
DIRIGO
MAINE

THE SPRUCE BUDWORM
AND THE SPRUCE CONEWORM

BEHAVIOR ON RED SPRUCE
AND
INSECTICIDE EFFICACY

Maine Forest Service
DEPARTMENT OF CONSERVATION
Augusta, Maine 04333

FINAL REPORT

STUDY OF SPRUCE BUDWORM (LEPIDOPTERA:TORTRICIDAE) AND SPRUCE CONEWORM (LEPIDOPTERA:PYRALIDAE) BEHAVIOR ON RED SPRUCE AS IT RELATES TO HOST PHENOLOGY AND DAMAGE

MARCH 19, 1985

REPORT TO

MAINE FOREST SERVICE

DEPARTMENT OF CONSERVATION

SUBMITTED BY

CHARLES J. SPIES III

ROBERT D. STRATTON

ECO-ANALYSTS, INC.

94 WESTERN AVENUE

BATH, ME 04530

ABSTRACT

A study of the feeding and concealment behaviors of spruce budworm, Choristonuera fumiferana (Clem.), and spruce coneworm, Dioryctria reniculelloides (Mutuura and Munroe), on red spruce, Picea rubens (Sarg.), was conducted in Maine in 1984. Also, the efficacy of two aerial insecticide treatments to red spruce was evaluated for both insects.

Direct observations were made on untreated caged and "wild" insects during the last two larval instars (budworm L5-L6, and coneworm L4-L5). Indirect observations were made during larval stages L3 - L6 of budworm and coincident L2 - L5 of coneworm on branch samples pole-pruned from three sample line replicates within a Bacillus thuringiensis (B.t.) spray block, a Zectran spray block and an untreated control block. Branches were frozen soon after collection and examinations were made under laboratory conditions.

Results show that feeding and concealment behaviors were similar for both species. Caged budworm and coneworm destroyed an average of 9.4 and 9.0 buds respectively. Attack by either species most often led to functional bud destruction from severing of the central bud stem. The number of buds attacked in all treatment areas increased significantly after budworm and coneworm reached peak fourth and third instars, respectively. Thirty to forty percent of the larvae were concealed during all sample periods, usually entirely within vegetative or flower buds.

In the study areas neither species was effectively controlled on red spruce. However, these results are not representative of the entire spray project as both BT and Zectran did provide better results on other operational spray blocks.

Intensive laboratory observations made on branch samples show that standard field defoliation measurement techniques used on fir underestimate damage on spruce by one-half.

TABLE OF CONTENTS

1.0 INTRODUCTION

To apply insecticides in a frugal manner, it is essential to understand a) which pests are most responsible for the plant damage, and b) at what time in the season they are most vulnerable to a particular pesticide. This requires an understanding of the phenology (timing of seasonal development) of both the insect and the host plant, as well as the amount of time needed for a given insecticide to affect targeted insects.

Until recently, most insecticide applications in Maine targeted for spruce budworm, *Choristonuera fumiferana* (Clem.), have been aimed at the protection of balsam fir, *Abies balsamea* (L.) Mill. Consequently, timing and dosages of spray applications have been based on the phenology of spruce budworm and fir. However, in some locations there has been increasing damage to spruce, *Picea spp.*, so increased attention is being given to spruce protection. This requires a better understanding of the phenology of spruce bud development and the phenology of the insect pests of spruce.

Two pests of spruce are the spruce budworm and spruce coneworm, *Dioryctria reniculelloides* (Mutuura and Monroe). Spruce budworm is known to be an important defoliator on spruce. The relative importance of spruce coneworm as a defoliator is not clearly understood. Knowledge of their relative roles on spruce is essential to deciding if and when control efforts are necessary for both insects.

Budworm feed on the needles and closed buds of spruce for a longer period than on the needles and closed buds of fir. This is because budbreak occurs later on spruce, while budworm emergence times are consistent within a season regardless of host (Greenbank 1963, Mott 1963, Hansen and Dimond 1982). This probably affects the times at which budworm on spruce are most directly exposed to spraying. Thus, budworm on red spruce are not necessarily exposed during the time insecticides are applied for their control on fir.

Information to date on the spruce coneworm indicates that its life cycles, feeding behavior, and population trends (McLeod and Daviault 1963, Spies and Dimond 1985) are similar to the budworm. However, there is little information on its behavior on red spruce. It often occurs in mixed populations with budworm, sometimes in equal or greater numbers (Barker and Fyfe 1947, Spies and Dimond 1985).

In this study, we addressed the following questions through an intensive field and laboratory research effort:

1. What are the relative levels of damage on red spruce caused by the spruce budworm and the spruce coneworm?
2. Do budworm and coneworm on red spruce differ significantly in their feeding and concealment behaviors?
3. Are control efforts needed for each species?

2.0 METHODS

2.1 STUDY AREA

Work was done in the Chesuncook Lake area of Maine where spruce budworm and spruce coneworm had been found to be common. Study sites representing two forms of spray treatment and an unsprayed control area were located and mapped (Figure 1).

2.2 DIRECT OBSERVATIONS

Direct observations were performed on caged budworm and coneworm on red spruce during peak fifth and sixth instar. The cages provided a controlled environment for behavior studies. Individuals of each species and a combination of one of each species were reared in the cages without outside competition or predation.

The cages were constructed of lightweight synthetic (Nytex) screening with a boxed-bottom design. The stiff nature of the material and the boxed bottom prevented any cage collapse and kept the material from touching the branch. Cages were attached to branchlets by grooved Velcro closures which provided a tight seal around the branch stem.

Four cage sites were located in T2 R12, Piscataquis Co. Trees selected were mature, codominant, open grown individuals having relatively low indigenous populations and evidence of healthy vegetative growth. At each site, pipe scaffolding was erected to allow mid-crown access to one or two red spruce. Thener25-40 cages were attached to branchlets having 15-20 buds. The branchlets were searched, and all arthropods and damaged needles were removed before the empty cages were attached.

Originally, overwintering budworm and coneworm were to be forced out of diapause for use as cage insects, but delays in operation caused us to miss the optimum forcing out time. Therefore, insects had to be hand picked from branches. Caging of insects commenced on 25 May and was completed on 4 June. The procedure consisted of removing empty cages, searching again for unwanted arthropods, and then inoculating the foliage with either one budworm, one coneworm, or a combination of one budworm and one coneworm. The cages were replaced and the insects were allowed several days to acclimate. There were a total of 50 spruce coneworm cages, 49 spruce budworm cages, and 45 mixed species cages (Table 1).

At peak fifth instar (L5) for spruce budworm (13 June 1984), each cage at the four sample sites was observed for evidence of feeding activity. Data were recorded for species, feeding position, body exposure, and bud development of caged buds.

At peak sixth instar (L6) for spruce budworm (20 June 1984), observations were made on "wild" insects adjacent to cages. This method was adopted after L5 observations were completed. It was felt that enough "wild" insects were available on uncaged shoots to make destructive sampling possible. This provided more detail by allowing a greater number of observations and variables to be included. This did not diminish the value of the cages since they provided data on total vegetative consumption, number of buds consumed per insect, and feeding patterns.

Data on the following variables were collected from the L6 observations: species, larval instar, bud development of occupied buds, feeding position, feeding damage, bud stem severing, body exposure, and concealment type.

All cages were removed with their associated branchlets and insects on July 9, 10, and 11. Cages, branchlets, and insects were frozen as a unit. They were searched and data was collected as described above.

2.3 BRANCH SAMPLES

Foliage samples were taken from nine sample lines. Three lines were located in a Zectran spray block (E046), three lines were located in a Bt spray block (E034), and three lines were located in untreated control areas (Figure 1.). The trees themselves were located in well drained sites to minimize the effects of hybridization of red spruce with black spruce (Manley and Fowler 1969).

A total of five samples was taken from each line. Timing of sample periods corresponded, as nearly as possible, to peak budworm instars on balsam fir, Abies balsamea (L.) Mill. This method followed standard budworm sampling practices used to time spray operations. Four sample periods corresponded with peak 3rd, 4th, 5th and 6th larval instars of the budworm and are referred to as L3 - L6 sample periods in the text for both budworm and coneworm samples. Coneworm instars L2 - L5 corresponded with the L3 - L6 stages of the budworm. One sample was taken later in the season to gather more data on 5th instar coneworm which pupate later than budworm (Table 2).

Each sample line consisted of ten clusters of three red spruce each. Two branches per cluster were removed with pole pruners from the upper mid-crown of separate trees during each sample period. The tree sampling order was staggered to insure a random approach and provide sufficient numbers of suitable branches for each sample.

Sample branches were bagged and tagged separately when pruned. They were frozen the same day upon return to operation headquarters. Eventually they were transported in an insulated container to a commercial cold storage facility near the ECO-ANALYSTS INC. laboratory in Bath, Maine. Sampling was done in September to determine final defoliation using the method employed by the Maine Forest Service (Dorais and Kettela 1982).

2.4 SAMPLE PROCESSING

Each branch was assigned a distinguishing number identifying it by sample period, spray treatment, sample line, cluster, date and individual tree. On each branch, a mean bud index was estimated to indicate bud development, and branch area was calculated (Figure 2 and Appendix A).

Two-thirds of the sample branches had at least one branch sector examined for bud damage. A sub-sample size of 14 branches per line with 95 percent confidence was calculated for the sector collection based on the formulae given for discrete sample size by Freese (1967). A random numbers table was utilized to determine which of 9 possible branch sectors would be examined. Within that sector, 30 vegetative buds were examined for damage. Explanations of sector location and the location of feeding and damage assessment categories are in Appendix A.

The search for vegetative buds was initiated at one corner of a sector and proceeded continuously along the current and previous year's growth until 30 vegetative buds were counted. As the search progressed, the number of dormant (or late breaking) buds, killed buds from the previous growing season that were not attributable to current year insect damage and flower buds were recorded. This provided a ratio for these bud types per 30 vegetative buds.

When an insect was encountered, its species, stage of development, mode of concealment, and position on the foliage were recorded. This was done in the 30 bud sector and over the entire branch. Insects were associated with individual buds or needles only if they were found within the structure or clearly attached with silk.

Analysis of variance and Student-Neuman-Keuls multiple range tests were used to compare insect numbers after log transformations had been performed (Miller 1955 and Southwood 1978). Non-parametric tests were used to compare discret variables (Zar 1974).

3.0 RESULTS

Data from branch samples for feeding behavior a concealment behavior were pooled within sample periods by samp lines having statistically similar mean bud indices and simi budworm or coneworm instars (Table 10). This was done minimize any effects on behavior due to bud size and ins development. The data groups are referred to as: the BT group, the Zectran group, the Control group and 'all similar lines' for all plots and treatments combined. Only larvae within a bud or attached by silk were used to record data. These data were compared for sample periods L3 - L5 only because the large larvae collected at the last two sample periods moved around in the sample bags too much before freezing to allow enough "occupied bud" observations.

3.1 FEEDING BEHAVIOR-DIRECT OBSERVATIONS

3.1.1 Spruce Budworm

The frequencies of budworm occupying four types of feeding positions are shown in Table 3. It should be noted that n values are lower for cage numbers than those given in Table 1. This is because feeding activity was not observed in every cage. Table 3 shows that the majority of budworm feeding was near the base of the bud, either mining or on the surface. It was not possible to tell if the surface feeding activity would cease there or continue into a mine. Binomial tests on all sites except Site 2 indicated that significantly more budworm larvae fed at the base of buds rather than apically. Chi-square tests on pooled data for all sites showed no differences between basal mining and surface feeding, but showed significantly higher numbers feeding basally than apically.

Apical mining did not occur during the L6 stage. This category was dropped and replaced with "feeding along entire bud"(Table 4). This was the most common type of feeding at that stage. A chi-square test on pooled data showed a preference for basal bud feeding when basal and apical surface feeding were compared. This points towards a tendency to initiate feeding basally which then progresses into feeding along the entire bud.

Bud damage was not estimated at L5 to avoid disturbance to caged insects. At L6, the mean defoliation for budworm occupied buds in all sites was 62.5 percent, based on the Fettes system (Dorais and Kettella 1982), and 40 percent of the attacked buds had severed stems (Table 5).

3.1.2 Spruce Coneworm

The spruce coneworm also had a preference for basal feeding during the L5 sample period (Table 6). However, it was by mining only, no surface feeding of any kind was observed. A chi-square test on pooled data indicated that significantly more coneworm mined basally than apically.

Feeding along the entire bud was the most common behavior observed for coneworm during the L6 sample period (Table 7). Basal surface feeding was the second most common behavior, but a chi-square test on pooled data showed no significant difference between basal and apical surface feeding.

The mean defoliation for all coneworm occupied buds observed at L6 was 71 percent and 55 percent of the attacked buds had stems severed (Table 5).

Caged branchlets were examined after larval development was complete. Budworm had attacked an average of 9.4 buds and coneworm had attacked an average of 9.0 buds from the time they were caged at late third instar budworm and late second instar coneworm. These numbers may be conservative since damage to flower buds could not be assessed. Bud mining which led to 100 percent bud destruction was the most common type of bud damage tallied for both species. Extensive damage also resulted from surface feeding by both species. The usual outcome of bud attack was stem severing and complete bud loss.

3.2 FEEDING BEHAVIOR-BRANCH SAMPLES

3.2.1 Budworm on Vegetative Buds

Feeding Position

Budworm damage to vegetative buds was most often in the all-over position class for all three sample periods (Table 11). During sample period L3 the number of buds damaged apically was higher than those damaged basally in the all similar lines group and Bt group. This trend reversed over time and basal damage exceeded apical damage in all groups by sample period L5. A slight but steady increase in the number of destroyed buds occurred for all groups from sample period L3 to sample period L5.

Feeding Type

Bud mining was the most common type of budworm feeding behavior in all data groups and at all sample periods (Table 11). However, surface feeding did increase markedly during sample period L5. No comparisons to the control group could be made during sample period L4 because too few budworm were found in the vegetative buds.

Foliage Damage

Damage to occupied buds was evenly distributed throughout all five damage categories in all groups and at all sample periods (Table 12).

Stem Severing

The number of occupied buds with stems severed was greater than those with unsevered stems in all groups and at all sample periods except Zectran, sample period L3 (Table 12). From sample period L3 through sample period L5 the percentage of attacked buds with severed stems increased (approximately 52 percent to 65 percent to 79 percent for sample periods L3, L4, and L5 respectively) (Figure 3).

These data for budworm feeding behavior on vegetative buds indicate that the location of attack may be a function of bud development. We observed that undeveloped buds (bud index=1) have a thick outer bud scale that appeared to be impenetrable to most larvae. As the buds swelled the thick outer scale remained at the base of the bud and was replaced by thinner scales that were less of an obstacle to penetration by the insects. Therefore, larvae must wait for some bud swelling before entering the bud. This may explain the shift over time from apical to basal feeding. As the buds swelled and elongated the individuals could initiate feeding closer to the bud base, just above the thicker bud scale and thus reduce exposure to predation (Figure 4). The apical or basal initiation of feeding led to general feeding over the entire bud.

If one assumes that individuals found occupying buds with no damage (none) have just moved onto the bud, and that individuals found occupying consumed buds (destroyed) will soon be vacating, then these two percentages together give a rough indication of inter-bud movement. This estimate for budworm was 20 percent for all three sample periods. The value for sample period L3 is probably artificially high because individuals were abandoning needles and moving onto buds, thereby increasing the percentage of occupied buds with no damage. An even distribution of bud damage throughout the 5 damage categories would be expected if insects are consuming multiple buds and are sampled while this interbud movement is occurring. These data concur with data generated from caged individuals that showed that budworm had damaged an average of 9.4 buds each.

The high percentage of mining type feeding at the first two sample periods (L3 and L4) cannot be related to the high percentage of stem severing at these periods because in sample period L5, stem severing continued at a high rate while mining became less common.

The amount of foliage damage is a moot point when one looks at the high percentage of stem severing in each sample period. Most attacked buds are effectively destroyed by stem severing no matter what the extent of foliage consumed, as Figure 3 shows.

3.2.2 Budworm on Flower Buds

Feeding Position

During sample period L3, flower buds occupied by spruce budworm were most commonly damaged basally in the all similar lines and the Zectran groups. They were most commonly damaged all-over in the Bt group. Apical damage and destroyed buds were clearly less frequent (Table 11).

During sample period L4 the number of destroyed buds increased sharply, comprising approximately 30 percent in all the data groups. Basal and all-over damage were again most common.

Feeding Type

Mining was the most common type of feeding during sample period L3 (Table 12). During sample period L4 surface feeding increased for all data groups and became most common in the Zectran group.

Damage Extent

The greatest percentage of damage to occupied buds in all groups was found in the 0-20 percent and 21-40 percent damage classes during sample period L3. During sample period L4 the distribution became uniform across all categories.

Stem Severing

Stem severing occurred rarely during sample period L3, however, it did increase to approximately 50 percent by sample period L4. Most stem severing was basal (Table 12).

As with vegetative buds it appears that budworm attack either basally or apically and then proceed to feed over the entire bud. The large number of basally feeding insects at sample period L3 is probably due to the earlier bud break of flower buds versus vegetative buds. The large number of destroyed buds in sample period L4 may be due to the normal deterioration of mature flower buds. If one looks at cumulative percentages of buds in the none and destroyed categories as an estimate of movement, it appears that little movement occurred during sample period L3 (1 percent for all similar lines group), and movement increased during sample period L4 (33 percent). This is plausible since the large, soft flower buds could provide adequate food or shelter during sample period L3 while the declining flower buds at the L4 sample period would not provide as much food and shelter, thus encouraging movement. In contrast to vegetative buds, the movement of insects is infrequent at first, then increases rapidly. This probably results in the destruction of fewer flower buds than vegetative buds, because those insects vacating flower buds during sample period L4 would most likely move to expanding vegetative buds rather than to another, declining flower bud.

3.2.3 Coneworm on Vegetative Buds

Feeding Position

At sample period L3 spruce coneworm commonly fed over the entire vegetative bud (Table 13). The percentage of basally damaged buds was equal to the percentage of apically damaged buds. Since most coneworm in the Zectran plot were found on flower buds, due to a very large crop, no data pool subdivisions could be compared.

During sample period L4, coneworm again most commonly fed over the entire bud for all data groups. Basal feeding was more frequent than apical feeding and the number of occupied, destroyed buds increased. These trends were repeated during sample period L5.

Feeding Type

Mining was the most common type of feeding behavior during all three sample periods (Table 13). However, surface feeding did increase sharply during sample period L5 when it occurred 46 percent of the time.

Damage Extent

The frequency of buds occurring in the 5 foliage - destroyed categories was uniform during all sample periods in all groups (Table 14).

Stem Severing

The incidence of stem severing in attacked buds on similar lines increased from 50 percent to 58 percent to 81 percent respectively during sample periods L3, L4 and L5. Basal severing was most common overall.

In summary it appears that on vegetative buds, coneworm feeding behavior is very similar to budworm feeding behavior. They both attack buds either basally or apically and then proceed to feed over the entire bud. The coneworm may be less inhibited by the thick outer bud scale than budworm since it attacked the same number of buds basally as it did apically during the first sample period.

If the percentage of coneworm occupied buds with no damage (none) and the percentage of destroyed buds are summed together, we find this value decreases from sample period L3 to sample period L5 (24 percent to 15 percent). This infers that inter-bud movement by coneworm was greater than budworm at sample period 1 and less than budworm at sample period L5. As with budworm, recruitment into the none category of needle miners at sample period L3 may contribute to the relatively high value, thus increasing the estimate of movement at this sample period.

The type of feeding and amount of foliage consumed by coneworm were also very similar to budworm.

The incidence of stem severing was high and increased by sample periods for both budworm and coneworm. The end result in most cases is functional destruction of the vegetative buds soon after budworm or coneworm feeding begins, regardless of the amount of foliage damage.

3.2.4 Coneworm on Flower Buds

Feeding Position

The majority of flower buds occupied by coneworm were damaged basally during the first sample period. Buds damaged all-over were also common (Table 13). During sample period L4, damage to flower buds was distributed evenly between the basal, all-over, and destroyed categories.

Feeding Type

Bud mining was the most frequent type of feeding behavior on flower buds during sample period L3. Surface feeding increased during sample period L4, most notably in the Zectran group where it rose to 61 percent (Table 13).

Damage extent

Most buds fell into the 1-20 percent or 21-40 percent foliage damage categories during sample period L3 (Table 14). The Bt group had more damage to flower buds than the Zectran group. As with budworm, the majority of buds fell into the 80-100 percent foliage damage category during sample period L4.

Stem Severing

Stem severing occurred rarely during sample period L3. It increased to about 50 percent during sample period L4; basal cutting was most common.

3.3 CONCEALMENT BEHAVIOR - DIRECT OBSERVATIONS

During the L5 sample period, estimates of body concealment ranged from 50 to 90 percent for both species in cages. During the L6 sample period, the average body concealment of uncaged budworms was 78 percent for 93 observed larvae.

The most common concealment positions at L6 for budworm are categorized in Table 8. Multiple shoots were used 60 percent of the time, silk and severed plant material were used 22 percent of the time, and single shoots of old foliage were used least.

Spruce coneworm had an average body concealment of 82 percent based on 94 observations. This was statistically similar to the same value for budworm (p§0.05). Coneworm concealment positions were also similar to the budworm (Table 9). Multiple shoots were used 46 percent of the time, silk and severed plant material were used 30 percent of the time, and single shoots of old foliage were used least.

3.4 CONCEALMENT BEHAVIOR - BRANCH SAMPLES

3.4.1 Budworm on vegetative buds

Approximately 33 percent of budworm larvae occupying vegetative buds were found completely concealed in foliage and opaque thick silk, or just opaque thick silk, during the L3 sample period for all similar lines (Table 15). The BT group had similar values but the Zectran group had a notably greater number of concealed individuals. However, the Zectran group was based on a small number of individuals and may not be representative of the whole population.

The mean percent of budworms concealed increased slightly during the next two sample periods to approximately 42 percent at the L5 sample. All data groups showed similar trends in the last two samples. Since there was undoubttedly some movement of insects in or out of buds caused by jostling, solar heating in the bags or the freezing process, these concealment values must be considered estimates. Only insects completely covered with a physical barrier of foliage or opaque thick silk were categorized as concealed.

Whether or not this many insects were invulnerable to spray at all times is an open question. Varty and Godin (1983) consider larvae to be a "dynamic target" because the larvae move in and out of shelters to remove frass and spin silk. If one-third to one-half the population are effectively protected from spray droplets (in spite of some silk spinning and frass removal) good budworm control by direct contact of insecticides is unlikely on red spruce, during the L2-L5 larval stage. Also, if these insects are feeding on foliage that is effectively concealed by bud scales or silk, inoculated foliage would not be consumed.

3.4.2 Budworm on flower buds

Budworm larvae were better concealed on flower buds during the L3 sample period than in vegetative buds. (Table 15) This is probably due to the larger size of the flower buds, which allowed the insect to feed completely within the bud. This is shown in Table 16 where the most common concealment position for budworm in flower buds was "Anterior and Posterior in bud".

The percent concealed was less during the L4 sample period, when most flower buds were flaring and approaching maturity, thus providing less shelter for larvae.

The higher incidence of concealed individuals on flower buds during the L3 sample period could result in less effective insecticide applications during a "good" flower year such as 1984. This would be important when split applications are used as the first application is usually applied during the L3 stage in Maine.

3.4.3 Coneworm on vegetative buds.

The number of concealed coneworm on vegetative buds showed trends similar to those of budworm on vegetative buds. Overall, the incidence of concealed larvae increased between the L3 and L5 sample periods from 36.8% to 43.5% for all similar lines (Table 17).

3.4.4 Coneworm on flower buds.

The incidence of concealed coneworm larvae on flower buds was similar to trends shown by budworm during the L3 sample, but during the L4 sample period a higher percentage of larvae were concealed on flowers than were budworm larvae (Tables 15 & 17).

Table 16 shows that more coneworm than budworm were commonly found completely in buds at this stage. Overall, coneworm behavior on vegetative and flower buds is comparable to budworm behavior. This means the problems discussed earlier with insecticide applications to instars L3-L5 of budworm would also be associated with coneworm populations during their L2-L4 stage.

3.5 SPRAY EFFICACY

3.5.1 Application

The Zectran plot (E046) was sprayed on June 3, 1984 and again on June 16, 1984 with 1 ounce active ingredient (ai) per 20 ounces total volume per acre. A C-54 aircraft was used to apply Zectran. The BT plot (E034) was sprayed by a Thrush aircraft June 15, 1984 with 12 B.I.U. per 24 ounces total volume per acre. Maine Forest Service monitoring reports were used to confirm all dates.

3.5.2 Populations

Spruce Budworm

Densities of spruce budworm per square foot of red spruce foliage ranged from 1.8 per square foot on Line 1 of the Control plot during the L3 sample period to 10.3 per square foot on Control Line 2 during the L5 sampling period (Table 18.). On the BT plot, the numbers ranged from a low of 2.6 per square foot on Line 1 at the L3 sample period to a high of 8.5 per square foot on Line 2 at the L5 sampling period. On the Zectran plot, the numbers ranged from 2.6 per square foot on Line 3 at the second postspray sampling period (L6) to a high of 6.9 per square foot at the first postspray sampling period (L4). As can be seen, there was little variation within the plots at each sample period. The only significant differences within a sprayed plot was at the second postspray sample period (L6) when Line 1 (5.6/sq. ft.) had significantly greater spruce budworm than Line 3 (2.6/sq. ft.).

There were no significant reductions in numbers of spruce budworm (Table 19). Spruce budworm populations were significantly greater at the L4 collection on the Control plot and on all plots at the L5 collection.

In these study sites, BT and Zectran had no significant impact on spruce budworm populations. The lack of effect was consistent for both plots and for all lines within each plot. However, these blocks were not representative of the entire operational spray program; most other spray blocks did show evidence of some control (pers. comm. H. Trial, Me. For. Serv.).

Spruce Coneworm

There was a slightly greater range of densities with spruce coneworm, ranging from 1.6 per square foot on Control Line 1 at the first (L1 coneworm) sample period to 13.6 per square foot on BT Line 3 at the third (L3 coneworm) sampling period (Table 20.). Variability within plots was greater with coneworm than with budworm with significant differences noted during the first prespray and the first postspray on the BT plot and at the fourth (L4 coneworm) and fifth (L5 coneworm) sample periods on the Control plot.

There were no significant reductions in the populations of spruce coneworm on any of the treatments (Table 19). There were significantly greater numbers of coneworm at the L5 sample period on the BT plot and at the L5 and L6 sample periods on the Zectran plot. Numbers fluctuated on the Control plot. Again, there is no evidence to suggest significant population control on spruce coneworm on the two spray blocks.

Spruce Budworm and Spruce Coneworm Combined

Populations ranged from 3.1 per square foot at the L3 sample period on Line 1 of the Control plot to 21.3 at the L5 sample period on Line 2 and Line 3 of the BT plot (Table 21). Variability was greatest on the Zectran plot with significantly greater numbers on Line 1 and Line 2 at the L5 and L6 sample periods. There was a significant difference between Line 1 and Line 3 on the BT plot at the L6 sample period. No differences were found on the Control plot.

There were no population reductions on either treatment (Table 19). The trend was towards greater numbers at the L4 sample period with a decrease at the final sample L5 period. As with the individual species, there is no evidence that the two insecticide treatments exerted any population control on red spruce defoliators in the blocks studied.

3.5.3 Efficacy

Spruce Budworm

Neither Zectran nor BT were effective in controlling spruce budworm on red spruce in the spray blocks studied. Unadjusted kill ranged from a low of 0.6 percent to a high of 14.2 percent with Zectran (Table 22.). Unadjusted kill with BT was 39.8 percent. Adjusted kill with Zectran ranged from no control (negative kill) to 51.9 percent. Adjusted kill with BT was 7.5 percent.

Spruce Coneworm

Zectran and BT were also not effective in controlling the spruce coneworm on red spruce in these two study sites. Unadjusted kill with Zectran ranged from none (negative kill) to 42.4 percent (Table 22.). Unadjusted kill with BT ranged from 41.5 to 65.4 percent. Adjusted kill with Zectran ranged from none (negative kill) to 47.6 percent. Adjusted kill with BT ranged from 11.9 to 22.1 percent.

Spruce Coneworm and Spruce Budworm Combined

Looking at both species together to get an indication of "defoliator kill", unadjusted kill with Zectran ranged from none (negative kill) to 12.7 percent (Table 22.). Unadjusted kill with BT was 44.4 percent. Adjusted kill with Zectran ranged from none (negative kill) to 41.5 percent. Adjusted kill with BT was

21.4 percent.

These results indicate a problem in controlling the spruce budworm and spruce coneworm on red spruce in these two study sites. There seems to be no differential in the ease of controlling one insect compared to the other with the materials used in this study. Conventional thought has been that coneworm has been less easily killed than budworm. These data do not substantiate that theory. Since both materials control spruce budworm well on balsam fir, it appears that the insecticides did not reach either of the insects, not that the materials are inherently ineffective at the applied rates.

3.5.4 Defoliation

Two estimates of defoliation were taken during this study. The first is the final field defoliation collected in the traditional manner. There was no significant difference in foliage lost among the three plots (Table 23.).

The second defoliation estimate was taken from the samples analyzed in the laboratory in the study of spruce budworm and spruce coneworm behavior. As can be seen in Table 24, defoliation increased on all plots at all sample periods. Also, there was significantly more defoliation on both sprayed plots than on the control plot at each sample period, clearly showing the lack of foliage protection on red spruce. We could not compare expected defoliation values as is typically done by the Maine Forest Service for three reasons: 1) populations in the control block were significantly lower than in the spray blocks disallowing direct comparison; 2) we could not relate our values to MFS regression equations since our methodology was different than typical forest service techniques; 3) our own regression equation comparing combined insect densities per square foot to defoliation within the control block showed a poor correlation between the two variables (r-squared=0.074).

The data in Table 23 were collected before those in Table 24. The first data were analyzed in the conventional fashion while the second set of data came from the more detailed analysis method used for the behavior study. On the BT plot, the conventional defoliation estimate was 17 percent while the detailed estimate was 80 percent. On the Zectran plot, the conventional estimate was 24 percent while the detailed estimate was 42 percent. On the Control plot, the conventional estimate was 16 percent while the detailed estimate was 35 percent. This indicates that the amount of damage to red spruce has been underestimated when conventional defoliation methods have been used.

3.6 DAMAGE ASSESSMENT

Bud Types Encountered

The number of bud types encountered per 30 vegetative buds counted are shown in Table 25. The number of attacked vegetative buds increased significantly between the L4 and L5 sample periods on the BT and Zectran plots, and significant increases occurred between the L5 and L6 sample periods on the Zectran and Control plots. The numbers increased significantly on all plots between the budworm L6 and the later coneworm L5 sample periods.

This measure of bud damage in conjunction with defoliation (Table 24 and 25) gives an idea of how much damage occurred and when the number of damaged buds increased markedly.

The number of buds attacked was greatest on the BT block where combined defoliator population densities were highest (Table 19). Since significant changes occurred at almost the same time in all treatment areas, the number of buds attacked is probably a function of the rate of feeding as well as insect numbers. Blais (1977) found increased rates of feeding by budworm from peak fifth instar to pupation on balsam fir. Our results are similar, indicating that increased feeding rates began between the L4 and L5 sampling periods and continued to coneworm pupation.

The number of buds killed in previous years that were encountered by searchers decreased on all plots after the first sample period. Otherwise, they were not significantly changed during the later sample periods. The initial decrease is due to the action of expanding new buds which sloughed off much of the old bud material. Thus, fewer killed buds could be identified. Based on the relative consistency of the values for killed buds, it appears that searchers successfully identified these structures and differentiated them from current year's killed buds.

The mean number of flower buds encountered varied somewhat but was significantly different in only one case. This too indicates that they were accurately identified, even after the loss of reproductive structures in the later sample periods.

Finally, dormant buds were found to be virtually non-existent on the last year of growth. Those identified as such in the later samples were mostly buds that were very late in breaking.

Defoliation

During the course of our study, we found that standard procedures for measuring defoliation on fir were not adequate for determining damage on red spruce. The reason for this is that many buds are destroyed completely when very small via stem severing by both budworm and coneworm (Table 12 and 14). This leaves only the basal bud scales which are likely to be overlooked. Thus, accurate measurements of foliage damage on red spruce require closer scrutiny. Personnel should be trained to identify current year's bud bases and differentiate the various red spruce bud types.

4.0 CONCLUSIONS

Feeding

Feeding behavior of both species is very similar. No notable differences in the amount of foliage consumed, or their modes of feeding were found. Both insects consume multiple buds (9-10) throughout the growing season and cause equal amounts of damage.

Concealment

Both insects also exhibit similar concealment behaviors. We estimate that 30-50 percent of both species are physically concealed from direct contact with insecticides, at least part of the time, during the L3 - L5 instars of budworm and the coincident L2 - L4 instars of coneworm.

Efficacy

The efficacy of the two treatments used in this study was very poor. No registrable effect was noted for either treatment in spite of the intensive sampling methods used. However, the study sites used were not representative of the operational spray program as a whole.

Damage Assessment

Standard field defoliation assessment techniques commonly used on fir have underestimated damage on spruce. Past estimates of damage should probably be doubled.

LITERATURE CITED

Barker, R.B. and H.A. Fyfe. 1947. A mixed infestation in the spruce woods forest reserve, Manitoba. Can. Dept. Agr., Div. For. Biol., Bi-Mon. Prog. Rept. 10(3):2.

Blais, J.R. 1977. Timing of insecticide applications against spruce budworm (*Choristoneura fumiferana* (Clem.)) in relation to larval development and progressive damage to foliage on balsam fir (*Abies balsamea* (L) Mill.). Can. Centre Rech. For. Laurentides, Ste-Foy, Que. Rapp. Inf. LAU-X-27. 18 p.

Dorais, L. and E.G. Kettela 1982. A review of entomological survey and assessment techniques used in regional spruce budworm, <u>Choristoneura</u> <u>fumiferana</u> (Clem.), surveys and in the assessment of operational spray programs. Committee for Standardization of Survey and Assessment Techniques. Eastern Spruce Budworm Council. Quebec 43pp.

Freese, Frank. 1967. Elementary Statistical Methods for Foresters. U.S. Dept. of Agriculture, Forest Service, Agriculture Handbook 317.

Greenbank, D.O. 1963. Host species and the spruce budworm, pp. 219-223. <u>IN</u> R.F. Morris (Ed.) The dynamics of epidemic spruce budworm populations. Mem. Ent. Soc. Can. 31.

Hansen, R.W. and J.B. Dimond. 1982. The feeding biology of spruce budworm on several hosts with reference to timing of insecticidal sprays. Me. Life Sci. Agr. Exp. Sta. Misc. Rep. No. 266. 19pp.

McLeod, J.M. and L. Daviault. 1963. Notes on the life history and habits of the spruce coneworm (<u>Dioryctria</u> <u>reniculella</u> Grt.) (Lepidoptera:Pyralidae). Can. Ent. 95(3):309-316.

Morris, R. F. 1955. Development of sampling techniques for forest insect defoliators with special reference to the spruce budworm. Can. J. Zool. 33: 225-294.

Mott, D.G. 1963. Preliminary assessment of operational and experimental aerial spraying against spruce budworm in New Brunswick in 1961, pp.35-49. <u>IN</u> D.R. MacDonald (Ed.). Studies of aerial spraying against the spruce budworm in New Brunswick. XVIII. Operational summaries and assessments of immediate results -1960,1961,1962. Can. Dept. For., For.

Ent. Path. Lab. Info. Rep. 1963.

Southwood, T.R.E. 1978. Ecological Methods. Chapman and Hall, London and New York. 524 pp.

Spies, C.J.,III and J.B. Dimond. 1985. Some populational relationships between the spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae) and the spruce coneworm, *Dioryctria reniculelloides* (Lepidoptera: Pyralidae). Can. Ent. 117: 193-202.

Varty, I. W. and M. E. Godin. 1983. Identification of some of the factors controlling aerial spray efficacy. Can. For. Serv. Inf. Rep. M-x-142. 29pp.

Zar, J.H. 1974. Biostatistical Analysis. Prentice-Hall Inc., Engelwood Cliffs, N.J. 620 pp.

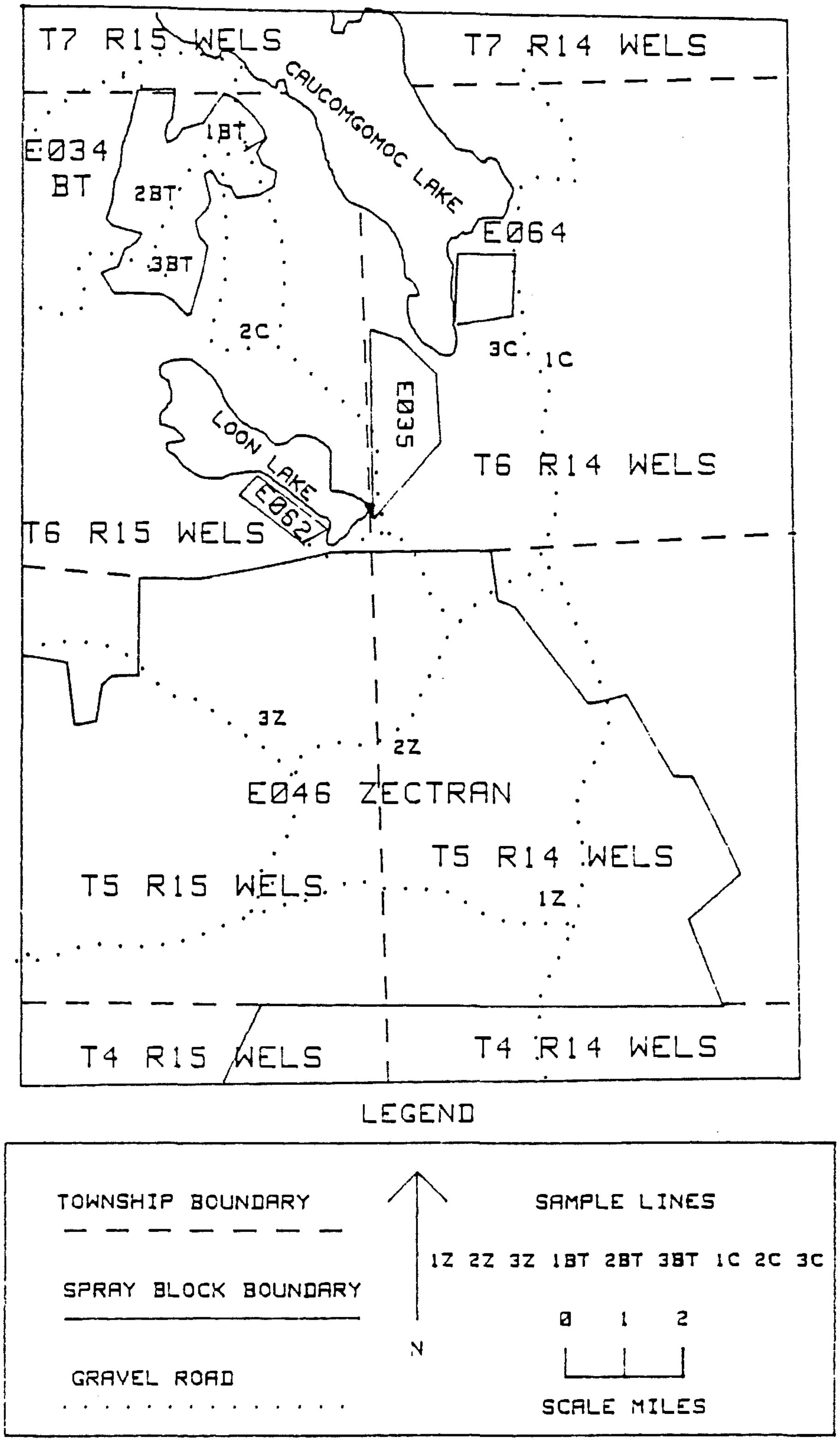
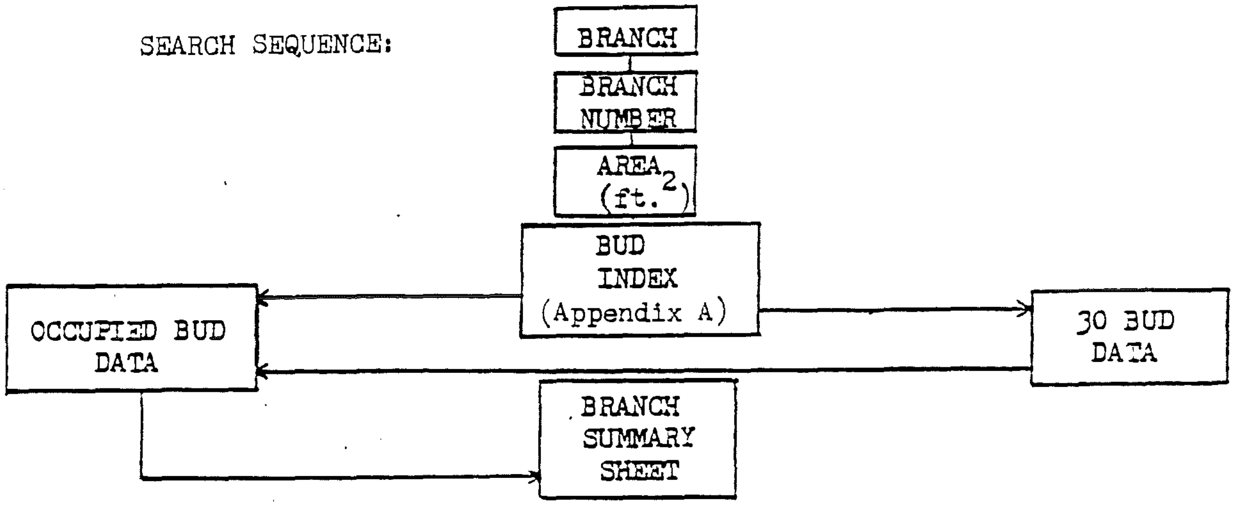


FIGURE 1 MAP OF SPRAY BLOCKS AND SAMPLE LINES USED FOR SPRUCE BUDWORM AND SPRUCE CONEWORM POPULATION SAMPLING IN 1984

SEARCH SEQUENCE:



VARIABLES

BRANCH NUMBER	30 BUD DATA (see Appendix A)	OCCUPIED BUD DATA (see Appendix A)	BRANCH SUMMARY SHEET (see Appendix A)
Sample period	Bud #	Bud #	Branch #
Plot	Bud index	Bud type	Sector #
Line	Damage	Insect	30 Bud Totals
Cluster	location	Species	# live buds
Tree	type	#	# dormant buds
Sample Date	extent %	instar	# killed buds
	stem cut	Damage	# flower buds
	Defoliation	location	Mean Bud Index
	Total Dormant Buds	type	Mean Defoliation
	Total Killed Buds	extent %	Peak Instar
	Total Flower Buds	stem cut	spruce budworm
	Mean Bud Index	Concealment	spruce coneworm
	Mean Defoliation	(see Appendix A)	Number
		head type	spruce budworm
		position	spruce coneworm
		amount	other
		exposure	total
		abdomen type	Branch Area

Figure 2 Branch searching procedures in a study of the behavior of spruce budworm and spruce coneworm on red spruce in northern Maine in 1984.

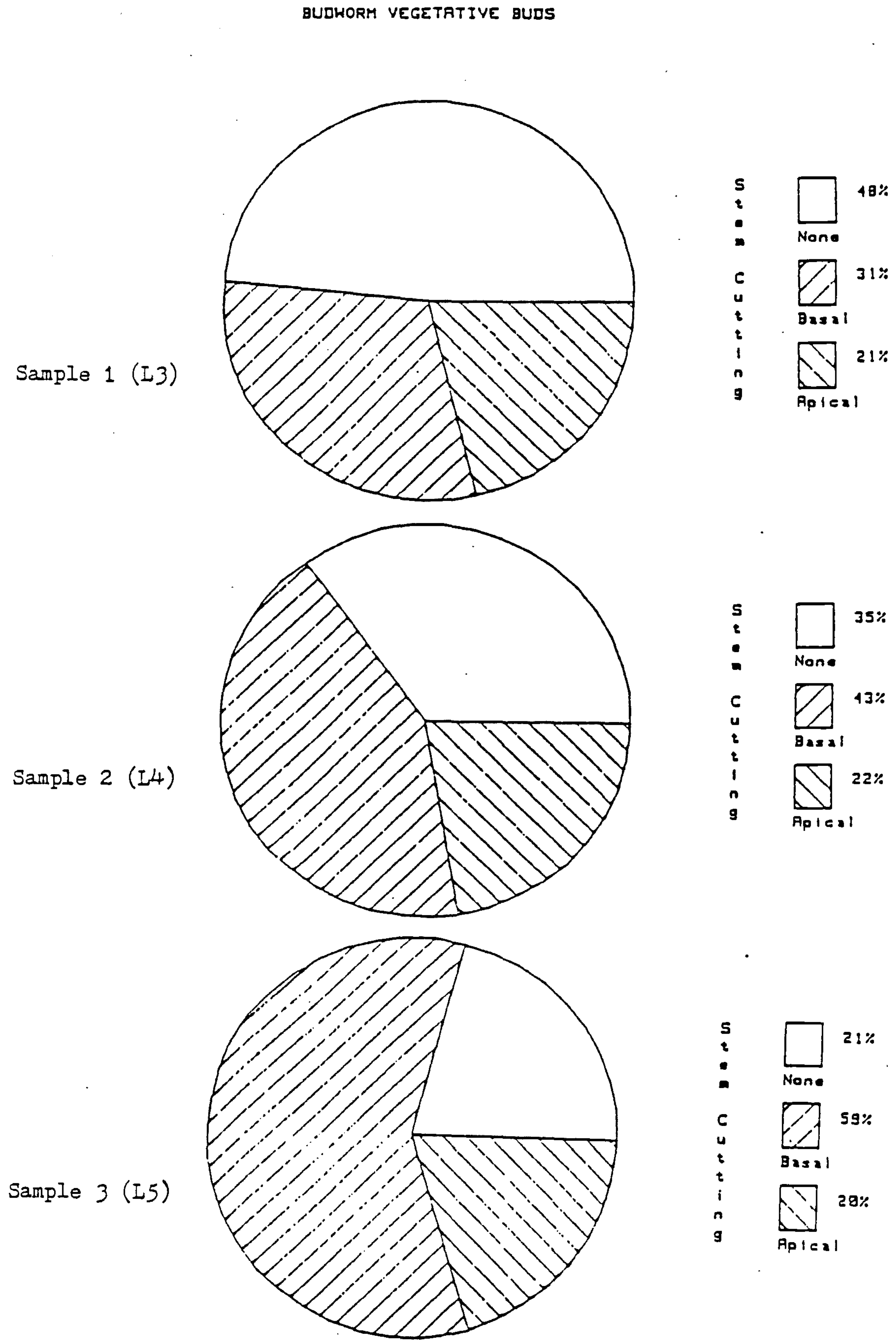


Figure 3. Percentage of red spruce buds having stems severed either basally or apically after attack by spruce budworm during three sample periods in 1984.

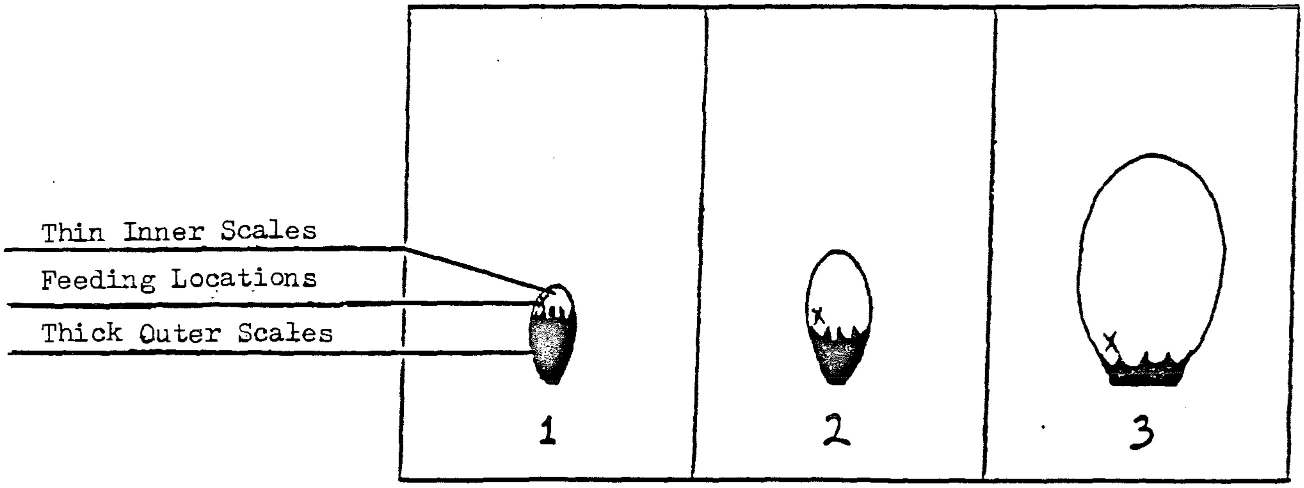


Figure 4. Most common feeding locations observed on growing buds during a study of spruce budworm and spruce coneworm behavior on red spruce in Maine, 1984

Table 1. Number and type of larval cages placed at each site during a study of spruce budworm and spruce coneworm behavior on red spruce in 1984.

Site	Number of cages	Cage Type Budworm	Coneworm	Budworm-coneworm
1	40	16	8	16
2	25	13	13	0
3	40	20	6	14
4	39	0	24	15
Total	144	49	50	45

Table 2. Sample periods, sample dates and budworm instar indices on spruce and fir for foliage sampling in sprayed and unsprayed study areas in 1984.

Sample period	Sample dates	Trees sampled	Budworm instar index Fir	Spruce
L3	30 May--02 Jun	A,B	2.87	2.75
L4	07 Jun--08 Jun	B,C	4.50	4.06
L5	12 Jun	C,A	5.00	4.52
L6	18 Jun	A,B	5.74	no data
L5(CW)*	05 Jul--06 Jul	B,C	---	---

*An extra collection was taken to examine late instar coneworm populations which pupate 7-10 days after budworm.

Table 3. Number (percentage) of spruce budworm larvae found in four feeding position categories at each site on June 13, 1984.

Site	Feeding position Basal mining	 Apical mining	 Basal surface feeding	 Apical surface feeding
1	4 (80.0)	0 (0.0)	1 (20.0)	0 (0.0)
2	2 (28.5)	1 (14.3)	4 (57.2)	0 (0.0)
3	5 (41.7)	1 (8.3)	6 (50.0)	0 (0.0)
4	--	--	--	--
Total	11 (45.8)	2 (8.4)	11 (45.8)	0 (0.0)

Table 4. Number (percentage) of spruce budworm larvae found in four feeding position categories at each site on June 20-21,1984.

Site	Feeding position Basal mining	 Basal surface feeding	 Apical surface feeding	 Feeding along entire bud
1	1 (4.8)	7 (33.3)	3 (14.3)	10 (47.6)
2	1 (4.5)	8 (36.4)	0 (0.0)	13 (59.1)
3	0 (0.0)	7 (31.8)	2 (9.1)	13 (59.1)
4	0 (0.0)	11 (45.8)	0 (0.0)	13 (54.2)
Total	2 (2.2)	34 (37.8)	5 (5.6)	49 (54.4)

Table 5. Proportion of occupied buds severed by budworm and coneworm at each site on June 20-21, 1984.

	Budworm		Coneworm	
Site	n	Bud severing (S.D.)	n	Bud severing (S.D.)
1	--	----	--	----
2	22	0.50 (0.51) a*	19	0.57 (0.50) a
3	22	0.50 (0.51) a	25	0.64 (0.49) a
4	24	0.20 (0.51) a	25	0.44 (0.50) a
Overall	68	0.40 (0.49) x	69	0.55 (0.50) x

*Means followed by same letters are not significantly different based on Newman-Keuls multiple range test (alpha<0.05).

Table 6. Number (percentage) of spruce coneworm larvae found in four feeding position categories at each site on June 13, 1984.

Site	Feeding position			
	Basal mining	Apical mining	Basal surface feeding	Apical surface feeding
1	3 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)
2	3 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)
3	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)
4	9 (95.0)	3 (25.0)	0 (0.0)	0 (0.0)
Total	16 (84.2)	3 (15.8)	0 (0.0)	0 (0.0)

Table 7. Number (percentage) of spruce coneworm larvae found in four feeding position categories at each site on June 20-21, 1984.

Site	Feeding position			
	Basal mining	Basal surface feeding	Apical surface feeding	Feeding along entire bud
1	0 (0.0)	10 (40.0)	8 (32.0)	7 (28.0)
2	0 (0.0)	10 (52.6)	1 (5.3)	8 (42.1)
3	0 (0.0)	10 (40.0)	0 (0.0)	15 (60.0)
4	0 (0.0)	8 (32.0)	2 (0.8)	15 (60.0)
Total	0 (0.0)	38 (40.4)	11 (11.7)	45 (47.9)

Table 8. Number (percentage) of spruce budworm larvae found in four concealment categories at each site on June 20-21,1984.

Site	Concealment category Silk and severed plant material	Attached needles (one shoot)	Attached needles (multiple shoots)	Old foliage
1	11 (44.0)	1 (4.0)	13 (52.0)	0 (0.0)
2	2 (8.7)	3 (13.0)	18 (78.3)	0 (0.0)
3	6 (25.0)	2 (8.3)	10 (41.7)	6 (25.0)
4	2 (9.1)	3 (13.6)	15 (68.2)	2 (9.1)
Total	21 (22.3)	9 (9.6)	56 (59.6)	8 (8.5)

Table 9. Number (percentage) of spruce coneworm larvae found in four concealment categories at each site on June 20-21, 1984.

Site	Concealment category Silk and severed plant material	Attached needles (one shoot)	Attached needles (multilple shoots)	Old foliage
1	16 (64.0)	4 (16.0)	5 (20.0)	0 (0.0)
2	2 (10.5)	4 (21.1)	13 (68.4)	0 (0.0)
3	9 (36.0)	2 (8.0)	10 (40.0)	4 (16.0)
4	1 (4.0)	7 (28.0)	15 (60.0)	2 (8.0)
Total	28 (29.8)	17 (18.1)	43 (45.7)	6 (6.4)

Table 10. Red/black spruce hybrid index, bud development index, spruce budworm development index, and spruce coneworm development index on three plots in Maine in 1984.

Period	Line	Hybrid Index	Bud index	BW Instar	CW Instar
First (peak-L3)	BT 1	0.64	2.00 b(1)	3.10 a	1.98 a
	BT 2	0.60	1.92 b	3.05 a	1.97 a
	BT 3	0.68	1.90 b	3.07 a	1.95 a
	Z 1	0.58	1.90 b	3.17 a	1.94 a
	Z 2	0.63	1.78 b	2.80 a	1.98 a
	Z 3	0.53	1.45 a	2.99 a	1.94 a
Second (peak-L4)	BT 1	0.64	2.33 a	3.71 c	2.42 b
	BT 2	0.60	2.30 a	3.32 a	2.31 b
	BT 3	0.68	2.20 a	3.58 c	2.57 b
	Z 1	0.58	2.23 a	3.83 d	2.53 b
	Z 2	0.63	2.07 a	3.57 c	1.98 a
	Z 3	0.53	2.30 a	3.54 c	2.50 b
	C 1	0.63	2.87 b	3.42 b	2.46 b
	C 2	0.72	3.23 c	4.16 f	2.80 c
	C 3	0.63	2.80 b	4.02 e	2.79 c
Third (peak-L5)	BT 1	0.64	4.18 d	4.82 b	3.51 a
	BT 2	0.60	4.08 d	4.68 ab	3.44 a
	BT 3	0.68	3.53 c	4.67 ab	3.23 a
	Z 1	0.58	3.71 d	4.89 ab	3.50 a
	Z 2	0.63	3.11 a	4.75 ab	3.35 a
	Z 3	0.53	3.34 b	4.38 ab	3.29 a
	C 1	0.63	4.21 d	4.49 ab	3.26 a
	C 2	0.72	4.50 e	4.81 ab	3.43 a
	C 3	0.63	4.08 d	4.53 a	3.39 a

(1) Student-Neuman-Keuls Multiple Range Test. Different letters within the same column for each period indicate a significant difference ($p<0.05$).

Table 11. The location and type of damage to vegetative(V) and flower(F) buds of red spruce attacked by spruce budworm larvae, data are expressed as percentages within descriptive categories in a study of spruce budworm and spruce coneworm in 1984.

Data Pool	Sample Period	Bud Type	Damage Location: Total # Buds	Damage Location: % None	Damage Location: % Apical	Damage Location: % Basal	Damage Location: % All-Over	Damage Location: % Des-Troyed	Damage Type: Total # Buds	Damage Type: % Mining	Damage Type: % Surface
Similar Lines	L3	V	147	9.5	15.0	9.5	57.8	8.2	132	99.2	0.8
BT	L3	V	131	9.9	15.3	8.4	57.2	9.2	117	99.1	0.9
Zectran	L3	V	16	6.2	12.5	18.8	62.5	0.0	15	100.0	0.0
Similar Lines	L4	V	266	5.6	7.1	12.0	63.2	12.0	252	96.8	3.2
BT	L4	V	199	6.0	6.0	14.1	61.4	12.5	188	96.9	3.2
Zectran	L4	V	67	4.5	10.4	6.0	68.7	10.5	64	96.9	3.1
Control	L4	V	--	--	--	--	--	--	--	--	--
Similar Lines	L5	V	447	3.4	2.5	7.4	71.6	15.2	432	58.8	41.2
BT	L5	V	114	1.8	1.8	12.3	67.5	16.7	112	55.4	44.6
Zectran	L5	V	78	2.6	2.6	5.1	64.1	25.6	76	71.1	28.9
Control	L5	V	310	3.9	3.6	7.7	73.6	12.3	298	55.0	45.0
Similar Lines	L3	F	216	0.5	16.2	43.5	38.9	0.9	230	93.5	6.5
BT	L3	F	43	0.0	18.6	30.2	46.5	4.7	53	75.5	24.5
Zectran	L3	F	173	0.6	15.6	46.9	37.0	0.0	177	98.9	1.1
Similar Lines	L4	F	63	1.6	1.6	30.2	34.9	31.7	62	54.8	45.2
BT	L4	F	58	1.7	1.7	15.5	53.4	27.6	57	66.7	33.3
Zectran	L4	F	24	0.0	0.0	41.7	25.0	33.3	24	25.0	75.0

Table 12. The amount of foliage destroyed and the incidence of stem cutting in vegetative(V) and flower(F) buds of red spruce by spruce budworm larvae, data are expressed as percentages within descriptive categories in a study of spruce budworm and spruce coneworm in 1984.

			Foliage Destroyed						Stem Cutting			
Data Pool	Sample Period	Bud Type	Total # Buds	0-20%	21-40%	41-60%	61-80%	81-100%	Total # Buds	% None	% Basal	% Apical
Similar Lines	L3	V	133	27.8	19.5	19.5	12.8	20.3	133	49.6	31.6	18.8
BT	L3	V	118	25.4	20.3	18.6	13.6	22.0	118	48.3	30.5	21.2
Zectran	L3	V	15	46.7	13.3	26.7	6.7	6.7	15	0.0	60.0	40.0
Similar Lines	L4	V	251	20.7	21.9	15.9	19.1	22.3	253	35.2	42.7	22.1
BT	L4	V	187	22.5	21.4	16.0	18.2	21.9	189	37.6	39.1	23.3
Zectran	L4	V	64	15.6	23.4	15.6	21.9	23.4	64	28.1	53.1	18.7
Control	L4	V	--	--	--	--	--	--	--	--	--	--
Similar Lines	L5	V	432	14.6	21.8	23.1	15.0	25.5	430	21.2	58.8	20.0
BT	L5	V	112	12.5	20.5	20.5	14.3	32.1	110	20.0	70.9	9.1
Zectran	L5	V	76	9.2	21.1	19.7	10.5	39.5	76	21.1	65.8	13.2
Control	L5	V	298	16.1	22.1	24.2	16.1	21.5	296	21.6	54.7	23.6
Similar Lines	L3	F	215	64.7	23.7	7.9	2.8	0.9	230	91.3	2.6	6.1
BT	L3	F	51	45.1	31.4	9.8	7.8	5.9	53	84.9	7.5	7.5
Zectran	L3	F	176	67.0	24.4	6.8	1.1	0.6	177	93.2	1.1	5.6
Similar Lines	L4	F	62	17.7	19.4	16.1	14.5	32.3	61	49.2	45.9	4.9
BT	L4	F	56	14.3	21.4	14.3	19.6	30.4	57	45.6	45.6	8.8
Zectran	L4	F	24	20.8	20.8	16.7	0.0	41.7	23	60.9	34.8	4.3

Table 13. The location and type of damage to vegetative(V) and flower(F) buds of red spruce by spruce coneworm larvae, data are expressed as percentages within descriptive categories in a study of spruce budworm and spruce coneworm in 1984.

			Damage Location						Damage Type		
Data Pool	Sample Period	Bud Type	Total # Buds	% None	% Apical	% Basal	% All-Over	% Des-Troyed	Total # Buds	% Mining	% Surface
Similar Lines	L3	V	143	16.8	13.3	13.3	48.2	8.4	115	97.4	2.6
BT	L3	V	143	16.8	13.3	13.3	48.2	8.4	115	97.4	2.6
Zectran	L3	V	--	--	--	--	--	--	--	--	--
Similar Lines	L4	V	464	6.0	7.5	13.2	60.1	13.7	434	98.6	1.4
BT	L4	V	309	5.8	9.4	12.3	55.3	17.1	289	98.6	1.4
Zectran	L4	V	65	4.6	6.2	13.8	69.2	6.1	62	96.8	3.2
Control	L4	V	66	7.8	2.2	15.6	67.8	6.7	83	100.0	0.0
Similar Lines	L5	V	957	1.4	3.0	8.7	72.5	14.4	944	54.0	46.0
BT	L5	V	277	0.7	3.6	7.2	68.9	19.5	275	53.1	46.9
Zectran	L5	V	152	2.0	2.0	5.9	69.1	21.1	149	59.1	40.9
Control	L5	V	528	1.5	3.0	10.2	75.4	9.8	520	53.1	46.9
Similar Lines	L3	F	146	3.4	12.3	45.2	35.6	3.4	142	88.7	11.3
BT	L3	F	59	3.4	13.6	39.0	37.3	6.8	57	75.4	24.6
Zectran	L3	F	87	3.4	11.5	49.4	34.5	1.1	85	97.6	2.4
Similar Lines	L4	F	61	0.0	1.6	34.4	31.2	32.8	61	60.7	39.3
BT	L4	F	43	0.0	2.3	30.2	37.2	30.2	43	69.8	30.2
Zectran	L4	F	18	0.0	0.0	44.4	16.7	38.9	18	38.9	61.1

Table 14. The amount of foliage destroyed and the incidence of stem cutting in vegetative(V) and flower(F) buds of red spruce by spruce coneworm larvae, data are expressed as percentages within descriptive categories in a study of spruce budworm and spruce coneworm in 1984.

			Foliage Destroyed						Stem Cutting			
Data Pool	Sample Period	Bud Type	Total # Buds	0-20%	21-40%	41-60%	61-80%	81-100%	Total # Buds	% None	% Basal	% Apical
Similar Lines	L3	V	116	25.9	17.2	29.3	7.8	19.8	114	50.0	27.2	21.9
BT	L3	V	116	25.9	17.2	29.3	7.8	19.8	114	50.0	27.2	21.9
Zectran	L3	V	--	--	--	--	--	--	--	--	--	--
Similar Lines	L4	V	435	22.8	18.9	24.6	12.6	21.1	438	41.8	35.4	22.8
BT	L4	V	290	20.0	18.3	23.1	13.8	24.8	293	37.5	38.6	23.9
Zectran	L4	V	62	29.0	22.6	27.4	11.3	9.7	62	54.8	25.8	19.4
Control	L4	V	83	27.7	18.1	27.7	9.6	16.9	83	47.0	31.3	21.7
Similar Lines	L5	V	944	12.7	23.1	26.3	14.0	23.9	934	18.6	60.2	21.4
BT	L5	V	275	10.5	18.2	27.6	17.5	26.2	271	20.3	64.2	15.5
Zectran	L5	V	149	10.1	16.1	26.8	12.1	34.9	147	15.6	70.7	13.6
Control	L5	V	520	14.6	27.7	25.4	12.7	19.6	518	18.5	54.8	26.6
Similar Lines	L3	F	141	68.1	17.0	7.1	3.5	4.3	142	89.4	6.3	4.2
BT	L3	F	57	50.9	28.1	10.5	3.5	7.1	58	84.5	12.1	3.5
Zectran	L3	F	84	79.8	9.5	4.8	3.6	2.4	84	89.4	6.3	4.2
Similar Lines	L4	F	43	22.9	19.7	9.8	6.6	41.0	61	44.3	47.5	8.2
BT	L4	F	43	20.9	18.6	11.6	9.3	39.5	43	41.9	46.5	11.6
Zectran	L4	F	18	27.8	22.2	5.6	0.0	44.4	18	50.0	50.0	0.0

Table 15. The percentage of concealed[1] and exposed[2] spruce budworm found in vegetative(V) and flower(F) buds of red spruce branches during three sample periods in 1984.

Data Pool	Sample Period	Bud Type	# of Insects	% Concealed[1]	% Exposed[2]
				*	*
All Similar Groups	L3	V	150	33.9	71.8
BT Group	L3	V	133	29.3	73.6
Zectran Group	L3	V	17	58.8	41.2
Control Group	L3	V	--	--	--
All Similar Groups	L4	V	271	39.1	60.9
BT Group	L4	V	202	36.6	62.2
Zectran Group	L4	V	68	42.6	57.3
Control Group	L4	V	177	37.2	62.4
All Similar Groups	L5	V	294	42.5	58.8
BT Group	L5	V	115	41.7	58.2
Zectran Group	L5	V	79	37.9	61.8
Control Group	L5	V	153	43.1	58.6
All Similar Groups	L3	F	231	72.7	26.8
BT Group	L3	F	52	51.9	49.9
Zectran Group	L3	F	179	79.3	20.0
All Similar Groups	L4	F	63	36.5	63.7
BT Group	L4	F	39	33.4	67.1
Zectran Group	L4	F	24	41.7	58.5

---

[1] Concealed = All body parts covered with plant material or thic (opaque) silk.

[2] Exposed = Some or all of the body NOT covered by plant materia or thick (opaque) silk.

* Sums of % concealed and % exposed do not always equal 100 due to rounding error.

Table 16. Most frequent concealment positions for spruce budworm and spruce coneworm on vegetative and flower buds of red spruce during three sample periods in 1984.

	PERCENT OCCURRENCE											
	BW VEG			BW FLOW			CW VEG			CW FLOW		
Most common positions observed	L3	L4	L5	L3	L4	L5	L3	L4	L5	L3	L4	L5
Concealed[1]												
Anterior and Posterior in thick silk w/plant material	5.3	8.1	7.8	--	11.1	--	8.8	10.1	11.7	--	11.3	--
Anterior and Posterior in bud	20.7	16.2	18.4	57.1	19.0	--	16.9	13.3	14.7	60.4	32.3	--
other*	8.0	14.8	16.3	5.6	6.4	--	11.1	11.3	17.1	7.5	9.6	--
Exposed[2]												
Anterior and Posterior exposed	18.0	--	8.8	--	12.7	--	23.5	19.8	11.0	12.8	17.7	--
Anterior exposed, Posterior in bud	--	--	--	5.6	--	--	--	--	--	--	--	--
Anterior and Posterior in silk	18.7	9.6	--	--	11.1	--	9.6	8.0	--	--	--	--
Anterior in bud, Posterior exposed	--	--	--	--	6.3	--	--	--	--	--	--	--
other*	35.2	51.3	50.0	31.2	33.6	--	32.7	36.2	46.0	18.9	28.8	--

[1] Concealed = All body parts covered with plant material or thick (opaque) silk.

[2] Exposed = Some or all of the body NOT covered by plant material or thick (opaque) silk.

* Concealed and exposed positions comprising less than 5% of total observations individually.

Table 17. The percentage of concealed[1] and exposed[2] spruce coneworm found in vegetative(V) and flower(F) buds of red spruce branches during three sample periods in 1984.

Data Pool	Sample Period	Bud Type	# of Insects	%[1] Concealed *	%[2] Exposed *
All Similar Groups	L3	V	136	36.8	65.8
BT Group	L3	V	136	36.8	65.8
Zectran Group	L3	V	--	--	--
Control Group	L3	V	--	--	--
All Similar Groups	L4	V	475	34.7	64.0
BT Group	L4	V	316	33.2	66.3
Zectran Group	L4	V	68	39.7	60.5
Control Group	L4	V	91	33.0	67.1
All Similar Groups	L5	V	692	43.5	57.0
BT Group	L5	V	277	42.3	59.0
Zectran Group	L5	V	152	42.5	59.4
Control Group	L5	V	262	45.5	55.2
All Similar Groups	L3	F	149	67.9	31.7
BT Group	L3	F	62	53.2	46.5
Zectran Group	L3	F	87	78.1	21.6
All Similar Groups	L4	F	62	53.2	46.5
BT Group	L4	F	44	39.1	58.3
Zectran Group	L4	F	18	77.9	22.4

---

[1] Concealed = All body parts covered with plant material or thick (opaque) silk.

[2] Exposed = Some or all of the body NOT covered by plant material or thick (opaque) silk.

* Sums of % concealed and % exposed do not always equal 100 due to rounding error.

Table 18. Comparisons of mean spruce budworm densities per square foot within three plots during an evaluation of the efficacy of Zectran and BT on red spruce in Maine in 1984.

Treatment	Sample Period	Mean Density		
		Line 1	Line 2	Line 3
BT	Prespray 1	2.6(0.5) a(1)	2.8(0.6) a	6.1(1.6) a
	Prespray 2	4.6(1.1) a	5.8(1.3) a	7.0(2.0) a
	Prespray 3	7.2(1.6) a	8.5(1.7) a	7.7(1.2) a
	Postspray 1	4.1(0.8) a	5.1(0.6) a	4.3(0.8) a
ZECTRAN	Prespray 1	6.5(1.6) a	4.3(1.0) a	3.0(0.6) a
	Postspray 1	6.9(1.8) a	2.8(0.5) a	3.0(0.6) a
	Prespray 2	5.5(0.8) a	5.3(0.9) a	3.4(0.8) a
	Postspray 2	5.6(1.1) b	4.2(0.8) ab	2.6(0.8) a
CONTROL	First	1.8(0.5) a	-	-
	Second	2.3(0.4) a	5.1(1.4) a	4.1(0.8) a
	Third	3.7(0.6) a	10.3(1.8) b	5.3(0.9) a
	Fourth	2.7(0.8) a	5.9(1.0) b	3.9(0.6) ab

(1) Student-Neuman-Keuls Multiple Range Test. Different letters within the same row indicate a significant difference ($p < 0.05$)

Table 19. Comparisons of mean spruce budworm, spruce coneworm, and combined species densities per square foot among sample periods during an evaluation of the efficacy of Zectran and BT on red spruce in Maine in 1984.

Species	Sample Period	Treatment		
		BT	ZECTRAN	CONTROL
BUDWORM	L3	3.7(0.6)a(1)	4.6(0.7) a	1.7(0.5) a
	L4	5.9(0.6) a	4.3(0.7) a	3.8(0.6) b
	L5	7.8(0.9) b	4.7(0.5) b	6.5(0.8) b
	L6	4.5(0.4) a	4.1(0.5) a	4.2(0.5) b
CONEWORM	L3	5.2(0.7) a	2.8(0.4) a	1.6(0.4) a
	L4	8.5(0.3) a	2.4(0.3) a	3.4(0.3)bc
	L5	13.0(1.3) b	6.5(0.7) b	6.1(0.5) d
	L6	7.8(1.1) a	5.7(0.7) b	4.6(0.6)cd
	L5(cw)	4.3(0.9)	3.7(0.7) a	2.5(0.6)ab
COMBINED SPECIES	L3	8.9(1.1)ay[2]	7.4(0.9)ay	3.4(0.8)ax
	L4	14.4(2.0)by	6.7(0.9)ax	7.3(0.7)ax
	L5	20.8(1.7)cy	11.3(0.8)bx	12.6(1.0)cx
	L6	12.3(1.2)bx	9.9(1.1)abx	9.1(0.9)bx

(1) Student-Neuman-Keuls Multiple Range Test. Different letters within the same column for each species indicate a significant difference ($p < 0.05$).

(2) Student-Neuman-Keuls Multiple Range Test. Different letters within the same row for each period indicate a significant difference ($p < 0.05$)

Table 20. Comparisons of mean spruce coneworm densities per square foot within three plots during an evaluation of the efficacy of Zectran and Bt on red spruce in Maine in 1984.

Treatment	Sample Period	Mean Density		
		Line 1	Line 2	Line 3
BT	Prespray	5.7(0.8) b(1)	3.3(0.9) a	7.2(1.6) b
	Prespray	7.5(1.4) a	7.4(1.3) a	10.5(3.3) a
	Prespray 1	12.6(2.0) a	12.8(2.4) a	13.6(2.2) a
	Postspray 1	11.2(1.6) b	7.6(2.8) a	4.7(0.9) a
	Postspray 2	4.2(0.9)	-	-
ZECTRAN	Prespray 1	2.6(0.6) a	4.1(0.8) a	1.8(0.4) a
	Postspray 1	2.4(0.6) a	2.4(0.5) a	2.2(0.5) a
	Prespray 2	7.4(1.0) a	7.9(1.3) a	4.4(1.0) a
	Postspray 2	6.0(1.2) a	7.4(1.5) a	3.9(0.9) a
	Postspray 3	5.2(1.9) a	3.7(0.9) a	2.4(0.4) a
CONTROL	First	1.6(0.4)	-	-
	Second	3.2(0.6) a	3.0(0.6) a	4.0(0.5) a
	Third	8.0(1.1) a	5.3(0.6) a	5.2(0.8) a
	Fourth	7.1(1.6) b	3.1(0.7) a	4.6(0.7) ab
	Fifth	2.7(0.1) ab	1.5(2.8) a	3.5(0.9) b

(1) Student-Neuman-Keuls Multiple Tange Test. Different letters within the same row indicate a significant difference ($p < 0.05$).

Table 21. Comparisons of mean combined spruce budworm and spruce coneworm densities per square foot within three plots during an evaluation of the efficacy of Zectran and BT on red spruce in Maine in 1984.

Treatment	Sample Period	Mean Density		
		Line 1	Line 2	Line 3
BT	Prespray 1	8.4(1.2) a(1)	6.1(1.3) a	13.3(2.9) a
	Prespray 2	12.2(2.0) a	13.2(2.4) a	17.6(5.1) a
	Prespray 3	19.8(3.2) a	21.3(3.3) a	21.3(2.5) a
	Postspray 1	15.3(1.8) b	12.7(3.0) ab	9.0(1.3) a
ZECTRAN	Prespray 1	9.2(2.1) a	8.4(1.6) a	4.7(0.8) a
	Postspray 1	9.4(2.4) a	5.2(0.8) a	5.2(0.7) a
	Prespray 2	12.9(1.3) b	13.2(1.4) b	7.7(1.3) a
	Postspray 2	11.6(1.6) b	11.6(1.6) b	6.5(1.6) a
CONTROL	First	3.1(0.8) a	-	-
	Second	5.5(0.7) a	8.2(1.7) a	8.1(1.0) a
	Third	11.6(1.4) a	15.6(2.0) a	10.5(1.3) a
	Fourth	9.8(2.1) a	9.1(1.5) a	8.6(1.1) a

(1) Student-Neuman-Keuls Multiple Range Test. Different letters within the same row indicate a significant difference ($p < 0.05$)

Table 22. Percent kill and adjusted percent kill (with 95% C.I.) of spruce budworm, spruce coneworm, and species combined treated with split applications of Zectran and a single application of Bacillus thuringiensis (BT) in Maine in 1984.

ZECTRAN

	Unadjusted Percent Kill			Adjusted Percent Kill		
	Budworm	Coneworm	Combined	Budworm	Coneworm	Combined
Pre 1-Post1	1.0(47.9)	20.5(31.7)	11.5(35.0)	37.2(40.9)	47.6(31.5)	41.5(34.0)
Pre 1-Pre 2	0.6(41.6)	Negative	Negative	51.9(26.5)	1.4(49.8)	34.8(30.7)
Pre 2-Post2	14.2(29.1)	13.8(30.2)	12.7(24.2)	Negative	Negative	Negative
Pre 2-Post3	n/a	42.4(24.0)	n/a	n/a	Negative	n/a

BT

	Unadjusted Percent Kill			Adjusted Percent Kill		
	Budworm	Coneworm	Combined	Budworm	Coneworm	Combined
Pre 1-Post1	39.8(18.0)	41.5(22.6)	44.4(16.1)	7.5(46.9)	22.1(39.5)	21.4(31.7)
Pre 1-Post2	n/a	65.4(21.4)	n/a	n/a	11.9(89.1)	n/a

Table 23. Mean defoliation on red spruce on three plots as determined from a final defoliation collection in a comparison of the efficacy of Zectran and BT in Maine in 1984.

Treatment	Sample Line	Mean Defoliation By Line	By Treatment
BT	1	2.75	
	2	2.84	2.73
	3	2.60	
Zectran	1	3.06	
	2	3.01	2.96
	3	2.81	
Control	1	2.39	
	2	2.78	2.64
	3	2.76	

Table 24. Mean defoliation on red spruce on three plots as determined from sample branches used in a behavior study of spruce budworm and spruce coneworm in Maine in 1984.

	Defoliation Between Sample Period by Plot								
	BT			ZECTRAN			CONTROL		
Sample Period	Mean	n	Sig.	Mean	n	Sig.	Mean	n	Sig.
L3	1.14	41	a(1)	1.01	41	a	-	-	-
L4	1.41	41	b	1.15	41	b	1.37	40	a
L5	2.69	41	c	1.81	41	c	2.03	40	b
L6	3.23	41	d	2.69	41	d	2.51	40	c
FINAL	5.22	20	-	3.71	41	e	3.44	40	d

Student-Neuman-Kuels Multiple Range Test. Different letters within the same column for each plot indicate a significant difference ($p < 0.05$).

Table 25 Mean numbers of defoliator attacked vegetative buds, buds killed the previous year, flower buds, and dormant buds encountered per 30 vegetative buds counted per red spruce branch during five sample periods in 1984.

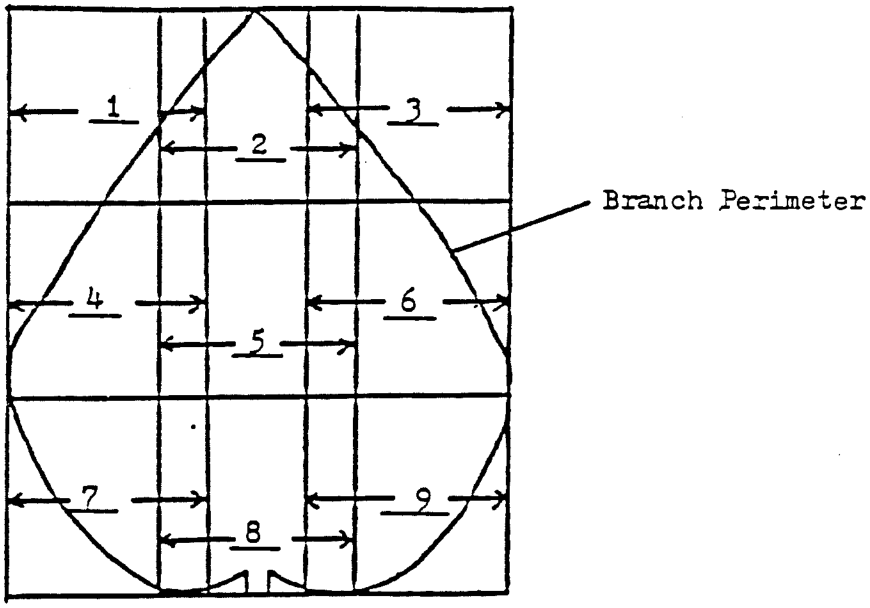
	BUD TYPE											
	ATTACKED						KILLED PREVIOUSLY					
Sample Period	N[1]	BT	N	ZEC	N	CONT	N	BT	N	ZEC	N	CONT
1 (L3)	43	1.6(2.2)A[2]	39	0.8(0.5)A	12	0.4(0.6)A	42	14.0(15.7)C	43	10.2(10.8)B	11	16.5(20.2)B
2 (L4)	44	3.7(4.3)A	41	1.4(2.1)A	44	3.5(3.2)AB	43	10.1(8.3)BC	41	3.8(4.3)A	43	10.0(11.9)A
3 (L5)	42	12.3(6.5)B	41	6.2(5.5)B	40	7.8(5.6)BC	40	7.3(5.5)AB	42	6.3(5.4)A	40	7.6(6.5)A
4 (L6)	46	14.1(6.2)B	45	11.0(7.2)C	48	11.0(7.0)C	46	4.8(5.4)AB	43	5.8(5.7)A	48	5.4(5.3)A
5 (L5 CW)	20	23.2(5.8)C	59	18.1(7.9)D	59	18.2(8.4)D	20	2.4(3.5)A	59	5.9(6.2)A	60	7.6(7.8)A

	BUD TYPE											
	FLOWER						DORMANT					
Sample Period	N	BT	N	ZEC	N	CONT	N	BT	N	ZEC	N	CONT
1 (L3)	42	1.7(3.1)A	43	4.3(11.6)A	11	0.4(0.5)A	42	0(-)	43	0(-)	11	0(-)
2 (L4)	43	1.1(3.4)A	41	5.5(15.8)A	44	3.7(14.8)A	43	0(-)	41	0(-)	44	0(-)
3 (L5)	40	1.2(4.3)A	42	5.2(14.7)A	40	0.4(1.5)A	40	0.8(2.8)A	42	0.5(1.6)AB	40	0.6(2.1)A
4 (L6)	46	1.3(5.7)A	43	5.7(12.7)A	48	0.4(1.9)A	46	0.5(1.2)A	43	1.1(2.3)B	48	0.7(1.7)A
5 (L5 CW)	20	11.0(15.0)B	59	4.8(12.7)A	60	6.6(26.8)A	19	0.1(0.3)A	59	0.2(0.7)A	60	0.2(1.1)A

[1] N = Number of branches examined.

[2] Means followed by the same letter within a bud type and treatment are not significantly different based on Student Nueman-Kuels multiple range test, (p§0.05).

APPENDIX A

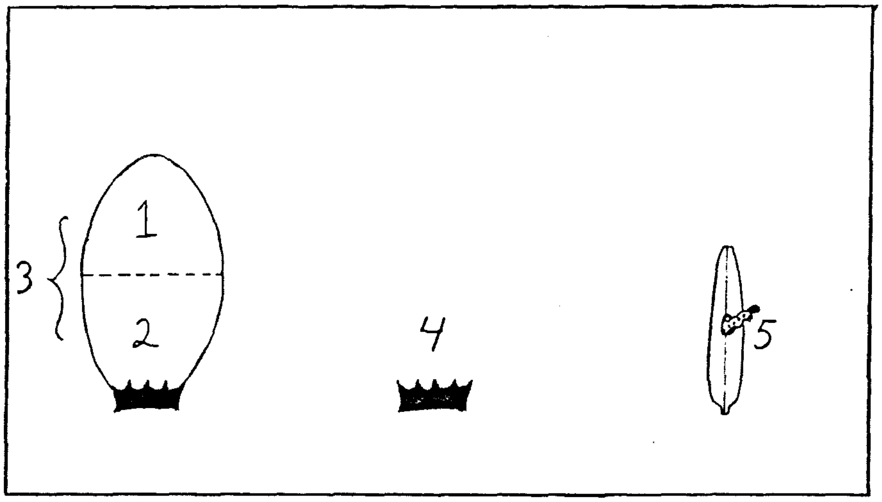


Number between 1 and 9 selected from random number table represents sector of the spruce branch to sample for 30 bud data.

Figure 1 Illustration of the sector distribution on a spruce branch for the "30 bud" survey in a study of the behavior of spruce budworm and spruce coneworm on red spruce in northern Maine in 1984.

A. Location

1 = Damage to distal 50% of bud
2 = Damage to proximal 50% of bud
3 = Damage to both regions 1 and 2
4 = Absence of remaining living matter
5 = Mined needle with discovered insect



B. Type

1 = Bud mining
2 = Bud surface feeding
X = Needle mining

C. Extent

0 = 0
1 = 1-20%
2 = 21-40%
3 = 41-60%
4 = 61-80%
5 = 81-100%
X = Needle mining

D. Stem Cutting

1 = None
2 = Basal
3 = Apical
X = Needle mining

E. Defoliation (Fettes system)

1 = 0
2 = 1-25%
3 = 26-50%
4 = 51-75%
5 = 76-100%
6 = Bud axil destroyed

Figure 2 Bud damage locations and codes used for other feeding behavior variables during a study of spruce budworm and spruce coneworm behavior on red spruce in Maine, 1984.

Table 1 Codes for Concealment Variables Used During a Study of Spruce Budworm and Spruce Coneworm Behavior on Red Spruce in Maine, 1984.

CONCEALMENT INDEX

HEAD TYPE:

1.= none
2.= thin silk
3.= thick silk
4.= silk with needles and/or plant material (scales)
5.= silk with bud cap
6.= silk attached to one shoot
7.= silk attached to several shoots
8.= in bud

LOCATION:

1.= new foliage
2.= old foliage
3.= 25% old / 75% new
4.= 50/50
5.= 75% old / 25% new

AMOUNT CONCEALED:

1.= exposed
2.= 25%
3.= 50%
4.= 75%
5.= 100%

BODY PARTS EXPOSED:

1.= entirely
2.= head
3.= abdomen
4.= none

ABDOMEN TYPE:

1.= none
2.= thin silk
3.= thick silk
4.= silk with needles and/or plant material (scales)
5.= silk with bud cap
6.= silk attached to one shoot
7.= silk attached to several shoots
8.= in bud

Table 2. Bud development categories for red spruce

Category	Description
1	Bud is constricted
2	Bud is swollen, scales beginning to separate, but no green needles visible
3	Bud capsule still intact but needles are clearly visible through scales in middle third of bud
4	Bud capsule split longitudinally, still attached to bud base
5	Bud capsule separated from bud base
6	Bud capsule lost completely elongation beginning
7	Notable elongation commenced

Data Form # 1.

BUD FILE DATA FORM--30 Buds Taken From 1/4 Branch

Observer______________________ Date_______________

Branch#_________ Sector#_____

Live Bud		Vegetative Damage				Defoliation
number	index	location	type	extent %	stem cut	
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						

Total dormant buds________

Total killed buds_________

Total flower buds__________

Total

Mean

Comments:

Data Form #2. OCCUPIED BUD FILE DATA FORM

Observer____________________ Date______________

Branch#______________

Bud		Insect			Damage				Concealment				
number	type	species	number	instar	location	type	extent %	stem cut	head type	position	amount	exposure	abdom typ

sbw(1): scw(2): onm(3): all leps:

Total Branch Count

Bag Count

Total

Data Form # 3.

BRANCH FILE DATA FORM

Observer________________

Date____________

	BRANCH #						BUDS						PEAK INSTA		NUMBER				
sampler	plot	line	cluster	tree	sample date	sector	live	dormant	killed	flower	$\overline{X}$ bud index	$\overline{X}$ defoliation	sbw	scw	sbw	scw	onm	total	branch area

Comments:

APPENDIX B

Table 1. Mean number of spruce budworm and spruce coneworm per 18" branch

Table 2. Mean number of spruce budworm and spruce coneworm per square foot

Table 1. Mean number of spruce budworm and spruce coneworm per 18" branch tip on red spruce in three treatment areas during five sample periods in 1984.

		SAMPLE 1 (L3)			SAMPLE 2 (L4)		SAMPLE 3 (L5)			SAMPLE 4 (L6)		SAMPLE 5 (L5 CW)	
Treatment Block	Replicate #	BW	CW		BW	CW	BW	CW		BW	CW	BW	CW
BT	1	4.7	9.1		8.7	12.8	10.6	19.5	TREATED	4.7	13.9	0.9	3.8
	2	5.7	6.2		8.7	10.2	10.3	16.0		7.0	7.8	--	--
	3	12.6	11.8		9.9	14.7	8.9	18.3		5.8	7.1	--	--
	MEAN	7.7	9.0		9.1	12.6	9.9	17.9		5.8	9.6	0.9	3.8
ZECTRAN	1	9.2	4.2	TREATED	11.4	3.9	10.3	12.4	TREATED	5.6	5.6	0.2	5.0
	2	7.8	6.3		3.8	4.3	8.0	12.9		3.9	7.3	0.2	6.4
	3	4.3	2.8		3.7	2.9	4.5	6.2		2.6	4.3	0.6	3.2
	MEAN	7.1	4.4		6.3	3.7	7.6	10.5		4.0	5.7	0.3	4.9
CONTROL	1	2.4	2.4		4.1	5.7	4.3	9.4		2.8	6.4	0.3	3.5
	2	--	--		7.0	4.5	11.8	6.2		8.2	4.4	1.0	1.7
	3	--	--		6.7	7.0	9.0	9.2		3.7	4.6	0.5	3.5
	MEAN	2.4	2.4		5.9	5.7	8.4	8.3		4.9	5.1	0.6	2.9

Table 2. Mean densities of spruce budworm and spruce coneworm per square foot of red spruce in three treatment areas during five sample periods in 1984.

Treatment Block	Replicate #	SAMPLE 1 (L3)			SAMPLE 2 (L4)		SAMPLE 3 (L5)			SAMPLE 4 (L6)		SAMPLE 5 (L5 CW)	
		BW	CW		BW	CW	BW	CW		BW	CW	BW	CW
BT	1	2.7	5.7		4.6	7.5	7.2	12.6	TREATED	4.1	11.3	0.9	4.3
	2	2.8	3.3		5.8	7.4	8.5	12.8		5.1	7.6	--	--
	3	6.1	7.2		7.0	10.5	7.7	13.6		4.3	4.7	--	--
	MEAN	3.9	5.4		5.8	8.5	7.8	13.0		4.5	7.8	0.9	4.3
ZECTRAN	1	6.5	2.6	TREATED	6.9	2.5	5.5	7.4	TREATED	5.6	6.0	0.1	5.2
	2	4.3	4.1		2.8	2.4	5.3	7.9		4.2	7.4	0.1	3.7
	3	3.0	1.8		3.0	2.2	3.4	4.4		2.6	3.9	0.5	2.4
	MEAN	4.6	2.8		4.2	2.4	4.7	6.5		4.1	5.8	0.2	3.8
CONTROL	1	1.7	1.6		2.3	3.2	3.7	8.0		2.7	7.1	0.2	2.7
	2	--	--		5.1	3.1	10.3	5.3		5.2	3.1	0.8	1.5
	3	--	--		4.1	4.0	5.3	5.2		3.9	4.6	0.7	3.5
	MEAN	1.7	1.6		3.8	3.4	6.4	6.2		3.9	5.0	0.6	2.6

A TEST COMPARING

INSECTICIDE EFFICACY ON

SPRUCE BUDWORM AND SPRUCE CONEWORM

USING RED SPRUCE FOLIAGE

FINAL REPORT

TO

MAINE FOREST SERVICE

DEPARTMENT OF CONSERVATION

BY

CHARLES J. SPIES, III

ECO-ANALYSTS, INC.

P.O. BOX 224

BATH, ME 04530-0224

Abstract

A laboratory comparison of insecticide efficacy was made for spruce budworm, *Choristonuera fumiferana* (Clem.), and the spruce coneworm, *Dioryctria renniculelloides* (Mutuura and Monroe), with a bioassay using a treated red spruce, *Picea rubens* (Sarg.), foliage diet.

Aminocarb and mexacarbate were significantly more effective on budworm than on coneworm. In one test series, *Bacillus thuringiensis* (BT) affected both species similarly, but was not as efficacious on budworm as the chemical treatments. Data from a second series of BT treatments was inconclusive.

These results show that coneworm control on red spruce is made more difficult by its relative resistance to some insecticides. This, along with the efficient concealment behavior of both budworm and coneworm, should be taken into account when developing strategies for red spruce protection.

ACKNOWLEDGMENTS

We wish to thank Dr. Blair Hellson, Dr. Chandra Nigam, Dr. John Dimond, and Dr. Alum Sundarum for technical advice regarding bioassay procedures and culturing larvae. We also thank Henry Trial and Jody Connor of the Maine Forest Service for information on sampling sites and insect development. Materials and technical information were provided by Mobay Chemical Corporation, Union Carbide., Inc, and Abbott Laboratories, Inc. This study was funded by the State of Maine, Department of Conservation through appropriation account number 1505.4100.4099.

TABLE OF CONTENTS

1.0.0 Introduction

This study was initiated due to concern over increasing red spruce, *Picea rubens* Sarg., mortality in Maine and the finding (Spies and Stratton,1985) that spruce coneworm, *Dioryctria renniculelloides* (Mutuura and Monroe), can cause as much damage to red spruce as the spruce budworm, *Choristonuera fumiferana* (Clem.).

Both species are commonly found in Maine on red spruce. Budworm is normally more abundant but in some years coneworm populations also reach damaging levels.

This study was designed to compare the relative efficacy of some commonly used insecticides on both insect species under controlled conditions. Aminocarb, mexacarbate and *Bacillus thuringiensis var. kurstaki* (BT) were tested.

2.0.0 Methods

No laboratory cultures of spruce coneworm or suitable artificial diet now exist (Dr. John B. Dimond, University of Maine pers. comm.). Therefore, we used field collected insects and a fresh red spruce foliage diet. Treated foliage was used to administer doses. This standardized the application procedure for all three insecticides regardless of the mode of action and created an environment that was close to field conditions. The rest of the procedures used are based on standard bioassay techniques and the recommendations of Dr. Chandra Nigam (pers. comm.) of the Maritimes Forest Research Centre, Fredricton, New Brunswick, Can. and Dr. Blair Helson (pers. comm.) of the Forest

Pest Management Institute (FPMI), Sault Ste. Marie, Ont., Can.

2.1.0 Insect Collection

Red spruce branches harboring budworm and coneworm were collected in Township 30 MDBPP on May 31 and June 15 and from Township 3 Range 12 WELS on June 20 and June 27. Three hundred branches were collected each time. They were transported to the Eco-Analysts, Inc. facility in Bath, Me. and searched for larvae.

2.2.0 Insect Rearing

Groups of ten larvae were placed in 100mm by 15mm petri dishes with fresh white spruce (Picea glauca (Moench) Voss.) foliage. This foliage was readily available in large quantities and both species readily fed upon it. The full dishes were stored alternately at room temperature (21-27 degrees C.) and in a refrigerator at 10 degrees C. for two day intervals. This enabled us to slow larval development until treatments could be performed. Foliage was changed and frass was removed every four days. Insects were reared in this manner until budworm reached 6th instar and coneworm reached 5th instar. This corresponds with timing of instars in the wild (McLeod and Daviault 1963).

2.3.0 Insecticide Formulations

2.3.1 Aminocarb

Matacil 180 Flowable liquid concentrate (Mobay Chemical Corp.) was used as the source of aminocarb. This product contains 19.6% active ingredient (AI) by volume. Batches were mixed to

500ml or 250ml total volume for 0.2% AI and 0.4% AI, respectively. Number 2 fuel oil was used as a carrier. The following mix ratios resulted:

180 Flowable	No.2 Fuel Oil	Total Volume	%AI
5.10ml	494.90ml	500.00ml	0.2%(0.18%)*
5.10ml	244.90ml	250.00ml	0.4%(0.37%)*

*Values in parenthesis are based on weight/volume. These were used when comparing data.

2.3.2 Mexacarbate

Zectran DB liquid concentrate (Union Carbide,Corp.) was used as the source of mexacarbate. This product contains 21.7% mexacarbate by weight or 1.8 pounds AI per gallon. Batches were mixed to 500ml or 250ml total volume at 0.2% AI or 0.4% AI respectively, using No.2 fuel oil as a carrier. The following mix ratios resulted:

Zectran DB	No.2 Fuel oil	Total Volume	%AI
4.64ml	495.36ml	500.00ml	0.2%
4.64ml	245.36ml	250.00ml	0.4%

2.3.3 Bacillus thuringiensis

Dipel 8L (ABG-6158, Abbott Laboratories, Inc.) was used as the source of BT. This product contains 64 billion international units (BIUs) per gallon. The batches were mixed with distilled water at a ratio of three parts water to one part Dipel 8L to make 400ml of total volume. The resulting mix contained 4.2BIUs/liter or 16BIUs/gal.

2.4.0 Foliage Treatment

2.4.1 Foliage Preparation

New shoots were clipped from red spruce branches. In all cases shoot elongation had commenced and no bud scales were present. Shoot length ranged from 1-2 inches. The foliage was laid out on plain white paper and insecticide was applied from directly above. The paper was changed after every treatment.

2.4.2 Spray Apparatus

A battery operated, rotary atomizer was used to apply all treatments. This was held one meter above the foliage within a still air space created by a cardboard enclosure surrounding the top and all sides. A boom attached to the atomizer was mounted on a wooden tower with a locking universal joint. This allowed movement in and out of the enclosure between treatments but eliminated any movement during applications.

All 0.2% AI or 0.18% AI chemical batches and the first BT batch were dyed with Rhodamine B Base. Kromekote cards were used with each treatment to record droplet sizes. Spread factors for the chemical formulations were provided by Dr. Alum Sundaram of FPMI. The spread factors for the BT formulations were provided by Dr. Robert Fusco of Abbott Laboratories, Inc. Mean droplet sizes ranged from 54 to 68 microns with maximum and minimum diameters being 39 and 72 microns, respectively. There was no significant difference in droplet size between any of the treatments or formulations ($\alpha < 0.05$, Student-Newman-Kuells multiple comparisons test).

2.4.3 Dosage Rates and Treatment Series

The atomizer consistently covered an area of 0.2 square meters at the one meter application height. This allowed dosage measurement by volume with a standard %AI batch mix. Pipets were used to meter volumes directly into the atomizer feed channel. The machine was run for three minutes during each replicate to make sure most material had passed through the system. Foliage was air dried for fifteen minutes after treatment. This was done to allow drying on spray deposit cards (C. Garner, Mobay Chemical Corp., pers. comm.).

Aminocarb and mexacarbate mixes were applied at rates equivalent to 5, 10, 20, 30, 40 and 50 liters/hectare (see Table 2 for gallons/acre equivalents) using 0.1ml, 0.2ml, 0.4ml, 0.6ml, 0.8ml and 1.0ml respectively in our apparatus. BT was applied at rates of 4, 8, 12, 16, 20, 24, 32 and 48 BIUs/acre using 0.047ml, 0.094ml, 0.140ml, 0.187ml, 0.234ml, 0.281ml, 0.374ml and 0.561ml respectively.

The above rates are used to make relative comparisons. They can not be directly related to aerial spray applications for three reasons: 1) our foliage was only treated on the upper surface and not exposed on all sides as in a forest canopy with suspended branches and swirling air currents; 2) we sprayed in a still air space at a very low altitude which minimized drift and evaporation; 3) the insects were not within or near silken shelters when first exposed to the treated foliage.

The treatment series is shown in Table 1. In addition to the insecticide tests, untreated controls and oil with dye and water with dye treatments were observed. The number of insects used per replication was dependent on their availability from the wild stands (Table 1).

2.4.4 Insect Observations

Two to three insects were placed by species on treated foliage in 49mm X 9mm petri dishes within three hours of treatment. Foliage from the same replicate was used for both species. Three 0.3mm holes were drilled in each dish to allow airflow. The dishes were stored at room temperature and exposed to the local daylight conditions. They were never placed in direct sunlight.

Observations were made at 24 hour intervals. Dead larvae, pupae and parasitized larvae were removed at each observation and their numbers were recorded. Frass was removed and fresh untreated foliage was placed in dishes with survivors at three day intervals or sooner if needed.

2.4.5 Gas Chromatography

Foliage from the lowest treatment rates causing 50% mortality in budworm populations after 48 hours were analyzed for aminocarb and mexacarbate deposit using gas chromatography techniques.

The foliage was pooled by treatment and was sent to the state public health laboratory in Augusta for analysis. There is no accurate way to quantify BT deposits on foliage (Dr. Phillip Haynes of the Maine State Department of Human Services, Public

Health Laboratory, pers. comm.), so this type of testing for BT was not done.

2.5.0 Data Analysis

Replicates were pooled and analyzed by treatment, because no distinct mortality trends were shown in any single replicate by both insect species. The exact cause of variations in mortality within treatments is impossible to determine. Therefore, no single replicate could be dropped or adjusted in an effort to eliminate experimental bias.

Mortality values were adjusted using Abbott's Formula (Simons and Chen 1974). Probit analysis was used to determine LC 50 values when mortality within a test series covered a suitable range, e.g. 37 to 63 adjusted percent dead.

3.0.0 Results and Discussion

3.1.0 Aminocarb Efficacy

The pooled, unadjusted budworm and coneworm mortalities for the first series of aminocarb tests are given in Appendix A, Table 1. The adjusted percent dead and LC 50 values are given in Table 2, Series A1.

Aminocarb gave good control of spruce budworm at 0.18% AI with an an adjusted mortality of 87.9% dead found at the 50 l/ha rate after 72 hours. The mortality curve indicates that the spraying apparatus gave consistent results. There is one inversion in the data set at the 20 l/ha rate for both budworm and coneworm. This may represent an operational error in which an overdose was given in Replicate 2 since a large number of budworm, 63%, died within the first 24 hours.

The LC 50 value for this series of tests was equivalent to 34 l/ha in our system.

Aminocarb did not give good coneworm control at any rates. This indicates that there is different susceptibility of the two species to this insecticide. This is strongly supported by the fact that both species were placed on foliage treated in the same replicates.

Since aminocarb did not provide good coneworm control at the 0.18% AI level, the amount of active ingredients was doubled to 0.37% AI and a second series of treatments was run (Table 2, Series A2). This test did give higher unadjusted coneworm mortalities, 19%, at the maximum rates. However, control mortality was also higher at this time and negated any measurable effects of aminocarb (Appendix A, Table 7). The reason for increased mortality in Control B is unknown, but may be due to higher heat and humidity conditions in our facility at this later test date, June 26.

In any case, mortality at the 0.37% rates was still low, so the test was repeated to be sure no mixing error had occurred (Table 2, Series A3). The results were similar. Again, there was high mortality in the control group which masked aminocarb effects. This is partially due to a large number of the larvae pupating within the first 48 hours (Table 2).

3.2.0 Mexacarbate Efficacy

Mexacarbate also gave good control of the spruce budworm at the 0.2% AI level (Table 3, Series M1). The mortality curve shows increases corresponding with higher application rates, except at the 20 l/ha level where there was another inversion for both species.

The LC 50 value calculated for Series M1 corresponds with 31 l/ha in our system. This is similar to the LC 50 value calculated for aminocarb, especially when the slightly lower AI levels for aminocarb are taken into account.

Mortality of coneworm larvae was lower than budworm larvae reaching only 40 percent at the 50 l/ha rate (Table 2).

A second test of mexacarbate was run using 0.4% AI. This caused higher coneworm mortality, but did not exceed 39 percent at the maximum rate (Table 3, Series M2).

3.3.0 Chemical Insecticide Residues

The results of the gas chromatography (GC) analyses are shown in Table 5. Due to a test failure with the GC apparatus results for aminocarb at 40 l/ha with 0.37% AI had to be discounted. Therefore, another test was run using foliage from the 30 l/ha treatment in that series.

Aminocarb residues were less than mexacarbate residues by approximately one-half when compared for the same application rate during the first test series. The lower aminocarb residues are partially due to slightly lower AI batch mixes, but are too low to be solely attributed to this cause. Pree et. al (1976) encountered similar differences in residues after applying equivalent emulsifiable concentrate mixtures of azinphosmethyl and dimethoate to apple leaves.

Although direct comparisons between extractible residues from the second test series are not possible, it appears that matacil deposits were again lower. Only 2.63 ppm aminocarb were found on the foliage treated with 30 l/ha. This is approximately twice the residue found at the same treatment rate in test series 1, indicating consistent apparatus performance. If this value is extrapolated to the 40 l/ha level it would equal 3.51 ppm which is only two-thirds as much as the 5.40 ppm found for mexacarbate.

The large difference in residue levels are unexpected since both chemicals have similar structures (E. Richardson, Maine State Public Health Laboratory, pers.comm). Possible reasons for differential residue levels could be: emulsifiable concentrate formulation; volatization and/or photolysis during the 15 minute drying period; or different chemical degradation rates.

The similar LC 50 values for spruce budworm in test series A2 and M1 are surprising. If the ppm values are roughly correlated with the LC 50 values through linear extrapolation of 30 l/ha up to 34 l/ha aminocarb and 30 l/ha up to 31 l/ha mexacarbate, they equal 1.55 ppm aminocarb and 3.18 ppm mexacarbate. This contradicts the findings of Hellson (pers. comm.) in which no significant difference in LC 50 values for budworm fed treated larch foliage was found. However he used colorimetric procedures to determine residues on adjacent filter paper and not on the foliage itself. Also, he used fifth instar larvae and did not delay analyses by drying and refrigeration. He plans further tests to determine if foliage type affects efficacy.

Our findings should be investigated further through tests that examine residues across a span of treatment rates rather than a single one.

3.4.0 Bacillus thuringiensis Efficacy

Trends in mortality for BT treatments were not consistent. This is not unexpected when BT's mode of action is considered. Sub-lethal doses probably occurred at all treatment rates. However, moribund insects were not counted until positively dead because this condition could not be consistently judged by observers.

In the BT1 series of tests, maximum adjusted budworm mortality was lower than coneworm mortality after 96 hours (Table 4, Series BT1), but, was similar to maximum coneworm mortality after 144 hours. The coneworm populations expressed most of the mortality before 96 hours and remained relatively stable after that time.

It appears that BT affected both species similarly in Series BT1. However, no meaningful LC 50 values could be calculated with these data due to low overall mortality.

A second BT test (Table 4) was run on both species using two higher rates, 32 BIU/acre and 48 BIU/acre. However, an error in data recording and high coneworm mortality render the data inconclusive.

4.0.0 Conclusions

Analysis of pooled data indicate that the coneworm populations tested were more resistant to aminocarb and mexacarbate than the budworm populations tested.

The LC 50 values calculated for budworm are similar for both chemicals when based on treatment rates. However, when they are correlated with extractible residues, aminocarb LC 50 values were lower than mexacarbate values. These findings need further investigation through experimentation before any valid assessments can be made. No meaningful LC 50 values for spruce coneworm could be calculated because mortality was too low.

BT affected both species in a similar manner in the first test series. Data from a second test series was inconclusive due to high control mortality and a recording error. Overall, budworm mortality was lower in BT tests than in chemical tests.

The study results show that coneworm populations present a control problem on red spruce. This undoubtedly has contributed to red spruce decline in some areas. Furthermore, as Spies and Stratton (1985) showed, both species behave in a manner that effectively shields them from contact with insecticides at least one-third of the time. Therefore, red spruce decline cannot only be attributed to lack of coneworm control, but also to ineffective budworm control with current spray strategies.

LITERATURE CITED

McLeod, J.M. and L. Daviault. 1963. Notes on the life history and habits of the spruce coneworm (*Dioryctria reniculella* Grt.) (Lepidoptera:Pyralidae). Can. Ent. 95(3):309-316.

Pree, D.J., K.P Butler, E.R Kimball, and D.K.R. Stewart. 1976. Persistence of foliar residues of dimethoate and azinphosmethyl and their toxicity to the apple maggot. J. Econ. Entomol. 69(4):473-478.

Simmons, G.A, and C.W. Chen. 1974 Two indices of insecticide effectiveness: Two computer programs for calculation. Life Sci. Agr. Exp. Sta. Univ. of Maine at Orono. Misc. Rept. 161.

Spies, C.J.,III and R.D. Stratton. Final Report: Study of spruce budworm (Lepidoptera: Tortricidae) and spruce coneworm (Lepidoptera: Pyralidae) behavior on red spruce as it relates to host phenology and damage. Report to Maine Forest Service. March 1985. In press.

TABLE 1. Treatment series used in bioassay of 6th instar spruce budworm and 5th instar spruce coneworm using red spruce foliage treated with aminocarb, mexacarbate and <u>Bacillus</u> <u>thuringiensis</u>.

BATCH MIXTURE*	SERIES TITLE	#INSECTS/REPLICATE BW	CW	#REPS.
Aminocarb 0.2%(0.18%)**AI	A1	30	5	3
Aminocarb 0.4%(0.37%) AI	A2	0	10	3
Aminocarb 0.4%(0.37%) AI	A3	0	10	3
Mexacarbate 0.2% AI	M1	30	5	3
Mexacarbate 0.4% AI	M2	0	10	3
BT 16 BIUs/gallon	BT1	30	5	3
BT 16 BIUs/gallon	BT2	5	10	3
Control A for series A1,M1,BT1	C1	30	5	3
Control B for series A2,M2,BT2	C2	15	10	3
Control C for series A3	C3	0	10	3
Oil & dye	OD	30	5	1
Water & dye	WD	30	5	1

*Series A1,M1,Bt1,OD,WD were dyed with Rhodamine B Base powder at rates equivalent to 4 grams/100 gallons.

**Values in parentheses are based on weight per volume. All mexacarbate batches were mixed on a weight per volume basis.

Table 2. Bioassay of 6th instar spruce budworm and 5th instar spruce coneworm using treated red spruce foliage. Pooled mortality values at 72 hours post-treatment with 0.18% and 0.37% AI aminocarb. Percent dead adjusted for control mortality with Abbott's Formula.

TREATMENT	RATES L/HA	 LBS/A	SPECIES	%DEAD	LC 50
Aminocarb 0.18%	5	0.0080	BW	15.13	
Series A1	10	0.0160	BW	36.13	
	20	0.0321	BW	55.49	
	30	0.0481	BW	51.73	3.41
	40	0.0642	BW	84.63	
	50	0.0802	BW	87.90	
	5	0.0080	CW	0.00	
	10	0.0160	CW	0.00	
	20	0.0321	CW	13.33	
	30	0.0481	CW	6.67	NA
	40	0.0642	CW	6.67	
	50	0.0802	CW	0.00	
Aminocarb 0.37%	20	0.0642	CW	0.00	
Series A2	30	0.0963	CW	0.00	NA
	40	0.1284	CW	0.00	
Aminocarb 0.37%	20	0.0642	CW	0.00	
Series A3	30	0.0963	CW	0.00	NA
	40	0.1284	CW	0.00	

Table 3. Bioassay of 6th instar spruce budworm and 5th instar spruce coneworm using treated red spruce foliage. Pooled mortality values at 72 hours post-treatment with 0.2% and 0.4% AI mexacarbate. Percent dead adjusted for control mortality with Abbott's Formula.

TREATMENT	RATES L/HA	LBS/A	SPECIES	%DEAD	LC 50
Mexacarbate 0.2%	5	0.0089	BW	6.67	
Series M1	10	0.0178	BW	40.26	
	20	0.0356	BW	54.92	
	30	0.0535	BW	67.72	3.12
	40	0.0713	BW	78.96	
	50	0.0891	BW	80.19	
	5	0.0089	CW	6.67	
	10	0.0178	CW	8.33	
	20	0.0356	CW	35.71	
	30	0.0535	CW	13.33	NA
	40	0.0713	CW	40.00	
	50	0.0891	CW	40.00	
Mexacarbate 0.4%	20	0.0713	CW	22.10	
Series M2	30	0.1070	CW	37.50	NA
	40	0.1426	CW	38.90	

Table 4. Bioassay of 6th instar spruce budworm (BW) and 5th instar spruce coneworm (CW) using treated red spruce foliage. Pooled mortality values at 72 hours post-treatment with <u>Bacillus thuringiensis</u> (BT). Percent dead adjusted for control mortality with Abbott's Formula.

	RATES				%DEAD	
TREATMENT	BIU/HA	BIU/A	SPECIES	96HRS	144HRS	240HRS
BT	9.88	4.0	BW	3.57	0.00	0.00
Series BT1	19.77	8.0	BW	18.89	21.00	9.26
	29.65	12.0	BW	38.63	42.41	45.86
	39.53	16.0	BW	25.03	34.05	39.56
	49.42	20.0	BW	34.09	36.29	45.21
	59.30	24.0	BW	42.50	52.91	53.73
	9.88	4.0	CW	13.33	13.33	66.67
	19.77	8.0	CW	17.67	17.67	17.67
	29.65	12.0	CW	8.33	8.33	8.33
	39.53	16.0	CW	26.66	26.66	33.33
	49.42	20.0	CW	36.66	36.66	36.66
	59.30	24.0	CW	51.67	51.67	60.00

				96HRS	168HRS
BT	39.54	16.0	BW	57.57	71.77
Series BT2	79.07	32.0	BW	34.73	ND
	118.61	48.0	BW	55.80	82.32
	39.54	16.0	CW	11.33	11.33
	79.07	32.0	CW	0.00	0.00
	118.61	48.0	CW	28.57	48.98

Table 5. Aminocarb and mexacarbate residues found on treated red spruce foliage using gas chromatography techniques.

TREATMENT	RESIDUES DETECTED (PPM WET WEIGHT)
Aminocarb 0.18%AI	1.39 ppm aminocarb
Series A1 30 l/ha	0 ppb mexacarbate*
Mexacarbate 0.2%AI	3.08 ppm mexacarbate
Series M1 30l/ha	79 ppb aminocarb
Aminocarb 0.37%AI	2.63 ppm aminocarb
Series A2 30 l/ha	0 ppb mexacarbate
Mexacarbate 0.4%AI	5.40 ppm mexacarbate
Series M2 40 l/ha	54 ppb aminocarb

* parts per billion contamination occured due to residual mixtures in the spray system that were not removed after flushing with pure fuel oil.