample examinations (Table 26). This is at variance with aerial photographs of defoliation taken from a helicopter on July 4 at peak browning of defoliated trees. In plots where considerable defoliation was indicated by branch tip examination, the top 1/3 or $\frac{1}{4}$ of the large trees were generally green and the lower parts reddish brown when viewed from the air. The discrepancy is probably related to the relatively small size of the sample trees. The branch-tip examination method represents a weakness in estimation of budworm damage on white spruce probably because the method was originally developed for balsam fir. Furthermore, protection of the top 1/3 of the crown is of the greatest importance since this is where growth takes place.

An analysis of the relationship between spray coverage and defoliation (Tables 27 and 28) indicated that on white spruce trees carrying 0.25 larvae per bud (14.4 per 45 cm branch) 29 drops/cm² of Dipel

WP + molasses + Orthene were required for less than 50% defoliation. The plot received an average of 48 drops/cm² for a 41% defoliation (Table 27). On balsam fir with a much lower population density (Table 28) 15 drops/cm² gave the required protection. Dipel-Sorbo-Orthene required 39 drops/cm² for acceptable protection of white spruce but the mean plot coverage was only 14. On balsam fir the mean plot coverage was 15 when 22 were required for less than 50% defoliation. White spruce trees with a larval density of 0.27/bud required about 10 drops/cm² of Dipel-Sorbo to give acceptable protection. This plot received 11 for a 48% defoliation. On balsam fir over 44 drops of this formulation were needed to give adequate protection whereas the plot received only 12. Actual plot coverage of Dipel-Dowanol TPM formulations were generally far below the level required to protect white spruce satisfactorily. On balsam fir plot coverage by the Dipel-Dowanol-Orthene (but not Dipel-Dowanol) was well within the desired range.

Based on pupal emergence data, all treatments, especially Dipel-Sorbo-Orthene, resulted in significant pupal mortality (Table 29). The differences in pupal mortality between males and females ranged from 10-53% in treatment plots compared with 15-20% in the check plots indicating that some of the formulations affected female pupae more than males. The number of viable eggs deposited in pupal rearing cages by emerged females was also lowest in the Dipel-Sorbo-Orthene treatment.

Results of the egg mass survey (Table 30) showed that field oviposition rates of viable egg masses in the two check plots were not significantly different. The oviposition rate on the Dipel-Sorbo-Orthene plot was significantly lower than that on both check plots. The density

of viable egg masses per 9.3 m² of foliage on the first 3 plots forecasts low populations of budworm in the coming year.

Data on the incidence of parasitism (Tables 31-33) indicated that the treatments had no detectable deleterious effect on larval parasitism (mainly *Glypta fumiferanae*). Pupal parasitism was generally low on all test plots with a range of 1.6 to 5.1%. The sprays had no apparent effect on pupal parasites (Table 34). Egg parasitism by *Trichogramma* sp. was not affected by the treatments and was very high in all test plots (Table 35).

Due to the delayed effects of B.t. and other microbials, it would seem that repeating treatments in two or more successive years is desirable. The Dipel WP + molasses + Orthene plot has been treated with B.t.-Orthene the previous year. Highlights of the two-year treatment are summarized in Table 36. It is apparent that the treatments continuously reduced the budworm density and maintained defoliation at acceptable levels without damaging larval, pupal or egg biotic control agents.

The data tabulated in the appendix indicate that the Dipel WP + Orthene and Dipel 36B + Orthene treatments severely delayed budworm development. About a week after spray application the percentage of budworm reaching pupation was 2-4 compared with 11-43 on the other plots.

Lastly, the cost per hectare of the 14 l/ha formulation was double the others (Table 37). Further experiments on high volume application of the high potency flowable + chemical insecticides, are warranted, since large spray operations of wettable powder formulations would be logistically more difficult and highly expensive.

CONCLUSIONS

The following conclusions were drawn from these data:

1. Moderate concentrations of Sorbo and Dowanol TPM (circa 25%) were bacteriostatic but not bacteriocidal to B.t. and did not reduce the efficacy of the pathogen.
2. Drop density in the plot sprayed at 14 l/ha was 3-6 times higher than in those sprayed at 2.35 to 4.7 l/ha. Foliage protection generally increased with drop density in all formulations tested. The number of spores and crystals per drop and standard error increased linearly with drop size. An analysis of 16 B.t. aerial spray applications over a 4 year period indicated that coverage was related to formulation used, airmass stability and relative humidity at spray time. B.t. deposits varied markedly on the 4 cardinal sides of the trees indicating that branch samples for population reduction and defoliation assessments of aerial sprays should be taken from the 4 sides.
3. The viability of B.t. spores (Dipel 36B) on open grown white spruce trees was drastically reduced after about 1 day of weathering but a high level of biological activity was maintained by the crystal spore complex up to 20 days post-spray.
4. The addition of a low concentration of Orthene to B.t. mix substantially enhanced budworm larval mortality and reduced moth emergence and oviposition. The treatment effectively reduced the population density of *Dioryctria reniculella*, an important lepidopterous defoliator associated with budworm.

5. The estimation of budworm density based on an 18" branch tip unit is less desirable than number-per-bud basis for microbial control tests.
6. Because of the characteristically delayed effects of microbial control agents, B.t. or B.t.-chemical insecticide combinations should give acceptable foliage protection if applied to the same plot two successive years, particularly where budworm populations are high.
7. B.t. + a low concentration of Orthene did not deteriorously affect larval, pupal or egg parasitism (mainly *Glypta fumiferanae*, *Phaeogenes hariolus* and *Trichogramma* sp., respectively).
8. Volume rates of 0.5 to 1.5 GPA appear to be generally more effective than 0.25 GPA against spruce budworm. Viable egg mass density in spray plots indicated low budworm populations for the following year.
9. The Dipel wettable powder of B.t. was twice as costly to apply as flowable concentrates and is logistically more difficult to handle in large scale operations.

ACKNOWLEDGEMENTS

We wish to thank W. Haliburton (C.C.R.I.) for his study of the physical characteristics of the spray mixes, W.W. Hopewell (C.C.R.I.) for technical assistance in the colorimetric analysis of the spray droplets, Abbott Laboratories and the management of the Petawawa Forest Experiment Station for their material and technical help; A. Moore and B. McErlane of C.C.R.I. and the Algonquin College summer students for a variety of assistance during the course of the field project. Thanks also go to

Dr I.W. Varty and Mr Fred Titus, Maritimes Forest Research Centre for their valuable help in identifying the parasites.

REFERENCES

- BURGESS, H.D., S. HILLYER and D.O. CHANTER, 1975. Effect of ultraviolet and gamma rays on the activity of delta-endotoxin protein crystals of *Bacillus thuringiensis*. J. Invertebr. Pathol. 25, 5-9.
- DEBOO, R.F., L.M. CAMPBELL and A.G. COPEMAN, 1973. A sampling technique for estimating numerical trends in larval populations of insect defoliators on conifers. I. Development and experimental evaluation of the technique. Phytoprotection 54, 9-22.
- CANTWELL, G.E., 1967. Inactivation of biological insecticides by irradiation. J. Invertebr. Pathol. 9: 138-140.
- FETTES, J.J., 1951. Investigations of sampling techniques for population studies of spruce budworm on balsam fir in Ontario. Ph.D. Thesis, Univ. of Toronto, 212 pp.
- HOPEWELL, W.W., 1974. Simulated aerial sprays in a young white spruce plantation, Shawville, Quebec. Section B. in "Evaluation of commercial preparations of *Bacillus thuringiensis* with and without chitinase against spruce budworm. Chemical Control Research Inst. Report CC-X-59.
- MARTINEAU, R. and P. BENOIT, 1973. A sampling technique for estimating numerical trends in larval populations of insect defoliators on conifers. II. Modification and operational use of the technique for extensive sampling of spruce budworm populations in Quebec. Phytoprotection 54: 23-31.

- MORRIS, O.N., 1973a. Dosage - mortality studies with commercial *Bacillus thuringiensis* sprayed in a modified Potter's tower against some forest insects. J. Invertebr. Pathol. 22: 108-114.
- MORRIS, O.N., 1973b. A method of visualizing and assessing deposits of aerially sprayed insect microbes. J. Invertebr. Pathol. 22: 115-121.
- MORRIS, O.N., 1975a. Susceptibility of the spruce budworm, *Choristoneura fumiferana*, and the white marked tussock moth, *Orgyia leucostigmata*, to *Bacillus thuringiensis*: chemical insecticide combinations. J. Invertebr. Pathol. 29: 193-198.
- MORRIS, O.N., 1975b. Effect of some chemical insecticides on the germination and replication of commercial *Bacillus thuringiensis*. J. Invertebr. Pathol. 26: 199-204.
- MORRIS, O.N. and J.A. ARMSTRONG, 1973. Aerial application of *Bacillus thuringiensis* - fenitrothion combinations against the spruce budworm *Choristoneura fumiferana* (Clem.). Chem. Control Res. Inst. Report CC-X-61, 24 pp.
- MORRIS, O.N. and J.A. ARMSTRONG, 1974. Aerial application of *Bacillus thuringiensis* - Orthene^(R) combinations against the spruce budworm, *Choristoneura fumiferana* (Clem.). Chem. Control Res. Inst. Report CC-X-71, 25 pp.
- MORRIS, O.N. and M.J. HILDEBRAND, 1974. Evaluation of commercial preparations of *Bacillus thuringiensis* with and without chitinase against spruce budworm. E. Assessment of effectiveness of aerial application, Algonquin Park, Ontario. Chemical Control Res. Inst. Report CC-X-59, 53 pp.

MORRIS, O.N. and A. MOORE, 1975. Studies on the protection of insect pathogens from sunlight inactivation. II. Preliminary field trials.

Chem. Control Res. Inst. Report CC-X-113, (in press).

YAMVRIAS, C. and T.A. ANGUS, 1970. The comparative pathogenicity of some *Bacillus thuringiensis* varieties of larvae of the spruce budworm, *Choristoneura fumiferana*.

J. Invertebr. Pathol. 15: 92-99.

Table 1

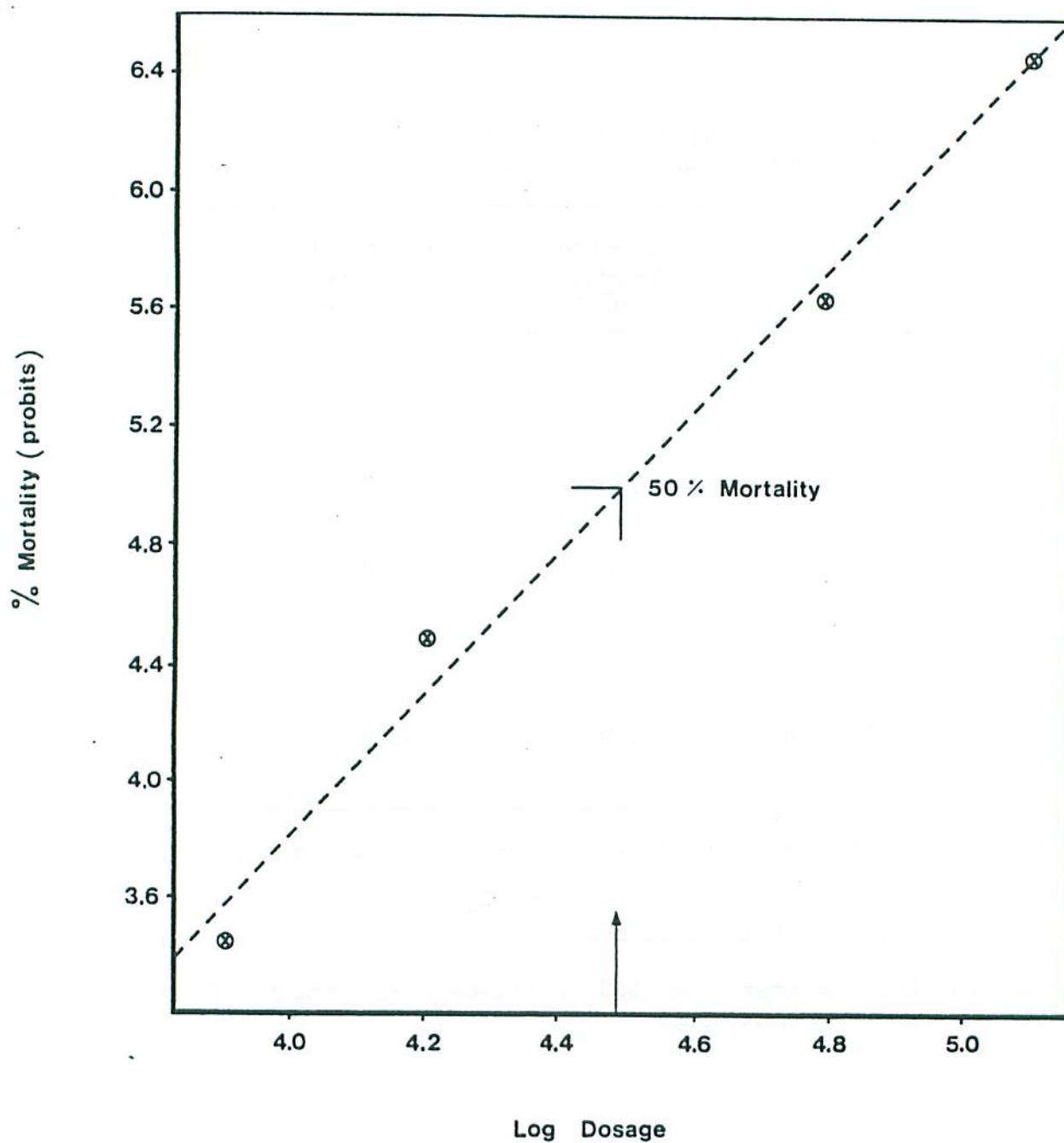
Bioassay of Dipel 36B against 4th Instar
Spruce Budworm on Artificial Diet¹

Concentration (IU)/l of Diet	Number of Larvae	Corrected ² Percent Mortality	Percent of Cadavers B.t. infected	LT ₅₀ ³ (days)
0 (Check)	5 x 20	(9)	0.0	-
8,000	5 x 20	2.2	54.5	-
16,000	5 x 20	39.6	69.0	-
64,000	5 x 20	87.9	85.4	4.0
128,000	5 x 20	97.8	95.0	3.5

¹ Rearing period 7 days at $22 \pm 1^{\circ}\text{C}$, 70-75% RH and 18 hr/day lighting.

² LD₅₀ = 31,010 IU/l of diet; 95% confidence limits
= 23,100 and 47,100 IU/l diet

³ Calculated from computer generated histograms. See appendix for mortality curve and histograms.



Mean of X = 4.5051
 Mean of Y = 5.0329
 Variance of X = .3021
 Variance of Y = 1.7789
 Correlation = .9943
 $Y = -5.8381 + 2.413 \times X$

Fig. 1 Bt. in diet. Percent Mortality (probits) vs. Dosage (logs of I.U./l of diet)

Table 2

Effect of Commercial Sorbitol (Sorbo) on
the Replication Rate of *Bacillus thuringiensis*¹

Concentration of Sorbo in B.t. Culture Media (%)	Number of Vegetative Cells/ml x 10 ⁶ in Liquid Culture Media and Cell Growth on Solid Trypticase Soy Agar Media after indicated Incubation time (hr)					
	2		4		6	
	No. Cells	TSA	No. Cells	TSA	No. Cells	TSA
0 (Control - No Sorbo)	0.5	++++	2.6	++++	43	++++
1	0.5	++++	2.6	++++	27	++++
5	0.5	++++	2.4	++++	12	++++
10	0.5	++++	0.5	++++	0.5	++++
35	0.5	+	0.5	+	0.5	+
50	0.5	+	0.5	+	0.5	+

¹ Three replicates per concentration. Cultures were smeared on TSA media at 9 replicate plates per concentration. Sorb is 70% Sorbitol in water.

Table 3

Effect of Dowanol TPM on the Replication
of *Bacillus thuringiensis*¹

Concentration of Dowanol TPM in B.t. Culture Media (%)	Number of Vegetative Cells/ml x 10 ⁶ in Liquid Culture Media and Cell Growth on Solid Trypticase Soy Agar Media after Indicated Incubation Time (hr)					
	2		4		6	
	No.Cells	TSA	No.Cells	TSA	No.Cells	TSA
0 (Control - No Dowanol)	0.5	++++	?	++++	107	++++
10	0.5	++++	0.5	++++	0.5	++++
25	0.5	++++	0.5	++++	0.5	++++
35	0.5	++++	0.5	++++	0.5	++++
50	0.5	++++	0.5	++++	0.5	++++

¹ Three replicates per concentration. Cultures were smeared on TSA plates at 9 replicates per concentration.

? Spectrophotometer light burnt out.

Table 4

The Effect of Commercial Sorbitol (Sorbo)
and Dowanol TPM on *Bacillus thuringiensis* Spore Germination¹

Concentration of Additives (%)		pH of 24 hr TSB Culture	Visual Germination	Growth on TSA
Sorbo	10	5.8	++++	++++
	20	5.5	++++	++++
	25	6.1	++++	++++
	35	6.7	0	++++
	50	6.8	0	++++
Dowanol	10	5.1	0	++++
	20	4.6	0	++++
	25	4.4	0	++++
	30	4.5	0	++++
Control		5.8		++++

¹ Three replicates per concentration and 2 smears per replicate.

Table 5

Mortality of 4th Instar Spruce Budworm Larvae
Fed Artificial Diet Mixed with *B. thuringiensis* and Sorbo
Experiment 1

Treatment IU/l of Diet	Number of ¹ Larvae Tested	Corrected Percent Mortality	Percent of Cadavers B.t. +	LT ₅₀ (days)
16,000 IU alone	2 x 100	38	68.9	-
16,000 IU + 10% Sorbo	2 x 100	12	57.5	-
16,000 IU + 50% Sorbo	2 x 100	4	48.0	-
64,000 IU alone	2 x 100	75	85.4	4.0
64,000 IU + 10% Sorbo	2 x 100	65	87.5	5.7
64,000 IU + 50% Sorbo	2 x 100	47	83.9	-
Check	1 x 100	(9)	0.0	-

¹ Ten larvae per container. Rearing conditions : $22 \pm 1^{\circ}\text{C}$, % RH 68-76,
lighting 18 h/day.

Table 6

Mortality of 4th Instar Spruce Budworm Larvae
Fed Artificial Diet Mixed with *B. thuringiensis*
and Sorbo or Dowanol TPM
Experiment 2

Treatments IU/l of Diet	Number ¹ Larvae Tested	Number Larvae Recovered	Corrected Percent Mortality	Percent of Cadavers B.t. +
16,000 IU alone	4 x 25	96	17	37
64,000 IU alone	4 x 25	96	27	75
30% Sorbo	4 x 25	88	0	0
30% Sorbo + 16,000 IU	4 x 25	77	19	26
30% Sorbo + 64,000 IU	4 x 25	83	6	69
25% Dowanol TPM	4 x 25	80	96	0
25% Dowanol TPM + 16,000 IU	4 x 25	61	79	0
25% Dowanol TPM + 64,000 IU	4 x 25	72	87	0
Control	4 x 25	100	(0)	0

¹ Five to 10 insects per creamer. Rearing conditions : $22 \pm 1^{\circ}\text{C}$, $63 \pm 4\%$ RH, 18 hr/day lighting.

Table 7

Mortality and Feeding Activity of 4th Instar Spruce Budworm
Fed Foliage Dipped in *B. thuringiensis* -
Sorbo or Dowanol TPM Suspension¹

Treatment	Number of Larvae	Corrected Percent Mortality	Percent of Cadavers B.t. +	Frass Wt. (mg) per larva
Dipel 36B	4 x 25	87	95.4	1.2
Dipel 36B + 30% Sorbo	4 x 25	96	93.8	0.2
Dipel 36B + 25% Dowanol TPM	4 x 25	99	78.8	0.1
Control	4 x 25	(2)	0	28.1

¹ Dipel 36B at 0.5% concentration.

AIRCRAFT CALIBRATION OF CESSNA AGTRUCK . DROP DENSITY AND SPOT SIZE FOR THREE FORMULATIONS.

(A) DIPEL 36 + TPM, .25 gal./ac. (2.35 l/ha)

— No. Drops/cm²
 ○ Spot Size

RH: 40-45%
 Temp.: 22°C
 Wind Vel.: 2mph

(B) DIPEL 36 + SORBO, .50 gal./ac. (4.70 l/ha)

— No. Drops/cm²
 ■ Spot Size

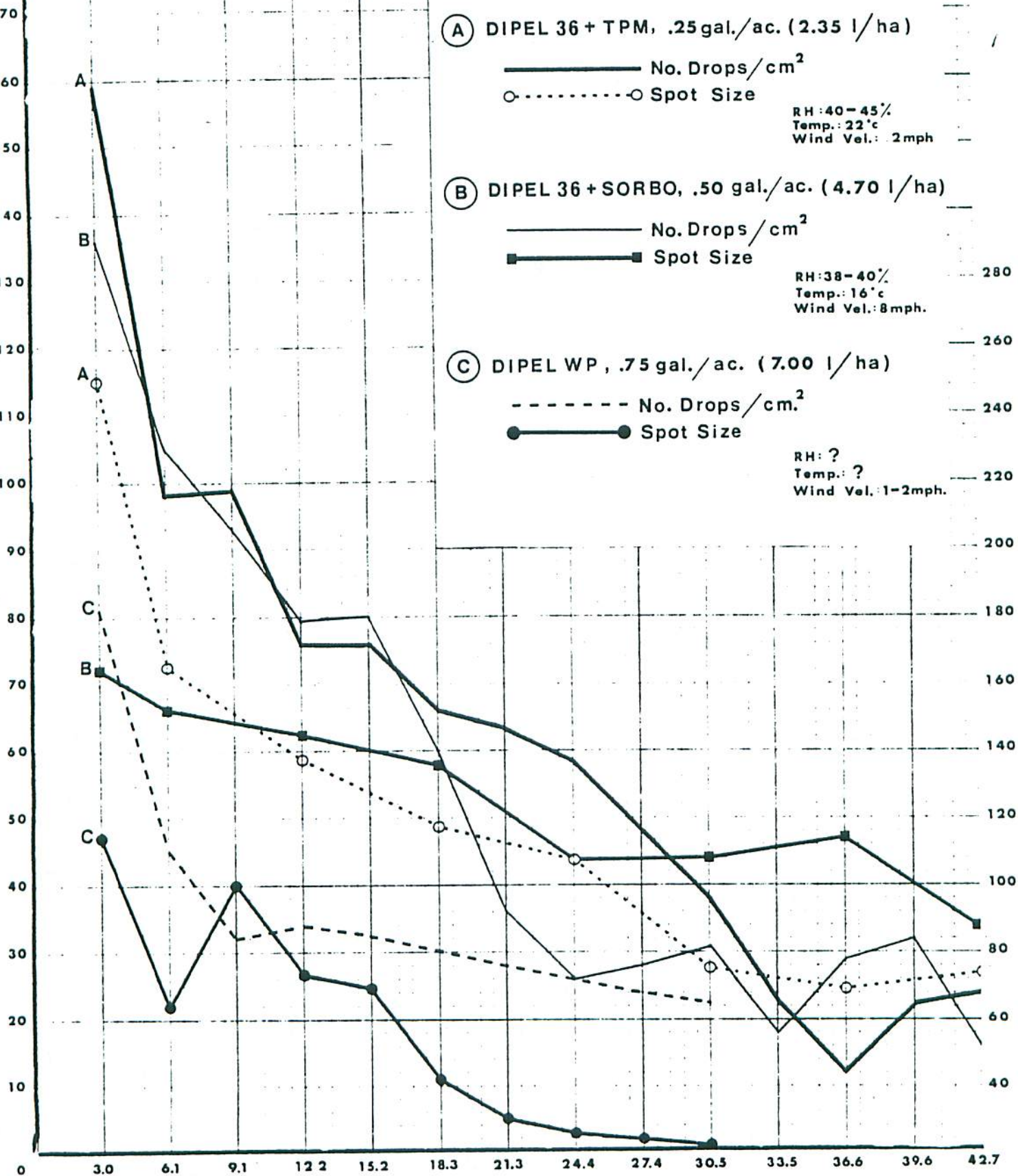
RH: 38-40%
 Temp.: 16°C
 Wind Vel.: 8mph.

(C) DIPEL WP, .75 gal./ac. (7.00 l/ha)

- - - No. Drops/cm²
 ● Spot Size

RH: ?
 Temp.: ?
 Wind Vel.: 1-2mph.

NO. DROPS/cm²



DISTANCE [m] FROM CENTRE LINE OF FLIGHT

FIG. 2

Table 8

Summary of *Bacillus thuringiensis* Formulations -
Petawawa Forest Experiment Station 1975

Treatments	BIU of B.t. + Orthene (g) per ha	Spray Dates	Treated Area (ha)	Total Volume (l)	Loads (l)	Dipel WP kg/load	Chevron Sticker ml/load	Erio Acid Red Dye gm/load	90% Orthene g/load	pH
Plot 1 - Dipel WP, 10% CIB 1st spray, 7.0 l/ha	10 + 21g	May 24	362	2536	5x507	40	380	609	55	4.2
Plot 1 - Dipel WP, 10% CIB 2nd spray, 7.0 l/ha	10 + 21g	May 25	362	2536	5x507	40	380	609	55	4.2
Plot 2 - Dipel 36B : Sorbo : Water 50 : 30 : 20, 4.7 l/ha	20 + 42g	May 28	194	908	2x454	0	550	546	144	4.1
Plot 3 - Dipel 36B : Sorbo : Water 50 : 30 : 20, 4.7 l/ha	20	May 28	196	915	2x458	0	550	550	NONE	4.1
Plot 4 - Dipel 36B : Dowanol TPM : Water 75 : 15 : 10, 2.35 l/ha	20 + 42g	May 29	288	674	1x674	0	809	809	427	3.9
Plot 5 - Dipel 36B : Dowanol TPM : Water 75 : 15 : 10, 2.35 l/ha	20	May 29	320	749	2x375	0	450	450	NONE	3.9

Mixing sequence : Water + Sorbitol or Dowanol TPM + Dipel + Sticker + Dye. Density (in descending order) : 1.108, 1.041, 1.099, 1.038 and 1.036.

Table 9

Spruce Budworm Development at Petawawa Forest Experiment Station, 1975
Expressed as Percentages of Various Instars

Date	White Spruce						Balsam Fir					
	L ₂	L ₃	L ₄	L ₅	L ₆	P	L ₂	L ₃	L ₄	L ₅	L ₆	P
May 19	45.0	50.0	5.0	0	0	0	31.0	60.0	9.0	0	0	0
May 22	46.0	47.0	7.0	0	0	0	45.0	46.0	9.0	0	0	0
May 24	26.0	55.0	17.0	2.0	0	0	32.0	62.0	3.0	3.0	0	0
May 26	1.5	33.8	53.6	8.8	2.3	0	6.0	55.1	36.1	1.3	0	0
May 28	1.0	22.6	39.4	31.4	5.6	0	2.9	39.7	43.9	11.8	2.9	0
June 10	0	3.2	8.0	13.0	57.7	18.1	0	9.9	15.6	22.4	50.3	1.8
June 20	0	0	0	0.2	2.5	97.3	0	0	1.4	2.0	17.3	79.3

Spray dates : May 24-25 and May 28-29.

Table 10

Estimate of Tree Vigor in Treatment and Check Plots Based
on the Number of Current Year's Buds per m² of Foliage

Treatment	Total Area* of Foliage Examined (m ²)	Total Number of Pre-spray Larvae	Total* Number Buds		Buds/m ² of Foliage		Ratio Buds/ Larvae Pre-spray	
	wS / bF	wS / bF	wS	bF	wS	bF	wS	bF
Dipel WP + Orthene, 14 l/ha	14.4 /15.8	386 / 135	10508/6472		729.7/409.6		8.8 / 15.2	
Dipel 36B + Orthene, 4.7 l/ha	15.2 /15.8	1189 / 548	8590/6494		565.1/411.0		1.7 / 2.7	
Dipel 36B alone, 4.7 l/ha	14.9 /15.8	743 / 534	10166/8054		682.3/509.7		3.7 / 4.7	
Dipel 36B + Orthene, 2.35 l/ha	13.7 /14.5	2077 / 612	8483/6462		619.2/445.7		1.1 / 2.7	
Dipel 36B alone, 2.35 l/ha	16.0 /15.8	1735 / 859	8782/6474		548.9/409.7		1.5 / 2.6	
Check I	15.3 /15.6	1149 / 644	9404/7831		614.6/502.0		2.8 / 4.3	
Check II	17.0 /15.2	1126 / 410	10214/5863		600.8/385.7		3.3 / 4.3	

* All branch samples combined.

Table 11

Meteorological Conditions at Time of Application of *Bacillus thuringiensis*
Orthene Combinations, Petawawa Forest Experiment Station, 1975

Treatment	Spray Date	Time of Application	Wind		Stability Ratio (range in brackets)	R.H. % (range)		Temp °C		Turbulence Factor
			Speed (m/sec)	Dir.		20m	6m	20m	6m	
P1 Dipel WP + Orthene 7 l/ha	24 May	0545-0809	1.07	N	39.1 (439-1.0)	83-63	92-59	15.9	15.3	1.13
7 l/ha	25 May	0532-0742	1.25	SE	15.2 (103-1.1)	82-67	87-68	12.7	11.6	1.50
P2 Dipel 36B + Orthene 4.7 l/ha	28 May	0546-0630	2.15*	WNW	1.6 (2.4-1.0)	94-88	92-86	9.6	9.1	0.9
P3 Dipel 36B alone 4.7 l/ha	28 May	0705-0745	2.01	WNW	2.9 (7.5-1.7)	88-82	86-79	12.5	11.3	1.7
P4 Dipel 36B + Orthene 2.35 l/ha	29 May	0540-0630	1.1	W	37.2 (148.1-4.9)	80-73	94-73**	8.4	6.7**	0.5
P5 Dipel 36B alone 2.35 l/ha	29 May	0706-0737	1.4	W	8.0 (22.7-1.6)	77-68	71-64	12.8	11.6	1.2

* Equivalent to 4.8 mph

** Dry bulb sensor not functioning for part of sample period, data based on available valid measurement.

Table 12

Meteorological Conditions Following Aerial Spraying of
Bacillus thuringiensis - Orthene Combinations
 Petawawa Forest Experiment Station, 1975

Inclusive Dates	Temperature °C			Percent Relative Humidity		Solar Radiation		Rainfall	
	Mean Max.	Mean Min.	Degree Days above 5.55°C	Mean Max.	Mean Min.	Cumulative (cal/cm ²)	Mean (cal/cm ² /day)	Cumulative (cm)	Mean cm/day
May 24 - June 19	23.3	11.3	291	93	39	11,380	422	6.8	0.252
May 28 - June 19	22.0	10.9	252	93	37	9,700	442	6.5	0.282

Table 13

Spray Deposit Rates at Ground Level on Plots Treated with
Bacillus thuringiensis - Orthene Combinations
Petawawa Forest Experiment Station, 1975

Treatment	Deposit Rates per acre (ha)		Orthene (g)	Percent of Emitted Volume Deposited ¹	Av. No. Drops/cm ²	Dia. Drop of Av. Vol. (μm)	Ratio of Drop Density/ BIU Deposit
	<i>B. thuringiensis</i> BIU	No. Viable Spores x10 ⁸					
Dipel WP + Orthene, 14 l/ha	1.0 (2.47)	13.4	0.7 (1.73)	12.2	39.7	93	39.7
Dipel 36B + Orthene, 4.7 l/ha	2.5 (6.18)	11.2	0.19 (0.47)	31.5	13.9	126	5.5
Dipel 36B alone, 4.7 l/ha	1.78 (4.40)	11.0	0.13 (0.32)	22.2	11.6	119	6.5
Dipel 36B + Orthene, 2.35 l/ha	1.70 (4.20)	5.2	0.13 (0.32)	21.3	6.3	114	3.7
Dipel 36B alone, 2.35 l/ha	1.9 (4.70)	4.0	0.14 (0.35)	23.1	10.9	98	5.7

¹ Calculated from colorimetric analysis of glass plate deposits.

Table 14

Relationship of Drop Size to Numbers of Spores
and Crystals of *Bacillus thuringiensis*
Based on Data from Aerial Application of Dipel
Wettable Powder in Suspension at 7 l/ha

No. of Drops Examined	Drop Diameter (Microns)		Number of Spores and Crystals		Number of Spores	
	Average	Std. Err.	Average	Std. Err.	Average	Std. Err.
18	19.6	1.12	75.3	12.2	34.4	6.2
15	33.1	1.07	164.3	13.6	71.5	7.6
8	47.5	0.91	215.4	42.4	103.3	36.5
11	93.8	5.18	289.2	58.8	144.0	29.8

Note: Only the smaller drops were countable due to heavy concentration of dye in larger drops. Number of drops/cm² at sampling site was 63.6.

Table 15

Ground Coverage Efficiency of Various *B. thuringiensis* Formulations
Aerially Sprayed under Various Meteorological Conditions

Formulation	Application Rate l/ha	Mean Stability Ratio	Group % Mean S.R.	Relative Humidity Range	Est. Vol. Deposit (% of Emitted)	Group % Deposited	Drop/cm ²	Group Drop/cm ²
<u>MOLASSES FORMULATIONS</u>								
Thuricide 16B, 50% water, chitinase	4.7	+174.0	+63.1	34-38	81		98	
Thuricide 16B, 50% water alone	4.7	+ 39.2	Very	57-64	34		37	
Dipel WP, 90% water, 10% CIB + Orthene	14.0	+ 27.1	Highly Stable	75-99	12		40	
Dipel WP, 90% water, 10% CIB + Orthene	21.0	+ 12.0		75-99	30	39	43	55
Dipel WP, 90% water, 10% CIB + Orthene	14.0	+ 7.9	+4.3	75-90	29		25	
Dipel WP, 90% water, 10% CIB alone	14.0	+ 7.9		70-90	13		25	
Dipel WP, 50% water, 50% CIB + Fen.	4.7	+ 3.6	Stable	?	27		18	
Chitinase, 50% water, 50% CIB	4.7	+ 1.3		50	18		16	
Dipel WP, 90% water, 10% CIB + Orthene	7.0	+ 1.0		75-85	19	21	20	20
Thuricide 16B, 50% water + Fen.	4.7	-1.1	-5.2	?	14		17	
Dipel WP, 50% water, 50% CIB + Orthene	4.7	-7.0	Unstable	63-69	27		17	
Dipel WP, 50% water, 50% CIB	4.7	-7.5		63-69	33	25	15	16
<u>SORBO and DOWANOL FORMULATIONS</u>								
Dipel 36B 75%, Dowanol 15%, water 10%, Orthene	2.35	37.2	+12.4	73-94	21		6	
Dipel 36B 75%, Dowanol 15%, water 10%	2.35	8.0		61-74	23		11	
Dipel 36B 50%, Sorbo 30%, water 20%	4.7	2.9	Stable	79-86	22		12	
Dipel 36B 50%, Sorbo 30%, water 20%	4.7	1.6		86-92	32	25	14	11

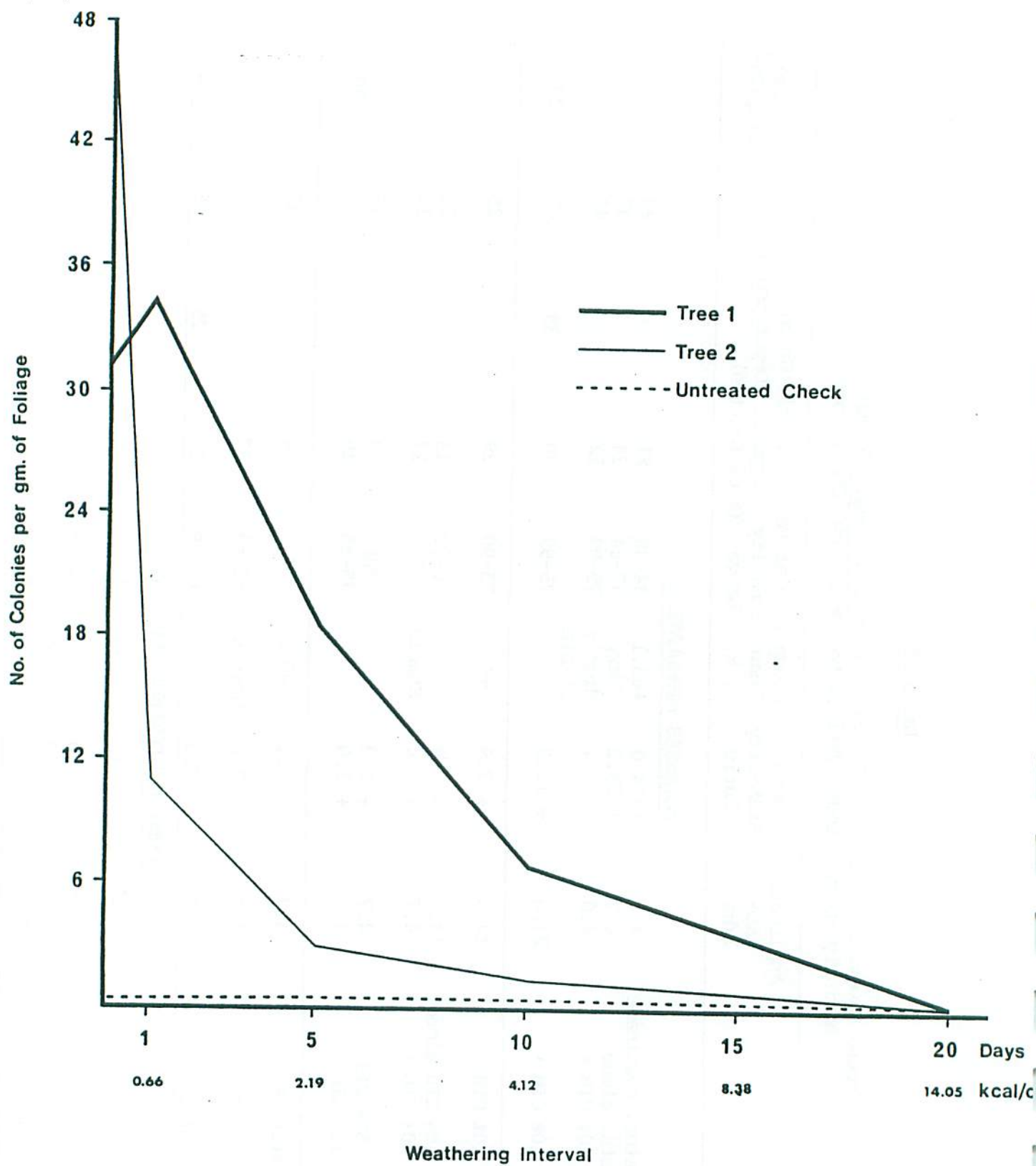


Fig. 3 Survival of *Bacillus thuringiensis* spores on aircraft sprayed white spruce trees

Table 16

Survival of B. thuringiensis spores on
Four Cardinal Sides of White Spruce Trees
Aerially Sprayed at Wind Direction of WNW

Cardinal Quadrant	<u>Number of Colonies/gm of Foliage</u>	
	<u>1 Day Post-spray*</u>	<u>5 Days Post-spray*</u>
N	31.7	3.9
S	21.4	1.6
E	15.0	2.3
W	19.7	3.8

* Trees 1 and 2 combined.

Table 17

Residual Activity of *Bacillus thuringiensis*
Applied by Aircraft to White Spruce¹

Number of Days of Weathering	Cumulative		Temperature		Percent R.H.		Number ² Larvae in Bioassay	Corrected Percent Mortality	Percent of Cadavers		
	Solar Radiation (Cal/cm ²)	Rainfall (cm)	Mean Max./Mean Min. (°C)	Mean Max./Mean Min.	Mean Max./Mean Min.	Mean Max./Mean Min.			B.t. +	NPV +	Micro- sporidia +
0 (spray date)	0	0	-	-	-	-	149	63.8	38.0	0	34.0
1	660	0.0	22.8/ 6.7	94	7		159	51.7	26.0	0	37.0
5	2190	1.7	21.6/10.7	92	33		175	28.0	5.0	0	58.0
10	4120	4.4	20.9/10.1	93	34		192	40.9	4.0	0	89.0
20	8380	6.4	21.3/10.2	93	37		171	69.8	13.0	0	84.0
30	14050	6.5	23.3/11.2	92	34		193	27.1	2.0	2	88.0
Check	14050	6.5	23.3/11.2	-	-		88	(60.8)	8.0	0	54.0

¹ Application rate of Dipel 36B was 20 BIU/ha depositing at 3.75 BIU/ha at ground level. Spray date May 28. Foliage collected from 4 quadrants of 2 trees at each bioassay date and tested separately.

² Larvae for days 0 to 5 and check, were field collected; others were from laboratory stock.

Table 18

Corrected Percent Budworm Population Reduction on White Spruce and Balsam Fir
Calculated on Number of Budworm per Bud

Treatment per acre (ha)	Larval Reduction						Percent Pupal Mortality	Total Reduction	
	Pre-spray Density		Post-spray # 1		Post-spray # 2			wS	bF
	wS	bF	wS	bF	wS	bF			
Dipel WP : 8 BIU + 0.6 oz * Orthene (20 + 42g) 1.5 GPA (14 l/ha)	0.25	0.07	0.0	0.0	48.5	45.2	35.2	23.1	40.8
Dipel 36B : 8 BIU + 0.6 oz Orthene 0.5 GPA (4.7 l/ha)	0.60	0.37	35.7	0.0	85.6	0.0	88.1	98.9	84.1
Dipel 36B : 8 BIU alone 0.5 GPA	0.27	0.21	0.0	0.0	51.5	0.0	51.2	86.2	41.0
Dipel 36B : 8 BIU + 0.6 oz Orthene 0.25 GPA (2.35 l/ha)	0.89	0.36	88.3	4.0	90.4	9.7	36.7	97.2	71.4
Dipel 36B : 8 BIU alone 0.25 GPA (2.35 l/ha)	0.66	0.38	76.2	20.3	73.4	14.3	40.1	90.0	74.6
Untreated Check I	0.35	0.39	(42.9)	(53.8)	(77.1)	(84.6)	15.6	(63.8)	(68.5)
Untreated Check II*	0.30	0.23	(40.0)	(56.5)	(76.7)	(73.9)	12.8	(89.6)	(84.8)

* Check plot II compared with spray plot 1. Check plot I compared with other spray plots.

Table 19

Corrected Percent Population Reduction on White Spruce and Balsam Fir,
Calculated on Number of Budworm per 18" (46 cm) Branch Tip

Treatment per acre (ha)	% Larval Reduction						Percent Pupal Mortality	Total % Reduction ¹	
	Pre-spray Density		Post-spray # 1		Post-spray # 2			wS	bF
	wS	bF	wS	bF	wS	bF			
Dipel WP : 8 BIU + 0.6 oz Orthene* (20 + 42g) 1.5 GPA (14 l/ha)	14.4	2.5	0.0	10.6	22.0	0.0	35.2	38.4	21.1
Dipel 36B : 8 BIU + 0.6 oz Orthene 0.5 GPA (4.7 l/ha)	25.2	11.9	0.0	0.0	60.6	0.0	88.1	95.5	80.0
Dipel 36B : 8 BIU alone 0.5 GPA	16.2	11.1	0.0	0.0	0.0	0.0	51.2	35.8	13.6
Dipel 36B : 8 BIU + 0.6 oz Orthene 0.25 GPA (2.35 l/ha)	46.1	13.7	75.9	25.8	83.8	28.8	36.7	85.0	54.7
Dipel 36B : 8 BIU alone 0.25 GPA (2.35 l/ha)	38.1	19.0	72.7	49.8	53.7	47.1	40.0	80.1	68.3
Untreated Check I	26.8	13.8	(60.8) ²	(44.7) ²	(80.3) ²	(75.8) ²	15.6	(83.3) ²	(75.7) ²
Untreated Check II*	25.0	9.0	(59.4) ²	(50.0) ²	(78.2) ²	(73.8) ²	12.8	(81.0) ²	(77.2) ²

* Check plot II compared with plot 1; check plot I compared with all other treatment plots.

¹ Post-spray 2 density less percentage pupal mortality, corrected by Abbott's formula.

² Actual percent reductions in check plots.

Table 20

Corrected Percent Budworm Larval Population Reduction
on White Spruce and Balsam Fir
calculated as Number per m² of Foliage

Treatment per acre (ha)	Pre-spray Density		Corrected % Reduction			
			Post Spray 1		Post Spray 2	
	wS	bF	wS	bF	wS	bF
Dipel WP *						
8 BIU + 0.6 oz Orthene						
(20 + 42g) 1.5 GPA						
(14 l/ha)	173.0	35.4	0.0	33.6	0.0	15.8
Dipel 36B :						
8 BIU + 0.6 oz Orthene						
0.5 GPA (4.7 l/ha)	402.9	183.2	21.1	0.0	55.8	0.0
Dipel 36B :						
8 BIU alone						
0.5 GPA	185.1	160.5	0.0	10.6	0.0	0.0
Dipel 36B						
8 BIU + 0.6 oz Orthene						
0.25 GPA (2.35 l/ha)	555.6	168.5	80.6	16.8	72.7	8.1
Dipel + 36B						
8 BIU alone						
0.25 GPA	491.2	200.6	74.8	26.5	51.9	39.7
Untreated Check I	318.1	180.6	(61.3)	(48.2)	(91.1)	(82.9)
Untreated Check II*	273.0	110.8	(65.9)	(59.6)	(92.3)	(86.4)

* Compared. Check plot I compared with all other treatment plots.

POPULATION DENSITY (BUDWORM/BUD) PLOTTED AGAINST
SAMPLE DATES FOR BALSAM FIR AND WHITE SPRUCE

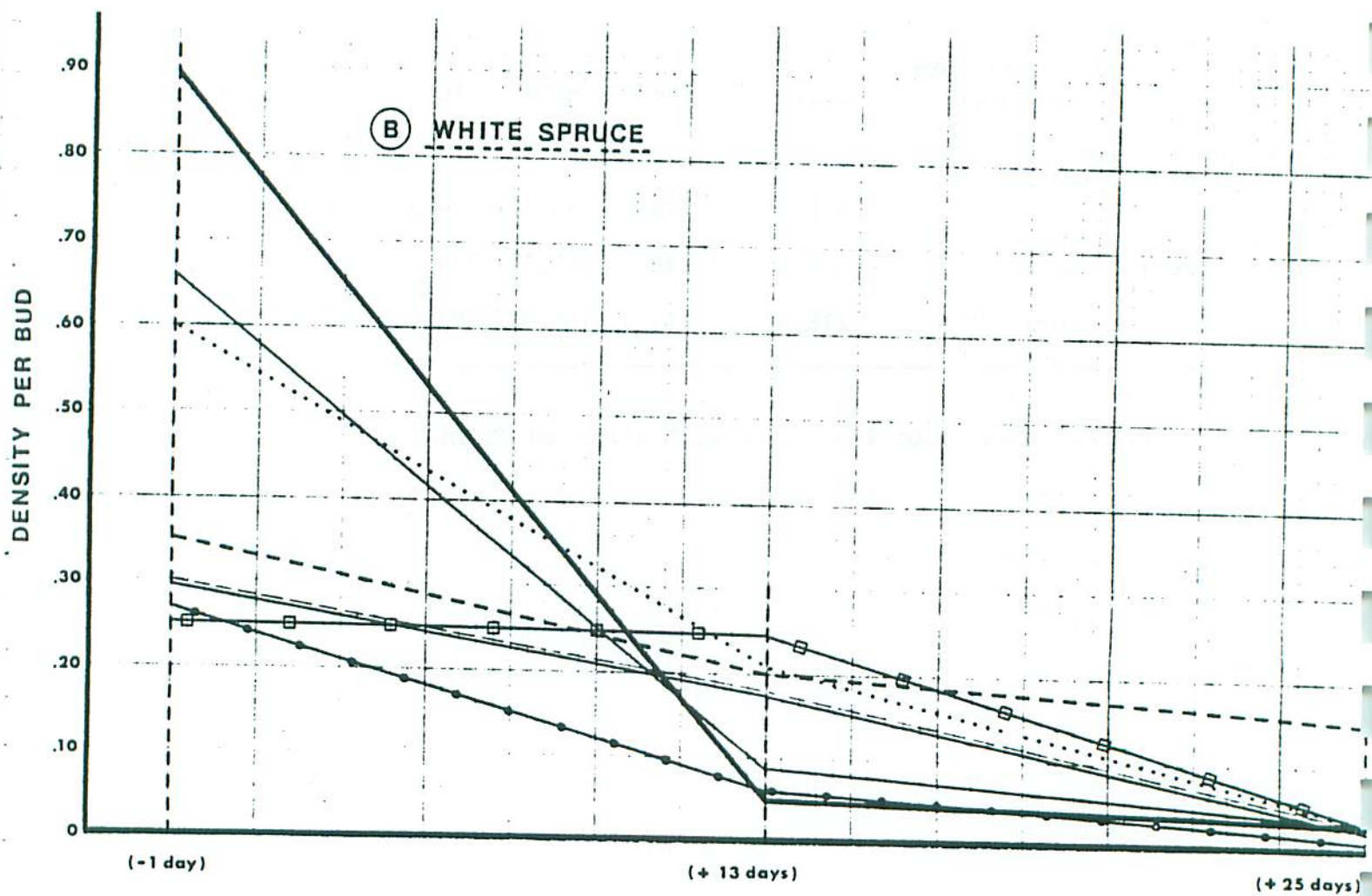
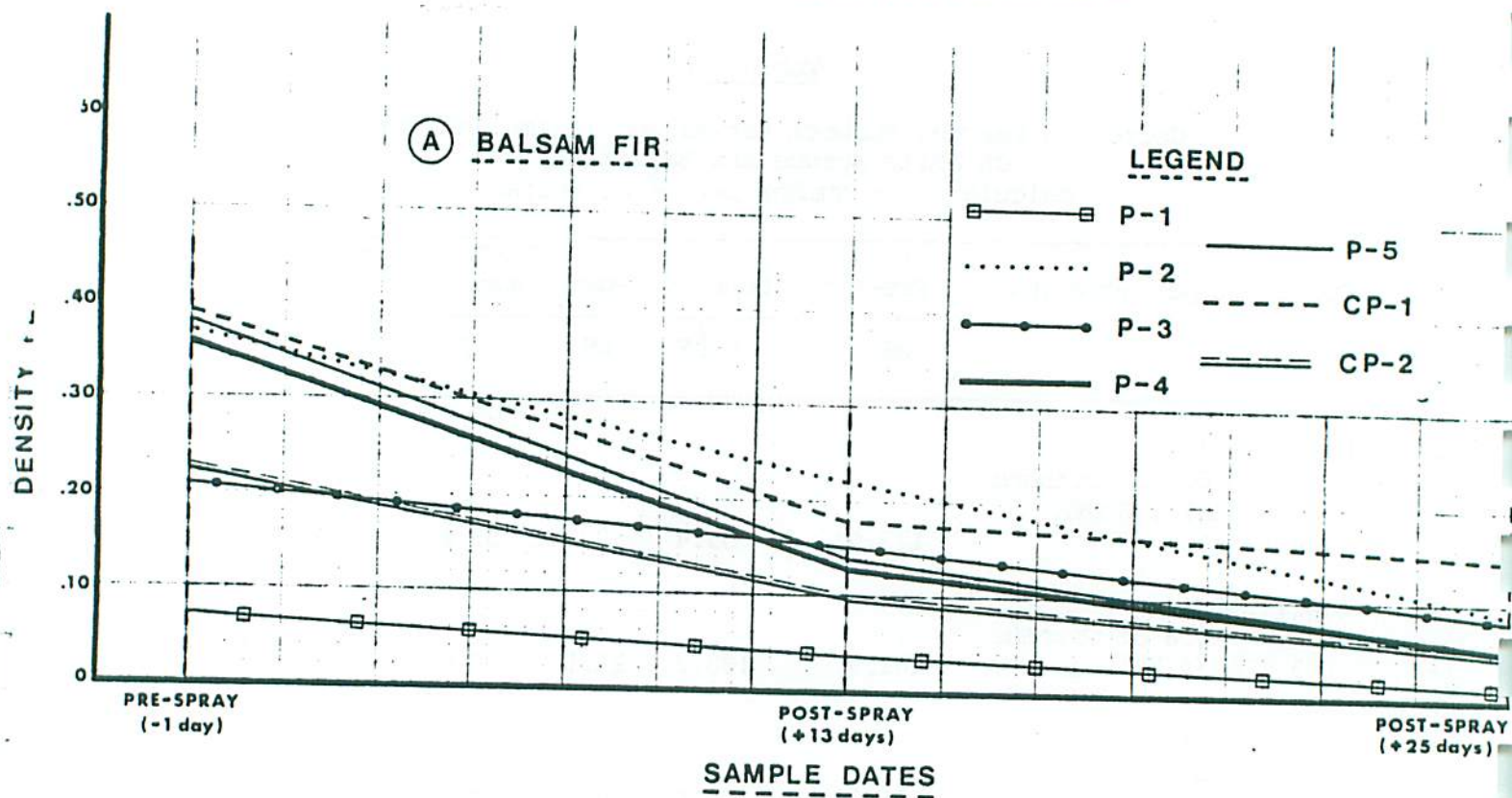


FIG. 4

Table 21

Corrected Percent Population Reduction and Foliage Protection
on White Spruce and Balsam Fir Aerially Sprayed with Orthene

Treatment	Pre-spray ¹ Density		Percent Population Reduction		Percent Current Growth Remaining Protected	
	wS	bF	wS	bF	wS	bF
6.0 oz AI/acre (420 g AI/ha) in 0.5 gal (4.7 l)	0.26	0.10	92.6	14.5	88.4	82.5
Untreated Check	0.30	0.23	(78.2)	(73.8)	23.3	46.4

¹ Based on number of budworm larvae per bud.

Table 22

Corrected Percent Population Reduction of Non-Target
Lepidoptera Larvae Associated with the Spruce Budworm
on White Spruce and Balsam Fir Trees¹

Treatment	Pre-spray Density	Percent Reduction
Dipel WP + Orthene, 14 l/ha	0.0016	0.0
Dipel 36B + Orthene, 4.7 l/ha	0.0214	79.4
Dipel 36B alone, 4.7 l/ha	0.0151	80.1
Dipel 36B + Orthene, 2.35 l/ha	0.0211	69.2
Dipel 36B alone, 2.35 l/ha	0.0258	76.7
Untreated Check I	0.0079	(16.5)
Untreated Check II	0.0114	(31.6)

¹ Data based on number of insect per bud. White spruce and balsam fir pooled at final post-spray population density assessment. Insects were nearly all *Dioryctria reniculella* of which 96.1% occurred on white spruce. Corrected by Abbott's formula.

Table 23

Diagnosis of Dead Spruce Budworm Larvae
Collected from Branch Samples from Test Plots,
Petawawa Forest Experiment Station, 1974

Treatments	Total No. Larvae Collected	Percent Dead	Percent of Cadavers Infected by		
			B.t.	NPV	Microsporidia
Pre-spray ¹	14,324	15.2	0.0*	0.1	40.0
Dipel WP + Orthene ²					
14 l/ha					
Pre-spray	748	30.3	0.0	0.0	41.0
Post-spray	1,174	23.4	10.1	0.5	35.5
Dipel 36B + Orthene ²					
4.7 l/ha					
Pre-spray	2,005	13.4	0.0	0.0	31.0
Post-spray	1,797	29.4	4.8	2.0	47.0
Dipel 36B alone ²					
4.7 l/ha					
Pre-spray	1,724	25.9	0.0	0.0	28.0
Post-spray	1,607	24.5	4.0	1.5	56.0
Dipel 36B + Orthene ³					
2.35 l/ha					
Pre-spray	3,083	12.8	0.0	1.0	49.0
Post-spray	941	34.0	3.0	6.5	48.3
Dipel 36B alone ³					
2.35 l/ha					
Pre-spray	3,241	20.0	0.0	0.0	45.0
Post-spray	1,117	24.9	4.0	4.8	44.8
Untreated Check I ³					
Pre-spray	1,878	4.5	0.0	0.0	46.0
Post-spray	1,596	17.4	0.0	0.5	45.3
Untreated Check II ³					
Pre-spray	1,645	6.6	0.0	0.0	38.0
Post-spray	1,185	17.7	0.0	3.3	49.8

¹ All plots combined.

² Treated with 4-12 BIU/acre the previous year.

³ No previous history of treatment by B.t.

* Non-spore forming bacterial incidence was 17.2% among pre-spray dead larvae.

Table 24

Estimate of Spruce Budworm Feeding Activity
on White Spruce Sprayed with *B. thuringiensis* - Orthene Combinations

Treatment	Wt. (mg) Frass/m ² /Day	Ratio Frass ¹ Wt./Pre-spray Density	Ratio Frass Wt./BIU Deposit Rate	Ratio Frass Wt./Spore Deposit Rate	Ratio of Frass Drop Rate/% Defoliation	
					Mat ² Trees Only	Plot ³
Dipel WP + Orthene, 14 l/ha	32.1	128.4	38.2	0.9	1.9	0.7
Dipel 36B + Orthene, 4.7 l/ha	11.8	19.7	5.1	0.4	0.2	0.2
Dipel 36B alone, 4.7 l/ha	93.7	347.0	62.5	3.1	1.9	1.8
Dipel 36B + Orthene, 2.35 l/ha	47.8	53.7	25.2	3.6	0.9	0.6
Dipel 36B alone, 2.35 l/ha	Frass accidentally destroyed by road widening crew.					
Check I	108.9	311.1	-	-	1.2	1.4
Check II	95.6	318.7	-	-	1.7	1.2

¹ Budworm density based on number of budworm per bud.

² Trees under which mats were placed.

³ All white spruce trees per treatment plot.

Table 25

Percent of Current Year's Growth Protected on
White Spruce and Balsam Fir Sprayed with
B. thuringiensis - Orthene Combinations

Treatment	Percent of Current Growth Remaining*			
	wS (Pre-spray Density) ¹		bF (Pre-spray Density) ¹	
Dipel WP + Orthene, 14 l/ha	59	(0.25) ^b	75	(0.07)
Dipel 36B + Orthene, 4.7 l/ha	30	(0.60) ^a	48	(0.37) ^{bc}
Dipel 36B alone, 4.7 l/ha	52	(0.27) ^b	43	(0.21) ^{ab}
Dipel 36B + Orthene, 2.35 l/ha	30	(0.89) ^a	61	(0.36) ^c
Dipel 36B alone, 2.35 l/ha	35	(0.66) ^a	32	(0.38) ^a
Check Plot I	31	(0.35) ^a	49	(0.39) ^{bc}
Check Plot II	30	(0.30) ^a	51	(0.23) ^{bc}

¹ Density based on number of budworm per bud. Equivalent figures based on budworm per 18" branch for wS are 14.4, 25.2, 16.2, 46.1, 38.1, 26.8 and 25.0, and for bF are 2.4, 11.9, 11.1, 13.7, 19.0, 13.8 and 9.0.

* Means within a column followed by the same letter are not significantly different at 5% level (SNK test).

Table 26

Comparison of Defoliation at Upper and Mid
Crowns of Sample Trees ¹

Treatment	Percent Defoliation			
	Upper Level		Mid Level	
	wS	bF	wS	bF
Dipel WP Orthene, 14 l/ha	39.8	27.0	47.4	28.4
Dipel 36B Orthene, 4.7 l/ha	94.3	56.8	77.9	56.8
Dipel 36B alone, 4.7 l/ha	51.8	60.8	55.1	68.2
Dipel 36B Orthene, 2.35 l/ha	73.0	42.9	82.6	43.8
Dipel 36B alone, 2.35 l/ha	67.2	78.7	74.3	70.8
Untreated Check I	75.0	54.8	77.0	57.2
Untreated Check II	78.6	57.3	75.1	50.5

¹ Twenty-five branches from each tree species per treatment plot.

Table 27

Analysis of Relationship between Ground Deposit and Percent Defoliation - White Spruce
Petawawa Forest Experiment Station, 1975

	Stability Ratio	Budworm Pre-spray Density* per bud/per branch	Plot BIU Deposited/ ha	Drops/cm ² (Range)	Percent Defoliation (Range)	Percent Plot Defoliation	Plot Drop Density/ cm ²
Dipel WP + Molasses + Orthene, 14 l/ha	39.1, 15.2	0.25/14.4	2.7	15.9 (10.0-19.4) 29.1 (23.4-34.2) 67.6 (41.4-94.2)	68.2 (50.9-81.1) 44.8 (17.1-66.6) 22.8 (6.7-52.9)	41	47.7
Dipel 36B + Sorbo + Orthene, 4.7 l/ha	1.6	0.60/25.2	6.2	3.0 (0.6- 4.8) 14.3 (9.0-18.6) 38.6 (22.6-48.0)	73.3 (32.3-99.2) 69.7 (46.1-98.4) 50.7 (32.5-98.9)	70	13.8
Dipel 36B + Sorbo alone, 4.7 l/ha	2.9	0.27/16.2	4.4	10.0 (0 -19.8) 30.0 (23.8-34.0)	49.4 (18.0-87.3) 49.3 (30.0-71.0)	48	10.9
Dipel 36B + Dowanol TPM + Orthene, 2.35 l/ha	37.2	0.89/46.1	4.2	1.5 (0.2- 2.8) 6.2 (4.0- 9.4) 23.3 (12.4-32.0)	68.5 (32.0-98.7) 78.5 (43.0-96.7) 67.0 (55.0-93.0)	70	5.9
Dipel 36B + Dowanol TPM alone, 2.35 l/ha	8.0	0.66/38.1	4.7	2.9 (0.6- 5.0) 8.3 (5.6-12.6) 21.0 (14.0-36.8)	79.9 (48.1-99.6) 59.9 (37.0-95.1) 42.5 (14.2-78.9)	65	9.2
Untreated Checks 1 and 2	-	0.33/25.9	-	-	(30.0-99.5)	70	-

* Check plots 1 and 2 densities 0.35, 0.30 per bud respectively (26.8, 25.0 per branch, respectively).

Table 28

Analysis of Relationship between Ground Deposit and Percent Defoliation - Balsam Fir
Petawawa Forest Experiment Station, 1975

Treatment	Stability Ratio	Budworm Pre-spray Density per bud/per branch	Plot BIU Deposited/ ha	Drops/cm ² (Range)	Percent Defoliation (Range)	Percent Plot Defoliation	Plot Drop Density/cm ²
Dipel WP + Molasses + Orthene, 14 l/ha	39.1 15.2	0.07/ 2.5	2.7	14.5 (8.0-19.8) 28.1 (26.4-31.0) 59.5 (38.6-95.8)	25.7 (6.5-57.6) 27.3 (10.8-36.1) 21.9 (12.5-36.9)	25	31.6
Dipel 36B + Sorbo + Orthene, 4.7 l/ha	1.6	0.37/11.9	6.2	2.7 (0 -10.2) 22.0 (12.0-36.4) 63.1 (48.6-91.6)	57.5 (13.0-94.3) 48.4 (24.7-74.6) 26.8 (19.1-38.1)	52	14.5
Dipel 36B + Sorbo alone, 4.7 l/ha	2.9	0.21/11.1	4.4	2.5 (0 - 6.4) 14.0 (10.2-20.4) 44.2 (35.6-52.6)	60.2 (33.0-98.4) 55.2 (25.0-97.1) 52.2 (11.1-92.5)	57	12.4
Dipel 36B + Dowanol TPM + Orthene, 2.35 l/ha	37.2	0.36/13.7	4.2	3.3 (1.0- 7.6) 18.5 (11.2-34.8)	44.2 (10.3-60.8) 30.0 (15.2-76.6)	39	6.6
Dipel 36B + Dowanol TPM alone, 2.35 l/ha	8.0	0.38/19.0	4.7	4.4 (0.2- 9.4) 13.2 (11.0-16.2) 30.3 (17.2-44.6)	69.4 (41.2-98.2) 73.4 (29.2-99.6) 58.0 (32.0-82.3)	68	13.1
Untreated Checks 1 and 2*	-	0.31/11.4	-	-	-	49	

* Check 1 and Check 2, 0.39 and 0.23, respectively.

Table 29

Pupal Emergence and Adult Oviposition Rates of Spruce Budworm
Collected from Plots Sprayed with *B. thuringiensis* - Orthene Combinations

Treatment	Number of Pupae Caged			Average Wt. (g)			Percent Emergence *			Average Number Egg Masses/Emerged Females	
	Males	Females	Total	Males	Females	Total	Males	Females	Total	Successful Emerged	Total
Dipel WP + Orthene, 14 l/ha	201	254	455	0.072	0.080	0.077	73(147)	62(158)	68	3.3	3.3
Dipel 36B + Orthene, 4.7 l/ha	227	244	471	0.059	0.081	0.071	19(44)	9(24)	14	2.9	2.9
Dipel 36B alone, 4.7 l/ha	249	226	475	0.062	0.085	0.073	69(174)	27(63)	48	8.1	8.1
Dipel 36B + Orthene, 2.35 l/ha	260	203	463	0.058	0.074	0.065	76(198)	33(69)	55	6.6	6.6
Dipel 36B alone, 2.35 l/ha	426	341	767	0.059	0.080	0.068	84(358)	31(96)	58	12.8	12.9
Check Plot I	222	201	423	0.066	0.084	0.062	85(198)	74(150)	80	3.7	3.8
Check Plot II	215	201	416	0.069	0.098	0.083	97(209)	77(155)	87	4.8	5.1

* Actual number in brackets to indicate if there were sufficient males in cages to fertilize females.

Table 30

Results of Egg Mass Survey of Plots Treated with
B. thuringiensis - Orthene Combinations

Treatment	Average Number Egg Mass per 100 sq. ft. of Foliage ¹					
	Emerged			Unemerged		
	WS	bF	Total	WS	bF	Total
Dipel WP + Orthene, 14 l/ha	37 ^{ab}	14 ^{ab}	26 ^{ab}	214 ^a	229 ^a	222 ^{ab}
Dipel 36B + Orthene, 4.7 l/ha	23 ^a	4 ^a	14 ^a	344 ^{ab}	335 ^a	340 ^{bc}
Dipel 36B alone, 4.7 l/ha	38 ^{ab}	22 ^{ab}	30 ^{ab}	366 ^b	282 ^a	374 ^c
Dipel 36B + Orthene, 2.35 l/ha	76 ^b	8 ^{ab}	42 ^b	315 ^{ab}	210 ^a	263 ^{abc}
Dipel 36B alone, 2.35 l/ha	106 ^{bb}	28 ^{ab}	57 ^b	287 ^{ab}	213 ^a	250 ^{abc}
Check Plot I	119 ^b	37 ^{ab}	73 ^b	226 ^{ab}	318 ^a	272 ^{abc}
Check Plot II	65 ^{ab}	15 ^b	51 ^b	227 ^{ab}	86	156 ^a

¹ One sq. ft. = 0.093 m². Means within a column followed by the same letter are not significantly different at 5% level. (SNK test used after transforming data to log (x + 1)).

Table 31

Percent Larval Parasitism based on Larvae collected from
White Spruce and Balsam Fir Sample Branches
During Population Density Assessments

Treatment	No. Live Larvae Collected			Percent of Larvae Parasitized		
	Pre-spray ¹	PS#1	Post-spray#2	Pre-spray	PS#1	Post-spray#2
Dipel WP + Orthene, 14 l/ha	521	748	151	0.19	0.13	0.0
Dipel 36B + Orthene, 4.7 l/ha	1734	1158	309	0.0	0.0	1.9
Dipel 36B alone, 4.7 l/ha	1277	834	380	0.0	0.0	1.8
Dipel 36B + Orthene, 2.35 l/ha	2689	477	174	0.11	0.0	1.7
Dipel 36B alone, 2.35 l/ha	2594	493	246	0.0	4.3	3.3
Untreated Check I	1793	951	367	0.0	0.0	2.5
Untreated Check II	1536	723	255	0.07	0.0	3.9

¹ Large majority 3rd and 4th instars at pre-spray, mainly 5th and 6th at post-spray 1 and mainly pupae at post-spray 2.

Table 32

Percentage Parasitism of 4th Instar Budworm Larvae Collected from
White Spruce on Test Plots and Reared on Artificial Diet¹

Treatment	Pre-spray ² Budworm Density	Number Larvae Reared	Percent Parasitism by ³							Total Percent Larval Parasitism
			<i>Glypta</i> <i>fumiferanae</i>	<i>Apanteles</i> <i>fumiferanae</i>	<i>Apanteles</i> <i>absonus</i>	<i>Apanteles</i> <i>morrisi</i>	<i>Apanteles</i> sp.	<i>Lypha</i> <i>setifacies</i>	<i>Winthemia</i> <i>fumiferanae</i>	
Dipel WP + Orthene, 14 l/ha	0.25	200	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Dipel 36B + Orthene, 4.7 l/ha	0.60	200	10.0	0.0	0.0	0.0	0.5	0.0	0.0	10.5
Dipel 36B alone, 4.7 l/ha	0.27	200	14.0	1.5	0.5	0.5	0.5	1.0	0.0	18.0
Dipel 36B + Orthene, 2.35 l/ha	0.89	200	14.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0
Dipel 36B alone, 2.35 l/ha	0.66	200	10.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0
Check I and II Combined	0.33	1100	7.8	0.0	0.0	0.0	0.0	0.0	1.0	8.8

Based on parasites emerged and dissected from laboratory reared larvae collected from test plots.

Based on number of larvae per bud.

Parasites identified by I.W. Varty, Maritimes Forest Research Centre, Fredericton, N.B.

Table 33

Density of *Apanteles* spp. and *Glypta* sp. Cocoons
on Foliage Based on Number of Cocoons per Bud

Treatment per ¹ acre (ha)	Density of			Ratio of ²		
	<i>Apanteles</i>	<i>Glypta</i>	A+G	Pre-S /AG	PS 1&2 /AG	PS 2/AG
Dipel WP + Orthene 1.5 GPA (14 l/ha)	0.0038	0.0010	0.0049	32.7	28.6	4.08
Dipel 36B + Orthene 0.5 GPA (4.7 l/ha)	0.0081	0.0033	0.0115	42.6	10.4	4.78
Dipel 36B Alone 0.5 GPA (4.7 l/ha)	0.0086	0.0027	0.0114	21.1	8.3	4.82
Dipel 36B + Orthene 0.25 GPA (2.35 l/ha)	0.0058	0.0022	0.0080	78.8	5.0	4.40
Dipel 36B Alone 0.25 GPA (2.35 l/ha)	0.0075	0.0033	0.0109	46.8	6.0	4.12
Untreated Check I	0.0064	0.0041	0.0106	34.9	16.5	14.15
Untreated Check II	0.0130	0.0104	0.0235	12.4	4.7	1.91

¹ Cocoons from white spruce and balsam fir combined.

² Pre-S = pre-spray density; PS # 1 and PS # 2 = density post-spray 1 and 2, respectively; A+G = *Apanteles* and *Glypta* combined.

Table 34

Percentage Parasitism among Pupae Collected from Test Plots and
Reared in the Laboratory and Total Budworm Parasitism

Treatment	Number Pupae Reared	Percent Parasitized by							Total Percent Pupal Parasitism	Percent* Budworm Parasitism
		<i>Omatoma</i> <i>fumiferanae</i>	<i>Glypta</i> <i>fumiferanae</i>	<i>Phaeogenes</i> <i>hariolus</i>	<i>Apecthis</i> <i>ontario</i>	<i>Aplomya</i> <i>caesar</i>	<i>Ictoplectis</i> <i>conquisitor</i>	Unidentified <i>Tachinids</i>		
Dipel WP + Orthene, 14 l/ha	455	-	0.22	1.30	0.44	-	-	3.10	5.1	6.1
Dipel 36B + Orthene, 4.7 l/ha	471	-	0.21	3.18	0.21	-	-	0.21	3.8	14.3
Dipel 36B alone, 4.7 l/ha	475	-	-	Parasites escaped			-	-	-	18+
Dipel 36B + Orthene, 2.35 l/ha	463	-	0.22	2.59	0.65	0.43	-	-	3.9	17.9
Dipel 36B alone, 2.35 l/ha	767	-	0.13	0.52	0.52	0.26	0.13	-	1.6	11.6
Check I & II combined	839	0.12	0.36	1.91	-	-	-	-	2.4	11.2

* Larval and pupal

Table 35

Percent Parasitism of Egg Masses Collected
from Plot Sprayed with *Bacillus thuringiensis* -
Orthene Combinations - Petawawa Forest Experiment Station, 1975

Treatments	Number Egg Masses Examined	% Parasitized ¹
Dipel WP Orthene, 14 l/ha	305	89.2
Dipel 36B Orthene, 4.7 l/ha	485	96.7
Dipel 36B alone, 4.7 l/ha	513	89.5
Dipel 36B Orthene, 2.35 l/ha	484	86.6
Dipel 36B alone, 2.35 l/ha	456	76.5
Check Plot I	423	77.1
Check Plot II	305	79.0

¹ Parasitism by *Trichogramma* sp; 75-100% of eggs in egg mass parasitized.

Table 36

Results of Aerial Application of *Bacillus thuringiensis* -
Orthene Combinations to the Same Plot in Two Succeeding Years

		1974 *	1975 *
Treatment per acre		4-12 BIU of B.t. + 0.3 - 0.6 oz Orthene	8 BIU of B.t. + 0.6 oz Orthene
Deposit per acre		0.75 - 3.67 BIU + 0.06 - 0.28 oz Orthene	1.0 BIU + 0.7 oz Orthene
Number of live budworm / 18" branch - Pre-spray	WS	18.2	14.4
	bF	8.0	2.5
Number of dead budworm / 18" branch - Pre-spray	WS	0.7	2.4
	bF	1.0	2.1
Number of live budworm / 18" branch - Post-spray (peak pupation).	WS	9.4	2.6
	bF	1.2	0.7
Incidence of Microsporidia (% of Cadavers)		19.3	37.5
Percent defoliation estimate **			
	WS	59.5 (65.4)	43.4 (76.7)
	bF	25.6 (32.9)	27.2 (53.6)
Average number egg mass per 100 sq. ft. foliage			
	Total	389 (high)	123 (mod)
	Successfully emerged	166 (mod)	25 (low)
Percent larval parasitism ¹		2.2	0.2
Percent pupal parasitism ²		4.1	8.3
Percent egg parasitism ³		56.6	81.5

* There were 3 plots in 1974 which were combined to form the 1975 plot.

¹ Based on parasites collected during population density assessment.
Percentage parasitism based on larval rearing in 1975 was 3.0.

² Based on rearing of field collected pupae.

³ Data from egg mass survey

** Untreated checks in brackets.

Table 37

Cost Analysis of Applications -
Petawawa Forest Experimental Station, 1975

Items	Treatments				
	Dipel WP	Dipel 36B	Dipel 36B	Dipel 36B	Dipel 36B
	+ Orthene 14 l/ha	+ Orthene 4.7 l/ha	Alone 4.7 l/ha	+ Orthene 2.35 l/ha	Alone 2.35 l/ha
Area, acres (ha)	2x893 (2x362)	480 (194)	484 (196)	712 (288)	791 (320)
B.t.	\$5358.00	\$1379.00	\$1390.00	\$1540.00	\$1724.00
Molasses	52.00	-	-	-	-
Orthene	318.56	85.36	-	112.72	-
Sorbitol	-	306.72	306.72	-	-
Dowanol TPM	-	-	-	216.27	243.00
Dye	65.79	11.78	11.78	8.83	9.80
Chevron Sticker	3.75	1.12	1.12	0.90	1.00
Aircraft Rental*	3576.00	964.00	964.00	1424.00	1582.00
Total	\$9374.10	\$2749.98	\$2673.62	\$3391.82	\$3559.80
Per Acre	\$10.50	\$5.73	\$5.52	\$4.76	\$4.49
Per Hectare	\$25.94	\$14.15	\$13.63	\$11.76	\$11.12

* \$2.00 / acre or \$4.90 / hectare.

APPENDIX

Larval Development at Pre- and Post-Spray
Assessment Dates

 * PLOT 1 2X 4 BIU + 0.3 OZ ORTHENE *
 * PRESPRAY @ 0.5 GPA *
 * MAY 22, 1975. *

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1
ALL SPECIES												
50	159	344	18	0	0	0	0	227	1	9	521	
	(30.5%)	(66.0%)	(3.5%)	(.0%)	(.0%)	(.0%)	(.0%)					
IS ONLY												
25	113	257	16	0	0	0	0	122	0	7	386	
	(29.3%)	(66.6%)	(4.1%)	(.0%)	(.0%)	(.0%)	(.0%)					
IF ONLY												
25	46	87	2	0	0	0	0	105	1	2	135	
	(34.1%)	(64.4%)	(1.5%)	(.0%)	(.0%)	(.0%)	(.0%)					

COMSHARE

 * PLOT 2 DIPEL:SORBO:H2O +ORIH*
 * PRESPRAY 50: 30: 20 *
 * MAY 25, 1975. @0.5 GPA *

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PJPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1
ALL SPECIES 50	213 (12.3%)	943 (54.3%)	321 (18.5%)	128 (7.4%)	130 (7.5%)	2 (.1%)	1 (.1%)	268	0	74	1737	
US ONLY 25	134 (11.3%)	567 (47.6%)	242 (20.3%)	114 (9.6%)	130 (10.9%)	2 (.2%)	1 (.1%)	166	0	72	1189	
OF ONLY 25	79 (14.4%)	376 (68.6%)	79 (14.4%)	14 (2.6%)	0 (.0%)	0 (.0%)	0 (.0%)	102	0	2	548	

COMSI-ARE

 * PLOT 3 DIPEL:SORB0:H20 *
 * PRE-SPRAY 50: 30: 20 *
 * MAY 27, 1975. @0.5 GPA *

NO OF REES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA-SITES *****	ASSOC SP *****	LIVE SBW *****	10
ALL SPECIES 51	41 (3.2%)	607 (47.5%)	445 (34.8%)	151 (11.8%)	33 (2.6%)	0 (.0%)	0 (.0%)	447	0	80	1277	
S ONLY 26	24 (3.2%)	325 (43.7%)	228 (30.7%)	133 (17.9%)	33 (4.4%)	0 (.0%)	0 (.0%)	286	0	77	743	
F ONLY 25	17 (3.2%)	282 (52.8%)	217 (40.6%)	18 (3.4%)	0 (.0%)	0 (.0%)	0 (.0%)	161	0	3	534	

COMSHARE

 * PLOT 4 DIPEL:TPM:H2O +ORTH *
 * PRE-SPRAY 75: 15: 10 *
 * MAY 28, 1975. @0.25 GPA *

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1 *
ALL SPECIES 49	40	690	1088	750	121	0	0	394	3	85	2689	
	(1.5%)	(25.7%)	(40.5%)	(27.9%)	(4.5%)	(.0%)	(.0%)					
WS ONLY 25	24	443	823	676	111	0	0	156	3	83	2077	
	(1.2%)	(21.3%)	(39.6%)	(32.5%)	(5.3%)	(.0%)	(.0%)					
BF ONLY 24	16	247	265	74	10	0	0	238	0	2	612	
	(2.6%)	(40.4%)	(43.3%)	(12.1%)	(1.6%)	(.0%)	(.0%)					

COMSHARE

 * PLUT 5 DIPEL:SORBO:H20 *
 * PRE-SPRAY 75: 15: 10 *
 * MAY 28,29 ,1975. @0.25 GPA *

NO OF REES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA-SITES *****	ASSOC SP *****	LIVE SBW *****	10
ALL SPECIES												
50	195	878	890	524	107	0	0	647	0	126	2594	
(7.5%)	(33.8%)	(34.3%)	(20.2%)	(4.1%)	(.0%)	(.0%)						
S ONLY												
25	123	578	512	421	101	0	0	252	0	117	1735	
(7.1%)	(33.3%)	(29.5%)	(24.3%)	(5.8%)	(.0%)	(.0%)						
F ONLY												
25	72	300	378	103	6	0	0	395	0	9	859	
(8.4%)	(34.9%)	(44.0%)	(12.0%)	(.7%)	(.0%)	(.0%)						

COMSI-HARE

 * CHECK PLOT 1
 * PRE-SPRAY
 * MAY 23, 1975.

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA-SITES *****	ASSOC SP *****	LIVE SBW *****	1
ALL SPECIES 49	749 (41.8%)	896 (50.0%)	138 (7.7%)	10 (.6%)	0 (.0%)	0 (.0%)	0 (.0%)	85	0	48	1793	
WS ONLY 24	405 (35.2%)	622 (54.1%)	112 (9.7%)	10 (.9%)	0 (.0%)	0 (.0%)	0 (.0%)	37	0	48	1149	
BF ONLY 25	344 (53.4%)	274 (42.5%)	26 (4.0%)	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	48	0	0	644	

COMSI-HARE

 * CHECK PLOT 2 *
 * PRE-SPRAY *
 * WS-MAY 23 BF-MAY 24, 1975. *

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1 *
ALL SPECIES												
50	279	947	279	30	1	0	0	109	1	63	1536	
	(18.2%)	(61.7%)	(18.2%)	(2.0%)	(.1%)	(.0%)	(.0%)					
WS ONLY												
25	167	687	246	25	1	0	0	89	1	59	1126	
	(14.8%)	(61.0%)	(21.8%)	(2.2%)	(.1%)	(.0%)	(.0%)					
BF ONLY												
25	112	260	33	5	0	0	0	20	0	4	410	
	(27.3%)	(63.4%)	(8.0%)	(1.2%)	(.0%)	(.0%)	(.0%)					

COMSHARE

 * PLOT 1 2X 4 BIU + 0.3 OZ ORTHENE *
 * POST-SPRAY 1 @1.5 GPA *
 * JUNE 6, 1975. *

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1 *
ALL SPECIES												
50	5	48	73	148	457	17	1	176	1	47	748	1
	(.7%)	(6.4%)	(9.7%)	(19.8%)	(61.0%)	(2.3%)	(.1%)					
NS ONLY												
25	5	33	53	135	437	17	1	139	1	46	680	
	(.7%)	(4.8%)	(7.8%)	(19.8%)	(64.2%)	(2.5%)	(.1%)					
BF ONLY												
25	0	15	20	13	20	0	0	37	0	1	68	
	(.0%)	(22.1%)	(29.4%)	(19.1%)	(29.4%)	(.0%)	(.0%)					

COMSHARE

 * PLOT 2 DIPEL:SORBO:H2O +ORTH*
 * POST-SPRAY 1 50: 30: 20 *
 * JUNE 9, 1975. @0.5 GPA *

NO OF REES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA-SITES *****	ASSOC SP *****	LIVE SBW *****	1
ALL SPECIES 50	4	110	149	240	611	44	4	220	0	156	1158	
	(.3%)	(9.5%)	(12.8%)	(20.7%)	(52.6%)	(3.8%)	(.3%)					
S ONLY 25	2	36	72	125	319	43	4	103	0	150	597	
	(.3%)	(6.0%)	(12.0%)	(20.8%)	(53.1%)	(7.2%)	(.7%)					
F ONLY 25	2	74	77	115	292	1	0	117	0	6	561	
	(.4%)	(13.2%)	(13.7%)	(20.5%)	(52.0%)	(.2%)	(.0%)					

COMSHARE

 * PLOT 3 DIPEL:SORBO:H20 *
 * POST-SPRAY 1 50: 30: 20 *
 * JUNE 12 & 13, 1975. @0.5 GPA *

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1
ALL SPECIES												
50	5	67	76	141	340	205	7	259	0	52	834	
	(.6%)	(8.0%)	(9.0%)	(16.8%)	(40.4%)	(24.4%)	(.8%)					
NS ONLY												
25	0	28	27	50	150	165	7	148	0	49	420	
	(.0%)	(6.6%)	(6.3%)	(11.7%)	(35.1%)	(38.6%)	(1.6%)					
OF ONLY												
25	5	39	49	91	190	40	0	111	0	3	414	
	(1.2%)	(9.4%)	(11.8%)	(22.0%)	(45.9%)	(9.7%)	(.0%)					

COMSI-HARE

 * PLOT 4 DIPEL:TPM:H2O +ORTH *
 * POST-SPRAY 1 75: 15: 10 *
 * JUNE 13, 1975. @0.25 GPA *

NO OF TREES ***** ALL SPECIES	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1
50	1	26	54	102	167	127	21	196	0	70	477	
(.2%)	(5.2%)	(10.8%)	(20.5%)	(33.5%)	(25.5%)	(4.2%)						
IS ONLY 25	0	0	7	18	51	92	18	130	0	69	168	
(.0%)	(.0%)	(3.8%)	(9.7%)	(27.4%)	(49.5%)	(9.7%)						
IF ONLY 25	1	26	47	84	116	35	3	66	0	1	309	
(.3%)	(8.3%)	(15.1%)	(26.9%)	(37.2%)	(11.2%)	(1.0%)						

COMSHARE

 * PLOT 5 DIPEL:TPM:H20 *
 * POST-SPRAY 1 75: 15: 10 *
 * JUNE 16, 1975. @0.25 GPA *

NO OF TREES ***** ALL SPECIES	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1 *****
50	2	18	32	77	163	201	13	197	21	80	493	
	(.4%)	(3.6%)	(6.3%)	(15.2%)	(32.2%)	(39.7%)	(2.6%)					
NS ONLY 26	1	7	8	27	41	133	5	132	8	78	217	
	(.5%)	(3.2%)	(3.6%)	(12.2%)	(18.5%)	(59.9%)	(2.3%)					
BF ONLY 24	1	11	24	50	122	68	8	65	13	2	276	
	(.4%)	(3.9%)	(8.5%)	(17.6%)	(43.0%)	(23.9%)	(2.8%)					

COMSHARE

 * CHECK PLOT 1 *
 * POST-SPRAY 1 *
 * JUNE 10, 1975. *

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1
ALL SPECIES												
50	1	54	93	139	561	103	0	144	0	28	951	
	(.1%)	(5.7%)	(9.8%)	(14.6%)	(59.0%)	(10.8%)	(.0%)					
IS ONLY												
25	0	18	40	63	319	96	0	80	0	28	536	
	(.0%)	(3.4%)	(7.5%)	(11.8%)	(59.5%)	(17.9%)	(.0%)					
IF ONLY												
25	1	36	53	76	242	7	0	64	0	0	415	
	(.2%)	(8.7%)	(12.8%)	(18.3%)	(58.3%)	(1.7%)	(.0%)					

COMSHARE

 * CHECK PLOT 2
 * POST-SPRAY 1
 * JUNE 10 & 11, 1975.

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1 *
ALL SPECIES												
50	4	51	75	119	312	162	10	131	0	72	723	
	(.5%)	(7.0%)	(10.2%)	(16.2%)	(42.6%)	(22.1%)	(1.4%)					
WS ONLY												
25	3	31	49	73	204	140	8	115	0	72	500	
	(.6%)	(6.1%)	(9.6%)	(14.4%)	(40.2%)	(27.6%)	(1.6%)					
BF ONLY												
25	1	20	26	46	108	22	2	16	0	0	223	
	(.4%)	(8.9%)	(11.6%)	(20.4%)	(48.0%)	(9.8%)	(.9%)					

COMSHARE

 * PLOT 1 2X 4 BIU + 0.3 OZ ORTHENE *
 * POST-SPRAY 2 @1.5 GPA *
 * JUNE 18, 1975. *

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1 *
ALL SPECIES 50	0 (.0%)	3 (1.9%)	3 (1.9%)	9 (5.6%)	24 (14.9%)	112 (69.6%)	10 (6.2%)	99	0	22	151	
NS ONLY 25	0 (.0%)	1 (.8%)	1 (.8%)	6 (4.7%)	6 (4.7%)	105 (82.0%)	9 (7.0%)	88	0	22	119	
BF ONLY 25	0 (.0%)	2 (6.1%)	2 (6.1%)	3 (9.1%)	18 (54.5%)	7 (21.2%)	1 (3.0%)	11	0	0	32	

COMSHARE

 * PLOT 2 DIPEL:SORBO:H2O +ORTH*
 * POST-SPRAY 2 50: 30: 20 *
 * JUNE 19, 1975. @0.5 GPA *

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA-SITES *****	ASSOC SP *****	LIVE SBW *****	1
ALL SPECIES 50	0 (.0%)	0 (.0%)	4 (1.2%)	14 (4.2%)	72 (21.7%)	219 (66.0%)	23 (6.9%)	110	6	25	309	
WS ONLY 25	0 (.0%)	0 (.0%)	2 (1.8%)	2 (1.8%)	16 (14.7%)	71 (65.1%)	18 (16.5%)	50	2	23	91	
BF ONLY 25	0 (.0%)	0 (.0%)	2 (.9%)	12 (5.4%)	56 (25.1%)	148 (66.4%)	5 (2.2%)	60	4	2	218	

COMSI-ARE

 * CHECK PLOT 1 *
 * POST-SPRAY 2 *
 * JUNE 18, 1975. *

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1
ALL SPECIES 50	0 (.0%)	0 (.0%)	2 (.4%)	3 (.6%)	43 (8.7%)	319 (64.8%)	125 (25.4%)	134	9	41	367	
WS ONLY 25	0 (.0%)	0 (.0%)	0 (.0%)	1 (.3%)	9 (2.8%)	197 (61.4%)	114 (35.5%)	92	9	41	207	
BF ONLY 25	0 (.0%)	0 (.0%)	2 (1.2%)	2 (1.2%)	34 (19.9%)	122 (71.3%)	11 (6.4%)	42	0	0	160	

COMSHARE

 * CHECK PLOT 2 *
 * POST-SPRAY 2 *
 * JUNE 20, 1975. *

NO OF REES ***** ALL SPECIES	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	10 **
50	0 (.0%)	0 (.0%)	1 (.3%)	4 (1.0%)	24 (6.1%)	226 (57.5%)	138 (35.1%)	76	10	45	255	
3 ONLY 25	0 (.0%)	0 (.0%)	0 (.0%)	0 (.0%)	6 (2.2%)	151 (54.9%)	118 (42.9%)	52	6	41	157	
F ONLY 25	0 (.0%)	0 (.0%)	1 (.8%)	4 (3.4%)	18 (15.3%)	75 (63.6%)	20 (16.9%)	24	4	4	98	

COMSI-ARE

 * PLOT 3 DIPEL:SORBO:H20 *
 * POST-SPRAY 2 50: 30: 20 *
 * JUNE 19, 1975. @0.5 GPA *

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1
ALL SPECIES												
50	0	0	3	23	91	263	32	134	7	23	380	
	(.0%)	(.0%)	(.7%)	(5.6%)	(22.1%)	(63.8%)	(7.8%)					
WS ONLY												
25	0	0	1	8	14	140	28	60	4	23	163	
	(.0%)	(.0%)	(.5%)	(4.2%)	(7.3%)	(73.3%)	(14.7%)					
BF ONLY												
25	0	0	2	15	77	123	4	74	3	0	217	
	(.0%)	(.0%)	(.9%)	(6.8%)	(34.8%)	(55.7%)	(1.8%)					

COMSI-ARE

 * PLOT 4 DIPEL:TPM:H2O +DPTH *
 * POST SPRAY 2 75: 15: 10 *
 * JUNE 19, 1975. @0.25 GPA *

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1 *****
ALL SPECIES 50	0 (.0%)	0 (.0%)	2 (1.0%)	10 (4.8%)	40 (19.0%)	122 (58.1%)	36 (17.1%)	124	3	38	174	
WS ONLY 25	0 (.0%)	0 (.0%)	1 (1.1%)	0 (.0%)	6 (6.5%)	54 (58.1%)	32 (34.4%)	55	3	35	61	
BF ONLY 25	0 (.0%)	0 (.0%)	1 (.9%)	10 (8.5%)	34 (29.1%)	68 (58.1%)	4 (3.4%)	69	0	3	113	

COMSHARE

 * PLOT 5 DIPEL:TPM:H20 *
 * POST-SPRAY 2 75: 15: 10 *
 * JUNE 19, 1975. @0.25 GPA *

NO OF TREES *****	II INSTAR *****	III INSTAR *****	IV INSTAR *****	V INSTAR *****	VI INSTAR *****	PUPAE *****	EMERGED PUPAE *****	DEAD SBW *****	PARA- SITES *****	ASSOC SP *****	LIVE SBW *****	1 *
ALL SPECIES 50	0 (.0%)	1 (.3%)	0 (.0%)	14 (4.5%)	58 (18.8%)	173 (56.2%)	62 (20.1%)	81	8	36	246	
NS ONLY 25	0 (.0%)	0 (.0%)	0 (.0%)	3 (1.6%)	24 (12.8%)	106 (56.7%)	54 (28.9%)	50	3	36	133	
BF ONLY 25	0 (.0%)	1 (.8%)	0 (.0%)	11 (9.1%)	34 (28.1%)	67 (55.4%)	8 (6.6%)	31	5	0	113	

COMSHARE

