PROCEEDINGS

of the

SPRUCE PROTECTION SYMPOSIUM

Bangor, Maine

October 23, 1984

Maine Forest Service
DEPARTMENT OF CONSERVATION
Augusta, Maine 04333

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INTRODUCTION

In 1983 the Maine Forest Service decided to conduct a thorough review of the protection of red spruce (Picea rubens, Sarg.) from spruce budworm defoliation. This work was funded through the Spruce Budworm Management Research program. Dr. Russell Keenan, a private consultant, conducted the review under contract to the Maine Forest Service.

The need to evaluate the status of red spruce protection has become all too obvious in recent years. Red spruce, once thought to be resistant to budworm attack, is declining at an alarming rate throughout Maine and eastern Canada. Although the rate of decline, as well as the importance of the species, varies from one region to another, the problem has become serious enough to be recognized as a major research priority by most entomologists and foresters working on spruce budworm topics in the various jurisdictions that are currently infested.

In October of 1984, the Maine Forest Service hosted a symposium on spruce protection. The purpose of the symposium was to bring researchers and spray program managers from the numerous agencies that had been studying the spruce problem together to review the status of spruce protection programs and to determine what additional research is needed to improve our ability to protect spruce.

The papers that were presented at that meeting are included just as they were received from the authors in this compendium. In addition, several papers that were not presented are also included. This compendium is meant only as a summary of that symposium. No effort has been made to edit or synthesize these presentations This will be accomplished in a final report to be prepared by Dr. Keenan in the spring of 1985. The final report will provide an up to date summation from these reports as well as other published and unpublished studies on the status of spruce protection. It will also provide us with a clear view of the direction we should take in pursuing future research on this topic.

MAINE FOREST SERVICE
DECEMBER 14, 1984

Status of Red Spruce Protection in Maine

By

Henry Trial, Jr.

Maine Forest Service
Old Town, Maine

STATUS OF RED SPRUCE PROTECTION IN MAINE

By

Henry Trial, Jr.

INTRODUCTION

In the late 70's and early 80's increasing damage to red spruce led to intensified surveys and protection in affected stands. Prior to this period, spruce protection was not widely practiced in Maine. Some people theorized that fir removal from mixed fir-spruce stands would be sufficient to protect the spruce component from budworm mortality. Spruce enhancement was certainly a significant factor in the silvicultural treatment theories of the mid 70's.

Faced with rapidly increasing levels of red spruce mortality in Washington County, Baxter Park, and portions of the Northwest in the late 70's, the Maine Forest Service (MFS) first recommended immediate protection of the most severely damaged stands and then began an accelerated effort in practical research on red spruce. The MFS concentrated its efforts in several basic areas of immediate value to a red spruce protection program. Areas of study were population prediction, damage measurement, hazard evaluation, efficacy determination, and testing of insecticide regimes. Progress in some of these areas has been substantial while little progress has been made on other topics. The work continues as time and money permits. The following is a summary of work that has been conducted or is ongoing.

POPULATION PREDICTION

Research in the area of red spruce population prediction has been successful. The MFS incorporated spruce data in its egg mass and L-II surveys in 1978 and has worked to improve the predictive power of this data since that time. Egg mass and L-II data from both spruce and fir has been correlated to each other, to spring L-III counts, and to defoliation. Correlations were calculated with a broad data base which included the full range of forest type, population levels, and tree condition. Significant findings from these studies are as follows:

1. Egg mass and L-II do not correlate particularly well for spruce or fir.
2. L-II counts correlate better to L-III and defoliation than do egg mass counts.
3. Spruce L-II counts are often different from fir L-II counts from the same area and spruce counts are usually in a higher category than fir counts.
4. The best correlations of L-II to resulting damage are obtained when both fir and spruce are sampled and when tree condition factors such as past defoliation are added.
5. The impact of spruce coneworm on predicted defoliation to spruce is probably highly significant and hinders predictions.

MFS work on population prediction is ongoing and is not yet published, but many findings from our testing program have been incorporated into our survey methods. Using our current methods, we feel we can accurately predict budworm population levels and resulting damage from budworm. We can not as yet predict spruce coneworm damage. Significant aspects of our current survey method are as follows:

1. The total survey effort consists of a general population survey throughout the infested area and a specific survey of lands considered for spray.
2. The egg mass method is used on about 40% of the general survey and all other sampling is done with the L-II method.
3. Both spruce and fir are sampled at all points where both species are available. Spruce samples are made on red (more red than black) spruce unless white is the major component.
4. A sequential method is used on egg and L-II samples.
5. Specific sampling (in potential spray blocks) requires 3 to 10 points per area with 2 fir and 2 spruce samples collected per point. Results are averaged for the total block.
6. If either spruce or fir counts are high, the area is considered to be high even if other host samples are low.
7. L-II lab costs are about 40less then egg mass costs on fir and about 60% less on spruce.

In practice, the MFS population prediction method is incorrect by one category about 5% of the time and by 2 categories less than 1% of the time.

Another area of work conducted by the MFS that effects population prediction on red spruce is the improvement of the L-II method. Extraction efficacy on spruce has been improved from about 40% to over 80%. Evaluations of the method have included checks of pH, water temperature, soaking time, agitation, rinsing methods, and overwintering position on branches.

Future work planned that effects spruce includes:

1. Further correlations and test of predictability.
2. Completion of testing on the L-II sequential system.

3. Development of a survey method to accurately predict spruce coneworm numbers and damage.

DAMAGE ASSESSMENT

Research on damage measurement has not progressed at all well compared to population prediction work. The most significant finding in this area is that there are many more questions than answers.

The MFS is convinced that former methods used for fir are totally unsatisfactory for red spruce. Defoliation on red spruce is not a clear loss of needles on expanded shoots as often observed on fir. Spruce also does not show a clearly bare top that is typical of heavy fir damage.

A method change for assessing spruce has occurred in Maine, but the accuracy of the method and its resulting value are still in question.

The former method involved assessment of 20 buds (shoots) on each 18" branch collected for larval, egg, or L-II assessment. Each bud or shoot was evaluated for defoliation with the Fettes method. The major changes in the new method are to evaluate 50 buds rather than 20 per branch and to put special emphasis on inclusion of mined buds, where they exist, as part of the 50 bud complement. In the past, most workers only included buds which produced shoots and overlooked shoots missing through mining before expansion. This change has required education of workers in the identification of mined, viable buds versus nonviable buds and flower buds. Bud evaluation techniques still need work.

An important change in defoliation was noted shortly after the new system was adopted. The new method produced a defoliation rating nearly twice as high as the former method. Values obtained with the new method are more consistent with the observed red spruce decline and correlate better with population prediction.

Overall damage assessment of spruce is still a mystery. Several general traits are evident. A spiky branch appearance is evident on damaged trees compared to thick, full branches on healthy trees. Damaged trees appear to carry more lichen than healthy trees and appear to lose foliage from the bottom up and inside out. Color on spruce is confusing. Often badly damaged trees are green until shortly before they die.

Bud complement may be a good indication of poor tree condition. Heavily damaged trees often have less than 100 buds per 18" branch compared to more than 300 on healthy trees. Variability on healthy trees and bud viability may make a correlation of bud count to tree condition difficult, but this area should be investigated.

HAZARD

The most confusing area of spruce research seems to be hazard evaluation. This area is so confusing that the MFS has spent little of its limited resources on hazard evaluation even though a good hazard prediction is essential for a protection program. We have gotten by in Maine because most of our spruce is in such poor condition that the threshold of when to start protection is long past.

The hazard system now used in Maine was designed for fir and has little value on spruce. Much of the problems on spruce comes from inability to assess current and previous damage and lack of knowledge about what this data would mean if available. Variability within red spruce is also important in a hazard system. Some red spruce is much more resistent to budworm than others. Variation is so great that a hazard system for red spruce would probably need at least 4 spray thresholds depending on varying host characteristics.

Most work conducted on spruce hazard by the MFS has centered on bud count as a single measure of tree condition and predicted population. In the future, the MFS expects to test a bud count hazard system. Population prediction may include an assessment of spruce coneworm in the future.

INSECTICIDE TESTING

The final area of spruce research conducted by the MFS is insecticide protection. Testing has been extensive in terms of insecticide choice and spray timing. Efficacy work has been hampered by numerous factors listed below.

1. Difficulty in assessing current defoliation.
2. Red spruce variability.
3. Interference from damage caused by other insects such as spruce coneworm and orange spruce needleminer.
4. Apparent low natural survival of budworm on spruce.
5. Larval sampling difficulties such as counting larvae in early instars.

Despite these problems, the MFS has compiled a long list of spray regimes that don't appear to work and a much shorter list of regimes that may be marginally effective for red spruce protection. Those lists are as follows:

Regimes That Do Not Appear To Provide Adequate Spruce Protection

Insecticide	Rate	No. App.	Timing
Carbaryl	1 lbs/acre	1	Peak 4th instar
Carbaryl	3/4 lbs/acre	1	Peak 4th instar
Carbaryl	.31 lbs/acre	2	Peak 4th Instar and early 6th instar

Carbaryl	.46 lbs/acre	2	Both applications before peak 4th
Matacil	1 oz./acre	2	Both Applications before peak 4th
Orthene	12 oz./acre (1/2 lbs. A.I.)	1	Peak 4th instar
Bt products (Many)	8 B.I.U.'s	1	Peak 4th instar

Regimes That Provide Adequate (Marginal) Spruce Protection

Carbaryl	.46 lbs/acre	2	Peak 3rd instar Peak 5th instar
Matacil	1 oz./acre	2	Peak 3rd instar Peak 5th instar
Zectran	1 oz/acre	2	Peak 3rd instar Peak 5th instar
Dipel 6L	12 B.I.U.'s	1	50% 4th instar to Peak 5th
Dipel 8L	12 B.I.U.'s	1	50% 4th instar to Peak 5th
Thuricide 32 LV	12 B.I.U.'s	1	50% 4th instar to Peak 5th

Bt products showed great promise in 1982 and 1983, but in 1984 split applications of Zectran gave better results. In most cases the Zectran advantage can be attributed to an extremely effective 2nd application and the fact that the combination of two applications of Zectran gave more complete coverage than a single application of Bt. Late applications of Bt and chemicals seem promising and we expect to keep up investigations of both chemical and biological materials until we find something that works.

Spruce Protection: Observations from the 1983 Budworm Spray Program in Nova Scotia

By

Nelson Carter
and
Lester Hartling

New Brunswick Department of Natural Resources
Fredericton, New Brunswick

SPRUCE PROTECTION: OBSERVATIONS FROM THE 1983 BUDWORM SPRAY PROGRAM IN NEW BRUNSWICK*

(N. Carter and L. Hartling)

In 1983, the New Brunswick Department of Natúral Resources assumed responsibility for monitoring spruce budworm population levels in the Province and also for timing and assessing the aerial control program against this pest. The following information was extracted from the report which was prepared on the 1983 program (Hartling, 1984).

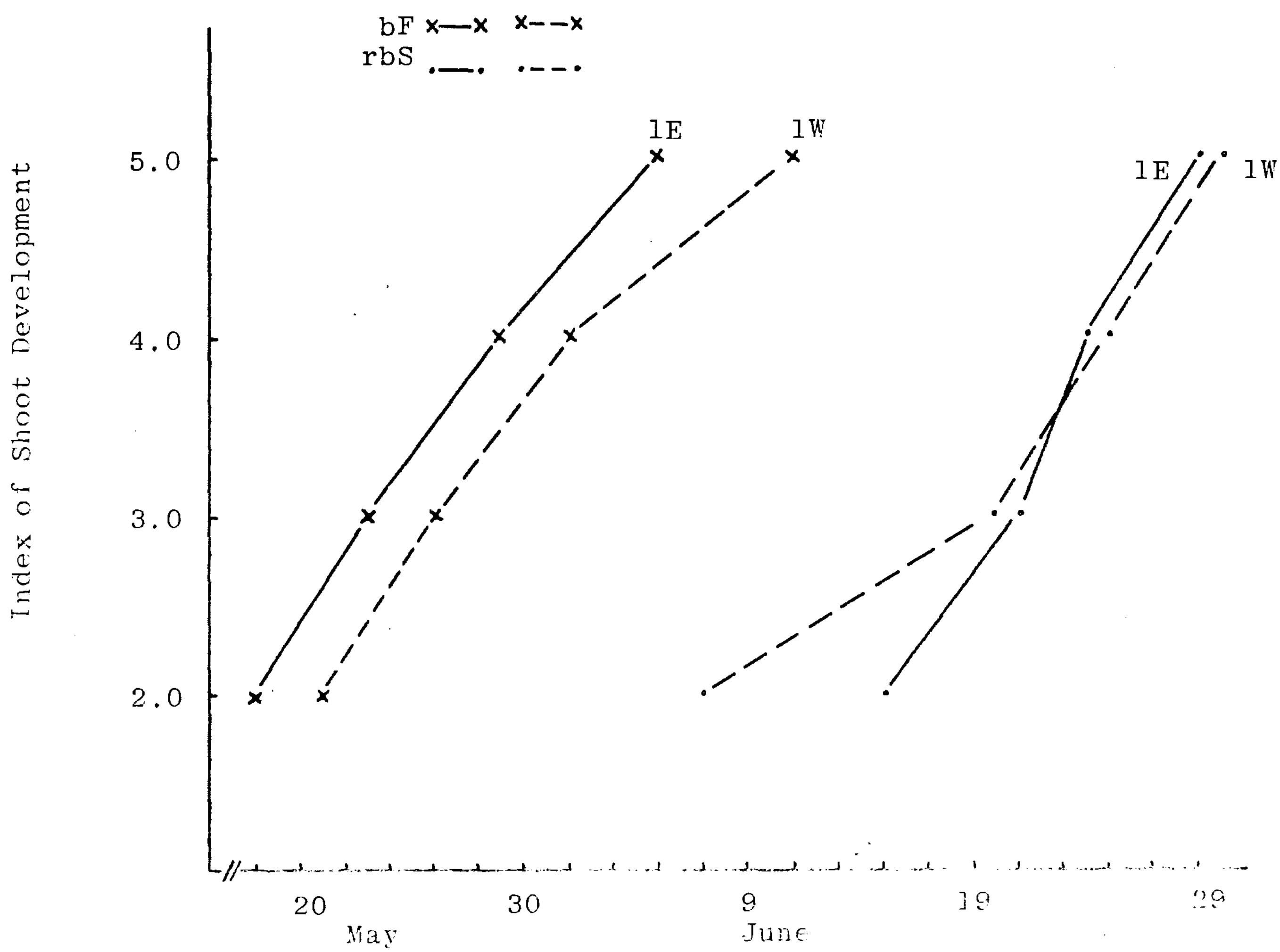
SHOOT DEVELOPMENT

In recent years it has become common to evaluate the rate of flushing of shoots on trees in spray blocks to time spray applications to coincide with exposure of new needles where larval feeding generally occurs. An index of shoot development has been adopted for balsam fir (Dorais and Kettela, 1982) and this has been extended in like fashion to the flushing of spruce. The theory for this monitoring is to have the insecticide deposited when and where the insect will more likely be exposed to it either by contact or ingestion or both. Figure 1 illustrates the relative rates of development of balsam fir and spruce in the eastern and western parts of phenology zone 1 in the Province in 1983.

(*Prepared for Red Spruce Protection Symposium held in Bangor, Me., October 23, 1984)

Figure 1.

Rate of Shoot development on balsam fir and red-black spruce in phenological zone 1 (east and west) in New Brunswick in 1983.



This figure shows that there were only minor variations in the rate of development of each species between the east and west parts of zone 1, but that there were major differences between species. In fact, balsam fir apparently was fully flushed (Class 5) before spruce had showed very little shoot development, generally only bud swelling. Equivalent "classes" occurred about 20-30 days later in spruce.

LARVAL DEVELOPMENT

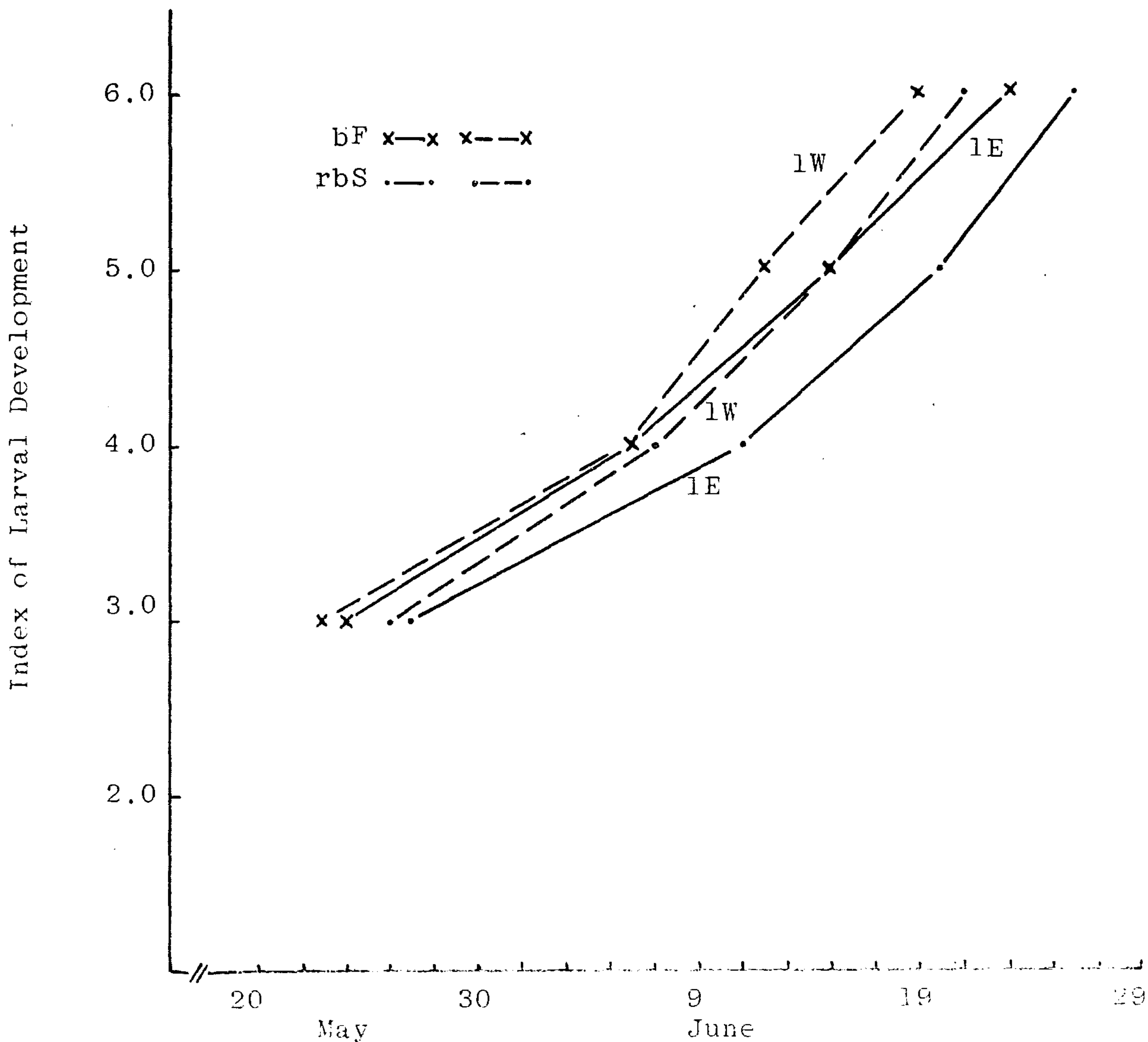
Rate of larval development has also been recently expressed as an index (Dorais and Kettela, 1982). Figure 2 illustrates the rates of larvel development on each host in the east and west parts of phenology zone 1 in 1983. These lines suggest that on like hosts larval development within the zone may vary by a few days and additionally that larval development might be a few days in advance on fir compared with spruce within the zone. Whether these observations were a sampling artifact or a true reflection of microsite climate variation or food characteristics is beyond the limits of these data. It is known, however, that food quality can affect adult weights and fecundity (Thomas, 1983; Mattson et al., 1983).

PROBABILITY OF DEFOLIATION

As a general rule, and given that all other things

Figure 2.

Rate of Larval development on balsam fir and red-black spruce in phenological zone 1 (east and west) in New Brunswick in 1983.



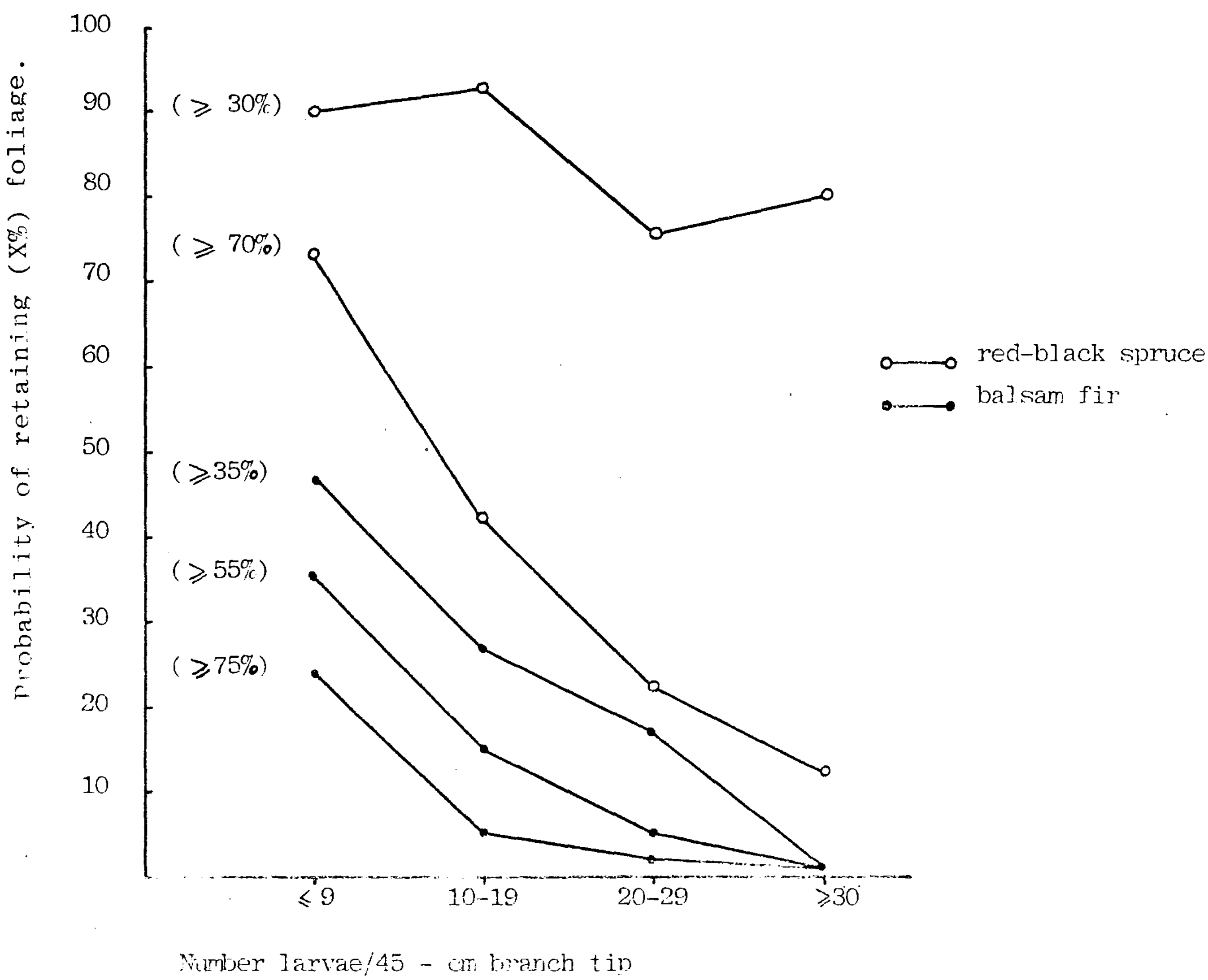
are equal, one would expect the probability of a given level of defoliation occurring to increase with an increase in the number of feeding insects present. Conversely, the probability of retaining a given amount of foliage would decrease with an increase in the number of feeding insects present. This is the essence of protection. In other words, spray is applied to reduce the numbers of feeding larvae and thereby increase the chances of limiting defoliation (=retaining foliage). Implicitly, this means reducing the numbers of insects at a time before the main feeding is accomplished.

Intuitively, one might expect that differences would occur between host species. That is, the same population of feeding insects may not cause the same proportion of defoliation on different species. This suggests a different population threshold for damage which might influence the forest manager's decision for intervention. Figure 3 illustrates some of the differences in probabilities of selected amounts of foliage being retained naturally on red-black spruce and fir with increasing numbers of feeding larvae as experienced in New Brunswick in 1983. Probability is here defined as the proportion of plots sampled in which the amount of foliage retained was equal to or greater than the level of foliage retention desired. This figure illustrates that:

a) increasing the numbers of feeding larvae reduces the probability of retaining a specified amount of foliage,

Figure 3.

Probability of retaining foliage on balsam fir or red-black spruce at varying population densities in New Brunswick in 1983.



b) the probability of retaining approximately* the same percent of foliage on spruce is higher than on fir, but the difference decreases as populations increase, and

c) at population levels up to 30 larvae/45-cm branch tip on spruce there was a 75 to 80 percent chance that about 30% of the foliage was retained naturally in 1983.

Effects of Spraying in 1983

The 1983 spray program in New Brunswick was comprised of large spray blocks in the industrial forest treated by TMB spray planes, and numerous small irregular shaped woodlots treated by small agricultural-type spray planes. Fenitrothion and Matacil (=aminocarb) were used in the industrial program and fenitrothion and Bt in the woodlot program. Results from the industrial program were based on a comparison between data collected from check plots and 65 TBM blocks sprayed with fenitrothion combined with 5 blocks treated with Matacil. Results from the woodlot program were based on 17 blocks treated with fenitrothion combined with 17 blocks treated with Bt. The number of plots sampled are indicated on the figures that follow. For this presentation no attempt has been made to separate the results by insecticide only.

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* Defoliation was rated differently for each species, making it impossible to compare equivalent levels.

Figures 4 to 6 illustrate the results that were obtained by spraying balsam fir and red-black spruce compared with untreated check areas. In all cases, it was apparent that the treatments applied increased the probabilities of retaining specified levels of foliage on the trees with various numbers of feeding larvae regardless of host type. Figure 6 in particular, however, suggests only a minor benefit to be gained by spraying spruce with populations of fewer than 10 larvae/45-cm branch tip and this is a reflection of the different population thresholds for defoliation on spruce (as previously stated).

These figures also reflect a very important concept for forest managers. In other words, if the objective is just to keep red-black spruce trees alive, it might not be necessary to treat infested trees even when populations reach up to 30 larvae per 45-cm branch tip, since there is (or at least was in 1983) a 75 to 80% chance that 30% of the current needles would be retained naturally (Figure 6A). If, on the other hand, one wishes to maintain tree vigor and growth which implicitely means keeping more foliage on the trees, then spraying is definitely beneficial since the probability of retaining 70% of the current needles might be improved from about 15% to about 60% even at population levels of 30 larvae/45-cm branch tip (Figure 6B). One must not forget, however, that results are subject to change each year depending on many natural factors such as weather, tree condition, and timing of treatment.

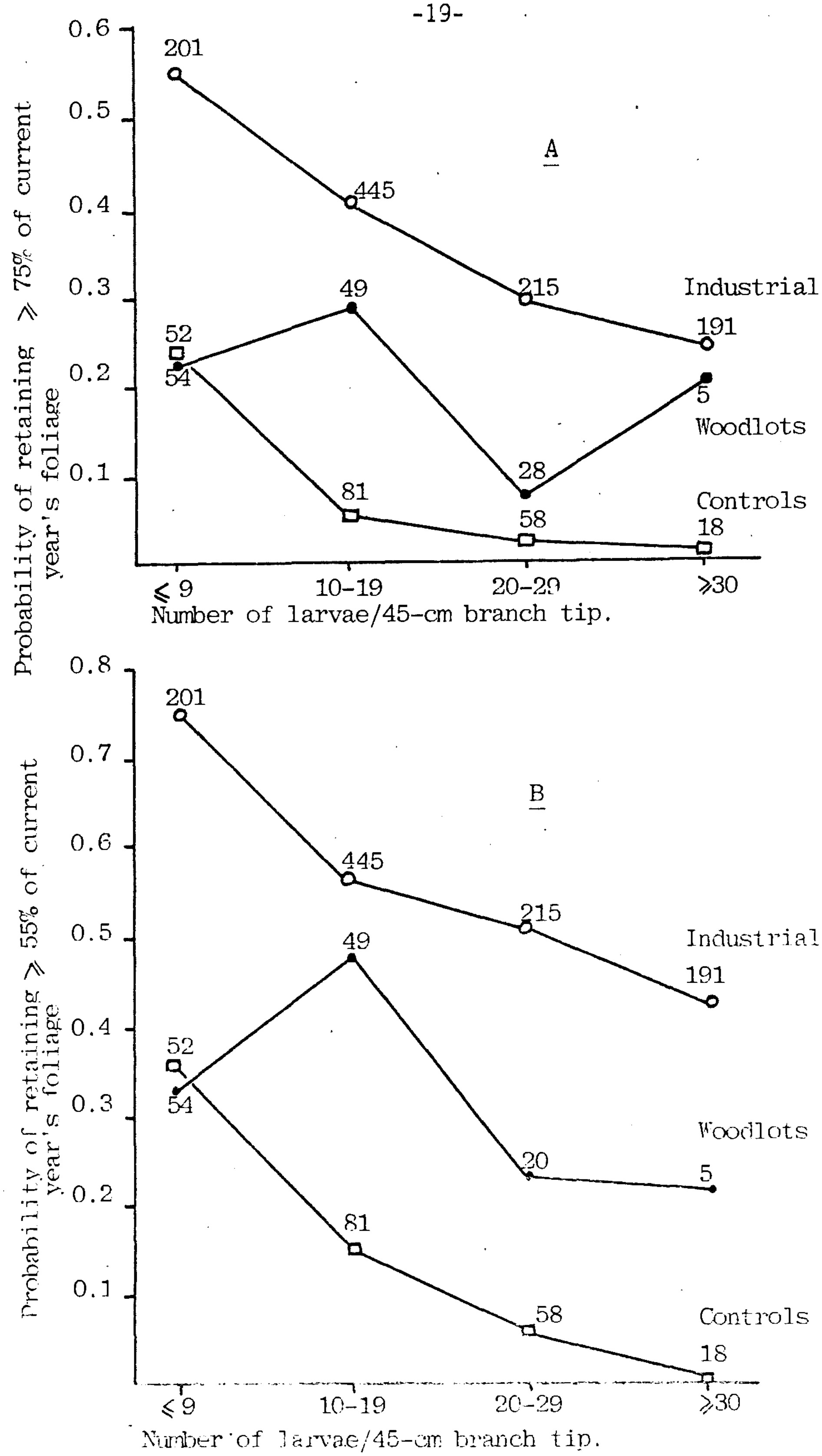

FIGURE 4. Probability of retaining a minimum of 75% (A) and 55% (B) current year's foliage on balsam fir in sprayed and unsprayed control plots (n=number of plots sampled).

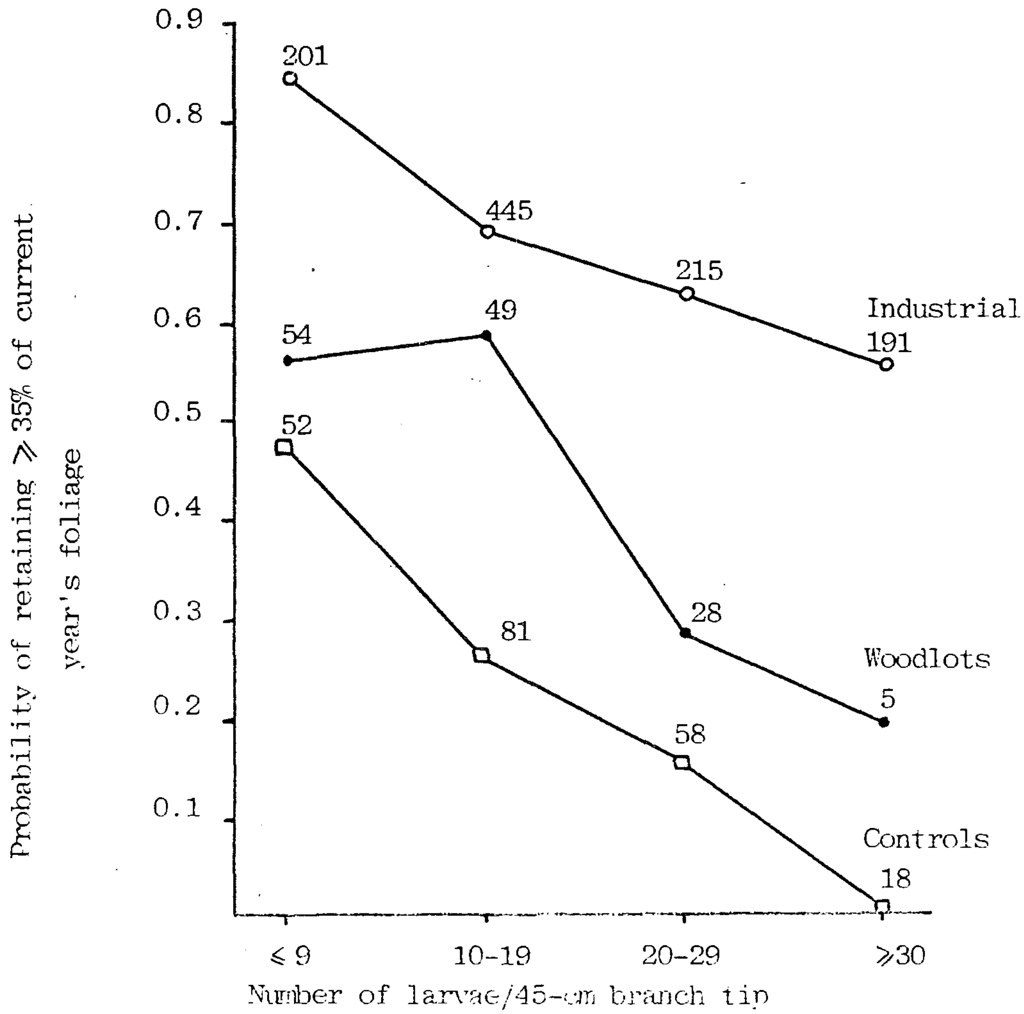

FIGURE 5. Probability of retaining a minimum of 35% current year's foliage on balsam fir in sprayed and unsprayed control plots (n=number of plots sprayed).

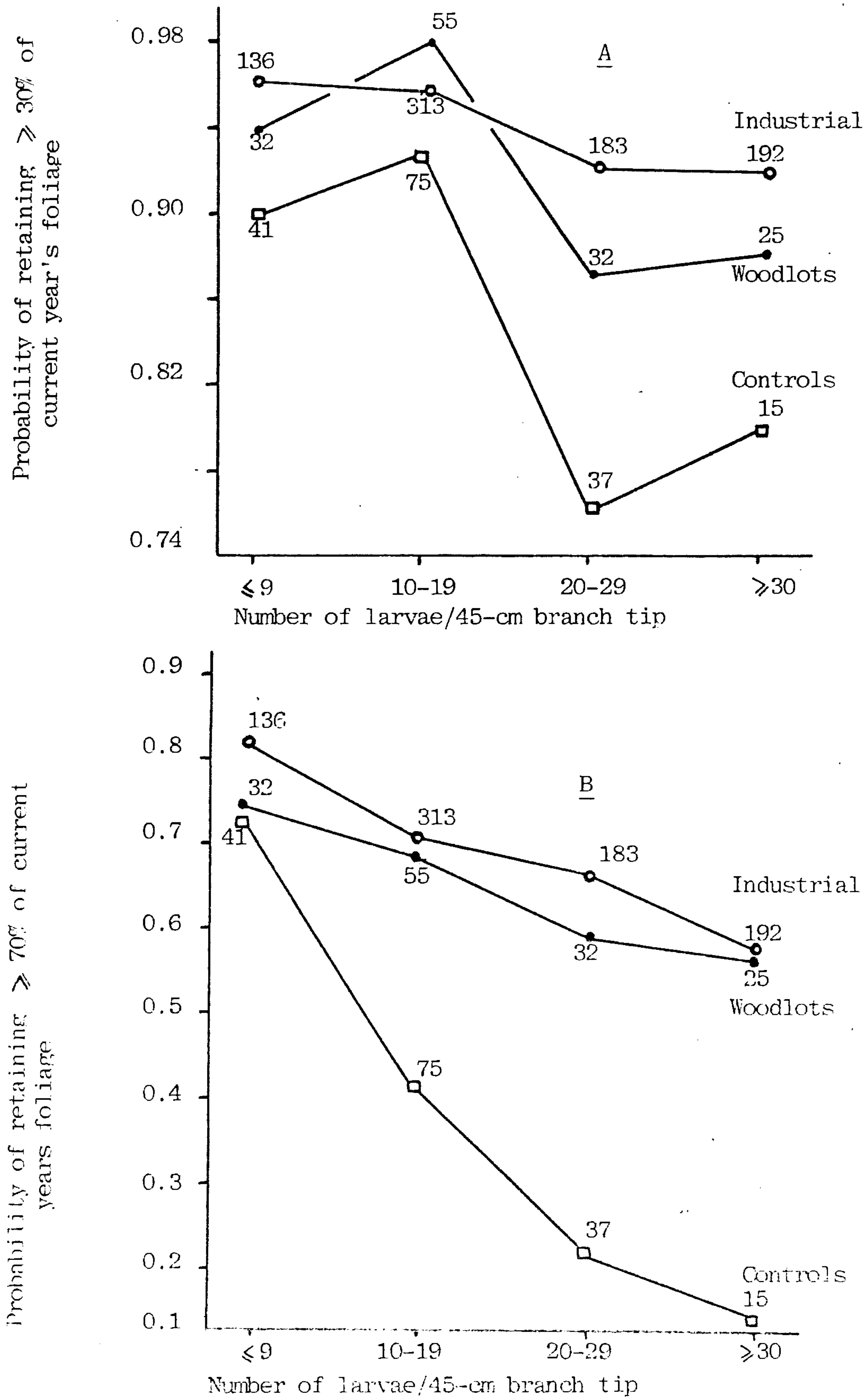

FIGURE 6. Probability of retaining a minimum of 30% (A) and 70% (B) current year's foliage on red-black spruce in sprayed and unsprayed control plots (n=number of plots sampled).

These generalities implicitly suggest a knowledge of growth loss, vigor, or mortality as a function of various levels of defoliation before a manager can decide on the benefits to be gained from spraying or alternatively the risks to be taken by not spraying. At present, our knowledge is more advanced, though not complete, about these relationships on balsam fir, but lacking on red-black spruce (MacLean 1980).

SUMMARY

1. The timing of spray applications requires the monitoring of insect numbers, larval development and behaviour, and tree phenology in target areas.
2. The probability of a specified amount of foliage being retained naturally decreases as the number of feeding larvae increases regardless of host species.
3. There is a higher threshold for defoliation on red-black spruce than on balsam fir i.e. it takes a greater number of feeding larvae/45-cm branch tip to cause equivalent defoliation on red-black spruce compared to balsam fir.
4. Spraying with insecticides improves the probability of retaining foliage (i.e. preventing defoliation) on infested trees though no attempt was made to determine if either of the insecticides used was better than the other in the 1983 operation.

5. More knowledge is needed concerning the relationship between numbers of larvae, defoliation, growth loss, vigor, and mortality in red-black spruce. In the meantime, projected wood supply difficulties dictate that the forest manager will have to be guided on the side of caution since a wrong decision about protection now could translate to irrecoverable losses in the future.

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Protection of red spruce (*Picea rubens sens. lat.*) from feeding by larvae of spruce budworm (*Choristoneura fumiferana* (Clemens 1865)) in Nova Scotia

By

Dr. T. D. Smith

Truro, Nova Scotia

I. INTRODUCTION

The spruce budworm (*Choristoneura fumiferana* (Clemens 1865)) is the foremost forest pest in Nova Scotia today. to date 24 million m^3 of wood have been killed by this pest, of this volume about 3.3 million is on Mainland Nova Scotia, and is primarily red spruce (*Picea rubens* sens. lat.).

The spruce budworm is indigineous to Nova Scotia. There have been five epidemics of this insect species in this century. The more intense being from 1925 to 1927 and from 1969 to present.

II. HOSTS

The spruce budworm is found in epidemic numbers throughout the Nova Scotia Highlands, the Maritime Plain and the Atlantic Uplands on Cape Breton Island (Figure 1). On Mainland Nova Scotia red spruce is the principal host whereas on Cape Breton balsam fir is the principal host. The present epidemic on Mainland Nova Scotia begain in1969 and on Cape Breton in 1974. The epidemic ended in Cape Breton in 1981 but has persisted on the mainland in spruce stands.

III. FOLIAGE PROTECTION

Foliage protection efforts began in 1979 against spruce budworm larvae in both red spruce and balsam fir (Table 1).

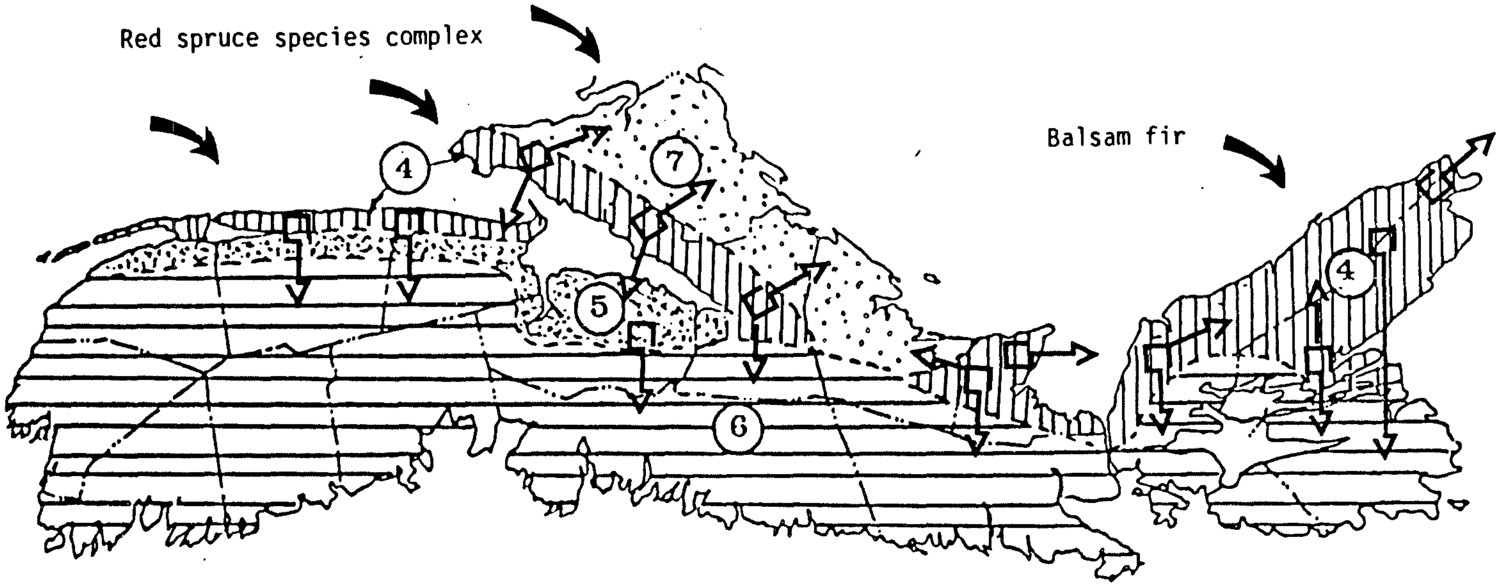

FIGURE 1. PHYSIOGRAPHIC REGIONS OF THE APPALACHIAN REGION IN NOVA SCOTIA.
(DANKS, H.V. 1979. CANADA AND ITS INSECT FAUNA. MEM. ENT. SOC. CAN. NO. 108.)

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(4) NOVA SCOTIA HIGHLANDS.
(5) ANNAPOLIS LOWLAND.
(6) ALANTIC UPLANDS OF NOVA SCOTIA.
(7) MARITIME PLAIN.
HYPOTHETICAL MIGRATION WITHIN NOVA SCOTIA OF SPRUCE BUDWORM ADULTS.

Table 1. Mean Relative Foliage Protection (20 BIU·ha^{-1}x 1).

Year	Host		
	balsam fir	white spruce	red spruce
1979	85	-	62
1980	55	-	79
1981	71	-	69
1982	43	-	44
1983	23	34	10
1984	-	87	23

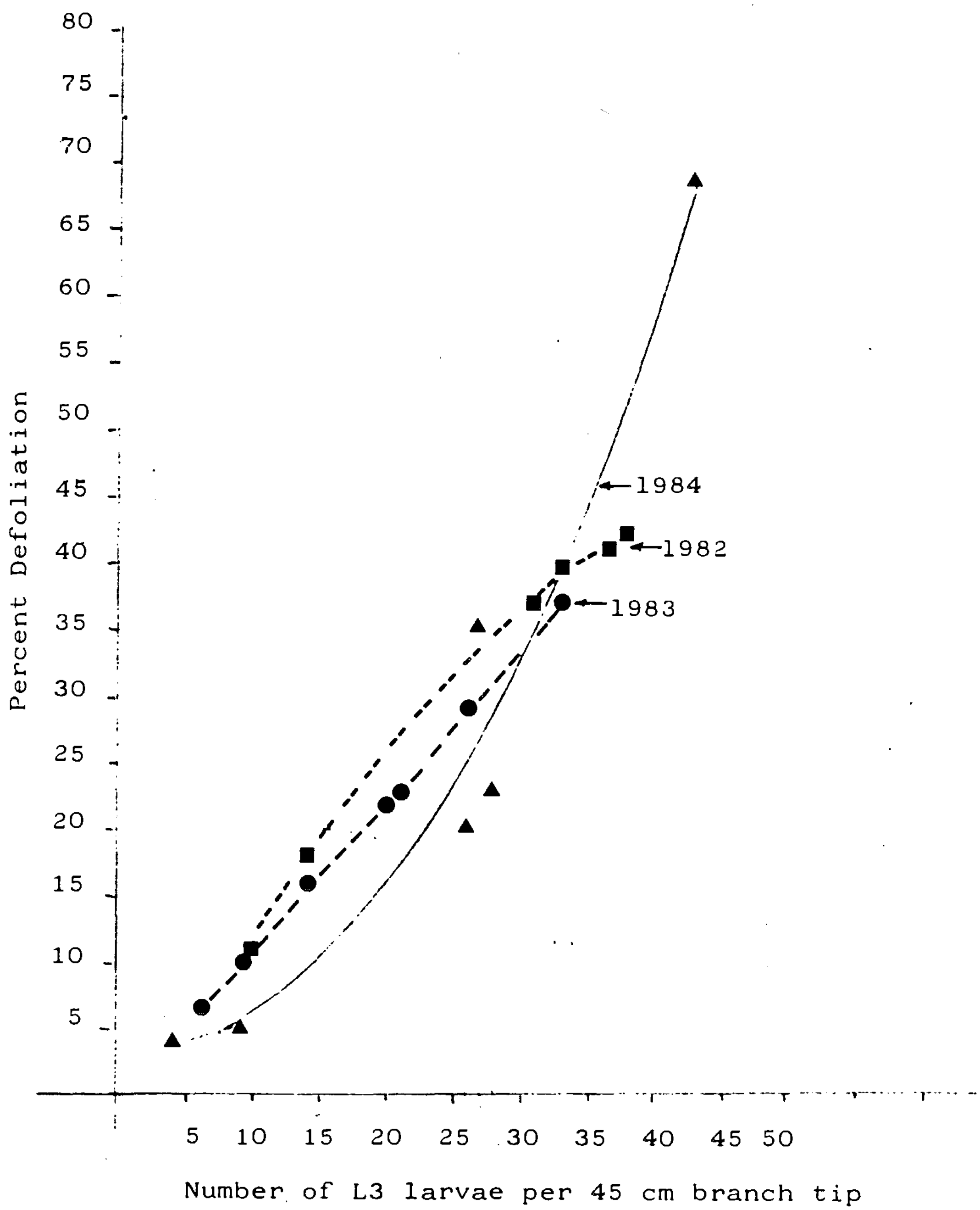
Foliage protection efforts for red spruce increased as spraying was discontinued in Cape Breton. The relative degree of foliage protection has been similar for balsam fir and red spruce except in1983. In that year balsam fir was a minor component of the program. No large area (500 ha or more) of balsam fir was treated in 1984.

IV. INSECT BEHAVIOUR

The behaviour of the insect varies throughout space and time in Nova Scotia (Figure 2). Each of the situations described by other speakers can be found within a radius of 100 km of Parrsboro, N.S. It was noted in 1984 that larvae in an area of new infestation destroyed about twice as much foliage as larvae in an area of declining infestation. It was also noted that spruce budworm larvae invaded red spruce buds during the third and subsequent stadia.

Figure 2.

Relationship between the number of L3 spruce budworm larvae and percent defoliation, red spruce species complex, Nova Scotia. 1982 (■), 1983 (●), and 1984 (▲).



In an area where red spruce are taller than balsam fir trees then red spruce is the preferred oviposition site.

Summary

The relationship between balsam fir and spruce budworm can only function as a guide to those between red spruce and spruce budworm in Nova Scotia. It wuld almost appear that a second edition of Morris (1963) needs to be done using red spruce as the host tree.

Morris, R.F. 1963. Dynamics of epidemic spruce budworm populations. Mem. Ent. Soc. Can. No. 31. 332 pp.

Red Spruce Protection on Indian Lands in Maine During the 1982-1984 Period

By

Imants Millers

USDA Forest Service
Durham, New Hampshire

RED SPRUCE PROTECTION ON INDIAN LANDS IN MAINE DURING 1982-1984 PERIOD

BY IMANTS MILLERS

FOREST PEST MANAGEMENT OF THE USDA FOREST SERVICE PROVIDES ON-THE-GROUND ASSISTANCE TO FEDERAL LAND MANAGERS. IN MAINE, WE HAVE ASSISTED THE PASSAMAQUODDY INDIAN TRIBE AND THE PENOBSCOT INDIAN NATION SINCE THE FALL OF 1981 (FIGURE 1). THEY HAD OBTAINED SOFTWOOD STANDS THAT WERE SEVERELY DAMAGED BY THE SPRUCE BUDWORM. WE WERE CALLED TO EVALUATE THE SITUATION LATE IN THE SEASON AND BEFORE THE ACTUAL BOUNDARIES OF OWNERSHIP WERE EVEN CLEARLY ESTABLISHED. THE HEAVY DAMAGE OF SPRUCE AND HEMLOCK, AND FREQUENT MORTAILITY OF BALSAM FIR, INDICATED PAST BUDWORM ACTIVITY. EGG-MASS SURVEY ESTABLISHED CONTINUED PRESENCE OF THE BUDWORM AND THE AREAS WERE TREATED IN 1982. THE OBJECTIVES WERE TO PROTECT SPRUCE AND HEMLOCK. SINCE THEN, AT LEAST 15,000 ACRES HAVE BEEN SPRAYED EVERY YEAR (TABLE 1).

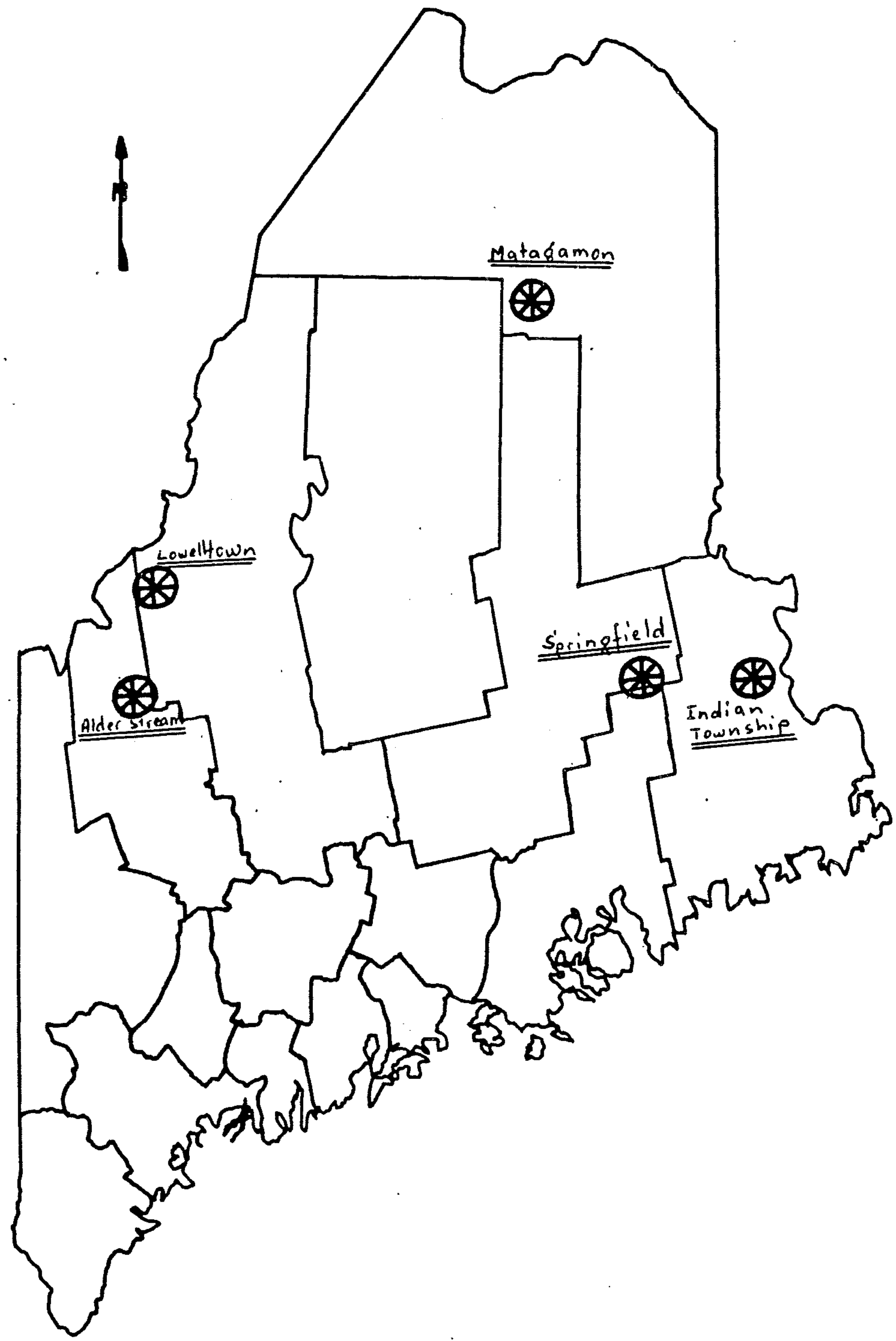


FIGURE 1. SPRUCE BUDWORM SUPPRESSION AREAS ON INDIAN LANDS IN MAINE, 1982 - 1984

TABLE 1. SPRUCE BUDWORM CONTROL ON RED SPRUCE IN BT TREATED STANDS ON INDIAN LANDS IN MAINE

		Spruce Budworm			
		Mortality		Defoliation	
Year Treated and Location	Pre Pop. No./branch	Spray %	Check %	Spray %	Check %
1982					
Alder Stream	3.6	94	89	1.5	3.4
Springfield	9.0	90	77	14	33
1983					
Springfield	10.6	97	-	21	-
1984					
Indian Twp.	13.2	92	82	7	10
Lowelltown	11.2	93	94	13	19
Matagamon	11.0	92	90	14	23

Most of the treatments were Bt at 12 BIU per acre:

1982	Dipel 4L; 96 fl. oz.; small helicopter and flat fan nozzles
1983	Dipel 6L (some 8L), Thuricide 32 LU and 48 LU; variable rates from 20 to 96 fl. oz.; application was with thrushes and mini-micronaire atomizers.
1984	Dipel 6L at 32 fl. oz.; a small area with Futura at 8 BIU in 20.5 fl. oz. per acre; all applications were with thrushes and minimicronaire atomizers.

Usually plans called for spraying to start when most larvae have reached the 3rd instar. Only in 1983 was spraying started that early, while in other years most of the larvae were in the 4th instar. By the end of the project, we usually had 5th instar larvae.

Negligible bud growth usually had taken place at the start of the project, but by the end, the buds were swollen and some green was showing at the base of the bud. As a rule, the budcaps were protecting the budworms from spray every year.

In general, the spruce budworm prespray populations have been low, but in the range where damage was to be expected (Table 1.) Fall surveys, both egg-mass and overwintering larvae suggested higher infestations than found in prespray surveys. The damage or hazard ratings usually indicated high hazard.

In the sprayed areas we usually had high budworm mortalities -- in the ninety percentage range -- and less than 20 percent defoliation. Thus, we can show good protection. And the spruce and hemlock, even balsam fir, do look better than before.

However, before we get too enthusiastic, let us examine the checks. Here also, the spruce budworm mortalities are high and defoliation is rather low. So now we can raise the question, "Did we really accomplish anything with spraying?" On basis of our own data from 3 years of spraying, I don't think we can recommend treatment again unless some of the problems are resolved.

This is not to say that the spruce is not ever affected seriously by the budworm. Obviously, many trees are in poor shape from previous damage.

So here is a list of questions that need to be answered before sound spruce protection can be expected:

A. HOW DOES SPRUCE BUDWORM CAUSE DECLINE AND MORTALITY?

1. The spruce budworm populations that we have been treating, i.e. 10 larvae per 18" branch, do not seem to cause much defoliation. How many more budworms are needed to cause damage?

2. Over the last 3 years, the natural mortality of budworms has been so high that perhaps there are not enough budworms in the 6th instar to cause much defoliation. Could this change in a different phenological development year?

3. Could it be that the bud damage from the small larvae is more important than the consequent defoliation of the remaining shoots? Let us examine a graph, based on theoretical assumptions, that compares total defoliation, removal of both buds and needles, with shoot defoliation alone. The moderate larval populations seem to do more damage than we think. If this is true, then we should prevent bud damage.

B. HOW DO WE DETERMINE RED SPRUCE HAZARD RATING?

The present values include top-kill, while spruce rarely is top-killed. Is it fair that we include balsam fir condition as part of spruce rating? And again, should our spruce budworm larval numbers values be the same for spruce and balsam fir?

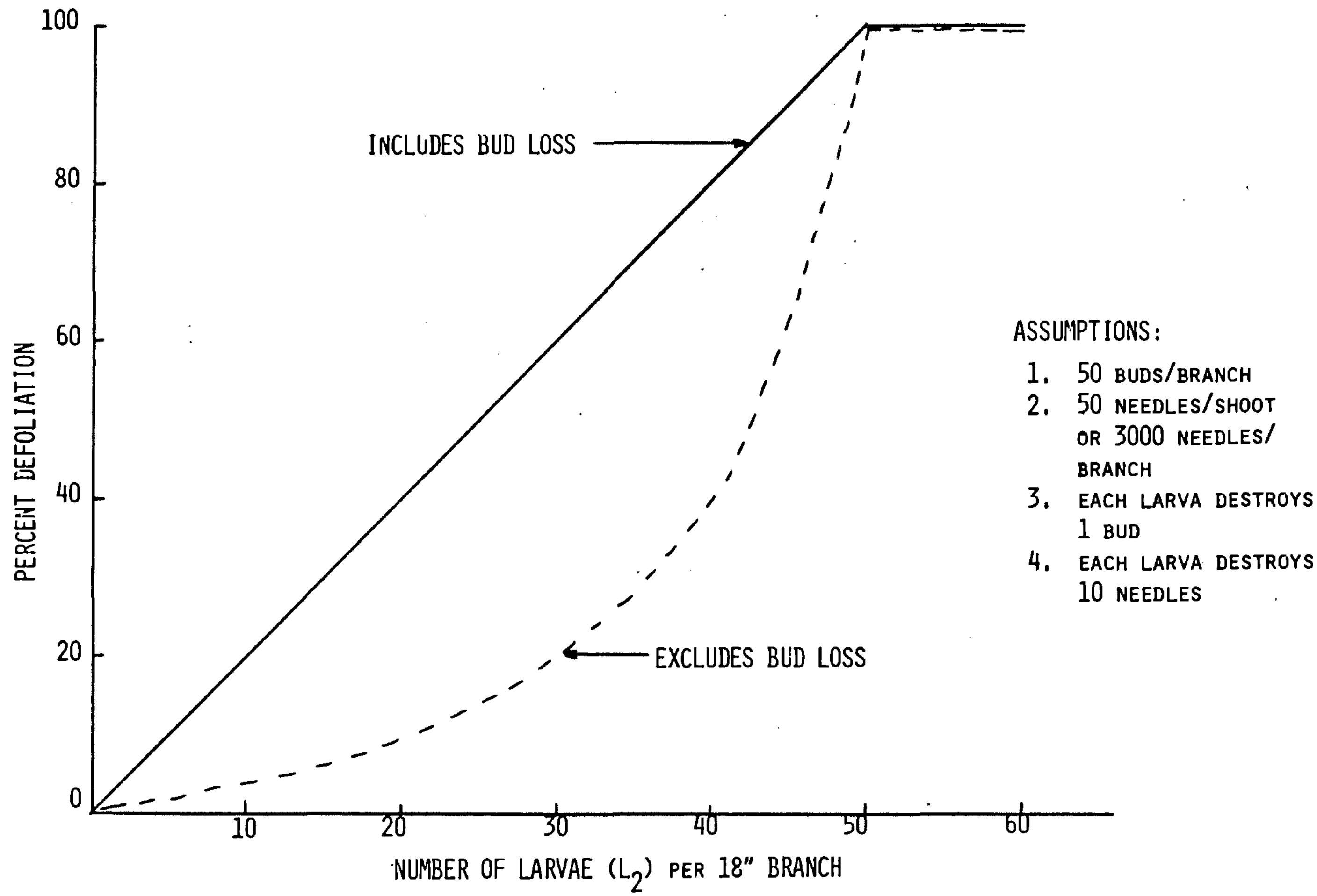


FIGURE 2. COMPARISON OF DEFOLIATION USING 2 METHODS: INCLUDING AND EXCLUDING LOSS OF BUDS.

C. HOW CAN WE SHOW THAT SPRAYING WILL PROVIDE FOLIAGE PROTECTION?

WE HAVE BEEN ABLE TO SHOW SIGNIFICANT DIFFERENCES BETWEEN TREATED AND UNTREATED SPRUCE BUDWORM POPULATIONS. HOWEVER, ON SPRUCE, WE HAVE A TOUGH TIME SHOWING FOLIAGE PROTECTION. EITHER OUR POPULATIONS HAVE BEEN TOO LOW, OR NATURAL MORTALITIES TOO HIGH; OR WE HAVE NOT CONSIDERED BUD DAMAGE, OR ALL OF THESE. BUT WE ARE EMBARRASSED WHEN WE ATTEMPT TO SHOW ACCOMPLISHMENTS.

EFFECTIVENESS OF NO SPRAY ON REDUCING SBW POPULATION
AND KEEPING AT LEAST 35 PERCENT FOLIAGE
1984 TESTS

AREA	PRE.POP. No./BRANCH	MORT. %	DEFOL. %
IT	13.2	82	10
LH	11.2	94	19
M	11.0	90	23

Efficacy of Aerially Applied Matacil to Control Spruce Budworm, *Choristoneura fumiferana* (clem.), in Balsam Fir and Red spruce

By

B.L. Cadogan

Forest Pest Management Institute
Sault Ste. Marie, Ontario

Efficacy of Aerially Applied Matacil to Control Spruce Budworm *Choristoneura fumiferana* (Clem.) in Balsam Fir and Red Spruce

B.L. Cadogan
Forest Pest Management Institute
Canadian Forestry Service
Sault Ste. Marie, Ontario P6A 5M7
Canada

SUMMARY

A study was conducted in 1981 near Bathurst, New Brunswick to determine the efficacy of two Matacil® (aminocarb) formulations to control spruce budworm, *Choristoneura fumiferana* (Clem.), on balsam fir, *Abies balsamea* (L.) Mill. and spruce, *Picea* spp.

Matacil 180F flowable insecticide was sprayed in both water and in ID585, Matacil 1.8D oil soluble concentrate (OSC) was applied in ID585 and in Sunspray® 6N. Atlox 3409F, the emulsifier used in the aqueous Matacil sprays, was mixed with water and applied as a non-insecticidal treatment. An untreated block was kept as a control. All Matacil sprays were applied at 70g AI/ha in 1.5L of tank mix with a Cessna® 188 Agtruck fitted with 4 Micronair® atomizers; and the Atlox was sprayed at 0.04 L/ha. The applications were made under stable weather conditions.

Prespray budworm populations were significantly lower on red spruce, *Picea rubens* Sarg. (Table 1). Application of the first sprays were timed to suit optimal phenological development of balsam fir - shoots were fully flared and had grown ∿ 2.6 cm. Red spruce buds were

still tightly closed. At the final count, residual budworm populations were higher on red spruce than on balsam fir (except in the Atlox and untreated blocks), suggesting that the insecticide was not as effective on red spruce as on balsam fir. Corrected percent population reduction and defoliation were also less on red spruce.

Post spray 'tinselling' or spinning down of budworm was less evident in red spruce than in the other species. Warm post-spray weather seems to volatilize Matacil, and this gaseous phase might be less effective on budworm when the shoots are not flushed. The low level of defoliation recorded on red spruce might have been caused by low budworm numbers on that species, or by the timing of the spray applications, which was based on balsam fir development.

It is recommended that (I) more research be undertaken to investigate the spray - budworm - red spruce interactions. (II) In areas where red spruce is the major species, insecticide applications be timed to suit the phenological development of that species. (III) When red spruce is a minor component of the area, an insecticide with residual activity should be used so that some insecticidal activity would still be available when the later flushing of red spruce occurs.

These points will have to be addressed if control of spruce budworm on red spruce is expected to be comparable to that on balsam fir or white spruce.

Table 1. Spruce budworm population reduction and percent defoliation in Balsam fir and red spruce, N.B. 1981

Block	No. of trees[1]		Budworm larvae/46cm branch at				% Population reduction[3]		% Defoliation	
			prespray		last count[2]					
	Bf	Rs	Bf	Rs	Bf	Rs	Bf	Rs	Bf	Rs
Matacil 180F + Atlox + water	43	10	21.2	7.9	0.5	1.5	96	71	10.4	3.8
Matacil 180F + ID585	34	10	11.5	5.4	1.2	1.6	79	43	9.5	2.8
Matacil 1.8D +6N	40	11	21.1	3.6	0.2	0.6	99	67	23.2	4.8
Matacil 1.8D + ID585	34	6	16.8	8.0	0.3	1.6	97	64	20.7	9.2
Atlox 3409F + water	30	10	19.5	9.2	10.9	7.9	0	0	62.3	19.7
Untreated	30	15	26.8	9.2	13.7	11.0	-	-	75.5	26.5

[1]Bf - balsam fir; Rs - red spruce.
[2]Taken 10-12 days after 2nd application.
[3]Matacil and Atlox reductions corrected for natural mortality (Abbott 1925 J. Econ. Entomol. 18: 265-267).

Reflections on Spruce Protection in New Brunswick

By

Charles Wiesner

New Brunswick Research and Productivity Council
Fredericton, New Brunswick

Reflections on Spruce Protection in New Brunswick

Spruce, mostly as red-black hybrids, is a major component of the softwood growing stock in N. B. During the 1975-79 survey, spruce comprised 47% of the softwood inventory. Spruce growth and survival are crucial to provincial wood supply policy.

Two recent studies (Clowater and Andrews, 1981 and MacLean et al., 1984) have concluded that (1) budworm defoliation has caused significantly less mortality of spruce trees than of balsam fir and that (2) the budworm protection program has had little effect in preventing spruce mortality. These studies confirm long-standing observations in all provinces that spruce is less vulnerable than fir. However, they also suggest that present protection strategy or tactics, while reasonably effective on fir, is unsuccessful on spruce.

Since, historically, the N. B. spray program has been designed specifically around protection of balsam fir, it is not inconceivable that one or even all components (hazard criteria, protection tactics, protection strategy and evaluation) of the program are inappropriate for spruce.

A re-evaluation of spruce protection is warranted. As an aid to assessing the situation a number of questions may be considered:

(1) Is the reported difference in current spruce mortality between protected and unprotected stands (13% and 20%, respectively) significant?

(2) Is the spruce mortality rate likely to increase or decrease?

(3) How are growth and vigor of spruce influenced by protection?

(4) What level of mortality or growth loss is acceptable from a wood supply point-of-view?

(5) If current mortality rates are acceptable, do we need to protect spruce?

(6) If current mortality rates are unacceptable, how do we go about protecting spruce?

The problem has two distinct aspects:

Technical Aspect

(a) Hazard criteria, population sampling techniques, and assessment techniques were developed for balsam fir, and are probably inaccurate indicators for spruce. Hence, any evaluation on spruce is suspect.

(b) There are indications from current research at MFRC and past experience at CCRI, of significant differences in both larval response and chemical deposits on spruce and fir exposed to the same spray.

It is quite possible, therefore, that our spray tactics (timing, dosage, number of applications, etc.) while effective on fir, are failing on spruce. Furthermore, it is likely that present evaluation techniques, if inappropriate to spruce, are generating meaningless assessments of success or failure of spruce protection.

Management Aspect

Managers must decide whether current mortality (and growth loss) of spruce will significantly affect regional wood supply. If not, then protection resources should be allocated to balsam fir stands or spruce/fir stands with a high fir component. If, however, it is concluded that the losses are unacceptable, then planners may be in the uncomfortable position of wanting to reinforce the protection of spruce by a strategy which evidently does not work.

Recent spray programs, as well as that proposed for 1984 have directed their limited resources at spruce stands at the expense of defoliated balsam fir stands.

Possible Actions on Technical Aspects

(1) Study group to evaluate:

(a) Are the conclusions of MacLean et al. definitive for conditions in spruce stands across the Province?

(b) What is the efficacy of current spray tactics on spruce vs. fir?

(c) What is the accuracy of present assessment techniques on spruce?

(2) Broad based literature review of available operational, experimental and laboratory evidence on the effectiveness of conventional dosages and insecticides on spruce.

(3) Ditto for Bacillus thuringiensis.

(4) Acceleration of current research of budworm vulnerability on spruce and fir.

(5) Study of comparative population dynamics on spruce and fir.

(6) Evaluation of hazard mapping criteria re spruce.

(7) Study of defoliation impact on growth, vigor and survival of spruce.

Feeding Rates of Spruce Coneworm and Spruce Budworm: Laboratory Observations on White Spruce

By

Clay A. Kirby
and
John B. Dimond

University of Maine
Orono, Maine

Feeding Rates of Spruce Coneworm and Spruce Budworm: Laboratory Observations on White Spruce

Clay A. Kirby and John B. Dimond, Entomology Department,
University of Maine, Orono, ME 04469

The larval instars of the spruce budworm and the spruce coneworm were compared for feeding rates and efficiency using foliage of white spruce in the laboratory. One goal was to determine whether feeding damage of the two defoliators in the field is likely to be of similar magnitude or different. It is already known that the five larval instars of the coneworm and six instars of the budworm follow a similar progression of early larval hibernation, needle mining, bud mining, and shoot feeding, and that these extend for both insects over the same period in the spring.

Several indexes of feeding efficiency were calculated for the two defoliators and were derived from weights of the insects, weights of food eaten, and weights of insect products such as frass and silk. The relative consumption rate was calculated from the weight of food ingested corrected for larval weight and duration of feeding in days. The relative growth rate was the weight gained, also corrected for larval weight and feeding duration. The approximate digestibility was the weight of food ingested minus the weight of frass eliminated. Two efficiency-of-conversion indexes were also calculated which measure the efficiency of converting ingested food to body matter. Details of these studies are the subject of an M.S. thesis[1] which can be consulted for greater understanding.

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[1] Kirby, Clay A. 1984. A comparative study of spruce coneworm, _Dioryctria reniculelloides_ Mutuura and Munroe (Lepidoptera: Pyralidae) and spruce budworm, _Choristoneura fumiferana_ (Clemens) (Lepidoptera: Tortricidae): consumption and utilization of food. M.S. Thesis, Graduate School, University of Maine, Orono, 43 p.

Because of the small size of early larval instars and difficulty in handling them, these were combined into one feeding period, with instars I - III combined for the coneworm, and II - IV combined for the budworm. The last two larval instars of each species were measured separately as feeding periods 2 and 3.

Of greatest interest in the present discussion is quantity of foliage eaten by the two species (Tables 1 and 2). Male coneworm and budworm consumed weights of foliage through the larval period that were about the same. Among females, however, coneworm consumed less, 77% of the amount of foliage of female budworm. This difference was statistically significant ($p < 0.05$). Amounts of foliage consumed in the three feeding periods were about the same for the two species, even though the periods correspond to different instars. Days of development were the same for the two species.

In other measurements, the two insects showed much similarity but with differences associated with the different size of the two insects. Larval weight gains during some of the feeding periods and pupal weights were significantly greater for both male and female budworms than they were for coneworms (Tables 3 and 4). Frass production increased with larval development and was greater for females than males, but it did not differ between species. Relative consumption rates of foliage tended to be greater for spruce coneworm than for spruce budworm in most feeding periods, but relative growth rate did not differ. This suggests that white spruce foliage was a less efficient food for the coneworm than for the budworm, and this was confirmed in the calculations of approximate digestibility. This index was lower in coneworm of both sexes and in all feeding periods, and some of these differences were significant. In both species, the approximate digestibility of foliage and the efficiency of conversion of food decreased substantially through the larval periods.

This corresponds to changes in structure and nutritional content of foliage as it grows in the spring.

Our studies suggest the following:

1. Coneworms are smaller than budworms reaching pupal weights that are 82% and 65% the weights of budworm pupae for males and females respectively. On the basis of pupal weight alone we might expect coneworm larvae to consume less foliage than the larger budworm larvae.

2. Differences in foliage consumed by the two species were less than the difference in pupal weights, however. Male coneworm consumed 93% (difference not significant) and female coneworms consumed 77% as much foliage as budworms. If these rates of feeding can be transposed to field conditions and if they also apply to other host tree species, we conclude that foliage consumed by individual coneworms is nearly as great as that of budworms, 85% assuming a 50:50 sex ratio.

3. White spruce foliage is a somewhat less satisfactory food source for coneworms than it is for budworms with more foliage consumed for a given quantity of growth in the former. The coneworm may have a greater affinity for tree reproductive structures in years when trees produce them. We have shown, elsewhere, significant increases in pupal weights of coneworm fed on cones.

Table 1. Mean consumption (mg) and duration of feeding period (days) for male spruce coneworm and spruce budworm larvae reared on white spruce foliage.[1]

Foliage Consumed	Feeding Period	Coneworm	Percent Total	Budworm	Percent Total
	1	11.0a[2] (±0.8)[3]	6	17.2a (±0.9)	9
	2	21.1a (±0.8)	12	23.3a (±1.8)	13
	3	139.3b (±2.8)	82	142.0b (±3.9)	78
	Total	171.4		182.5	
Duration of Feeding	1	10.1a (±0.2)	53	10.3a (±0.2)	50
	2	3.2b* (±0.1)	16	3.8b (±0.2)	19
	3	6.1c (±0.2)	31	6.2c (±0.2)	31
	Total	19.4		20.3	

1 n = 46-74
2 Data sharing common letter within a parameter column do not differ significantly as determined by Duncan's New Multiple Range Test (p = 0.05).
3 Standard error.
* Significant difference between species as determined by ANOVA (p = 0.05).

Table 2. Mean consumption (mg) and duration of feeding period (days) for female spruce coneworm and spruce budworm larvae reared on white spruce foliage.[1]

Foliage Consumed	Feeding Period	Coneworm	Period Total	Budworm	Percent Total
	1	13.3a[2]*(±1.1)[3]	6	15.8a (±1.2)	6
	2	23.8a (±1.2)	11	28.0a (±1.6)	10
	3	179.5b* (±3.6)	83	237.5B (±6.8)	84
	Total	216.6*		281.3	
Duration of Feeding	1	10.9a (±0.3)	52	10.1a (±0.2)	47
	2	3.5b (±0.2)	17	3.8b (±0.2)	18
	3	6.5c* (±0.1)	31	7.8c (±0.2)	36
	Total	20.9		21.7	

1 n = 39-66
2 Data sharing common letter within a parameter column do not differ significantly as determined by Duncan's New Multiple Range Test (p = 0.05).
3 Standard error.
* Significant difference between species as determined by ANOVA (p = 0.05).

Table 3. Mean weight (mg), weight gain and pupal weight for male spruce coneworm and spruce budworm larvae reared on white spruce foliage.[1]

Mean Weight	Feeding Period	Coneworm	Percent Total	Budworm	Percent Total
	1	4.3a[2]* (±0.1)[3]	-	5.8a (±0.3)	-
	2	17.9b (±0.5)	-	20.8b (±0.8)	-
	3	62.2c (±0.8)	-	76.4c (±1.4)	-
	Pupal	57.2 * (+0.8)		69.7 (±1.4)	
Weight Gain	1	4.3a * (±0.1)	7	5.8a (±0.3)	7
	2	13.6b (±0.4)	22	15.7b (±0.8)	20
	3	44.4c (±0.8)	71	56.1c (±1.5)	73
	Total	62.3*		77.6	

1 n = 64-75
2 Data sharing common letter within a parameter column do not differ significantly as determined by Duncan's New Multiple Range Test (p = 0.05).
3 Standard error.
* Significant difference between species as determined by ANOVA (p = 0.05).

Table 4. Mean weight (mg), weight gain, and pupal weight for female spruce coneworm and spruce budworm larvae reared on white spruce foliage.[1]

Mean Weight	Feeding Period	Coneworm	Percent Total	Budworm	Percent Total
	1	4.7a[2]* (±0.2)[3]	-	5.8a (±0.3)	-
	2	19.9b (±0.5)	-	27.7b (±1.0)	-
	3	71.9c * (±1.0)	-	109.4c (±2.5)	-
	Pupal	66.2 * (±0.8)		101.7 (±2.4)	
Weight	1	4.7a * (±0.2)	6	5.8a (±0.3)	5
	2	15.3b (±0.5)	21	22.3b (±1.1)	20
	3	52.4c (±1.0)	73	83.9c (±2.5)	75
	Total	72.4*		112.0	

1 n = 45-66
2 Data sharing common letter within a parameter column do not differ significantly as determined by Duncan's New Multiple Range Test (p = 0.05).
3 Standard error.
* Significant difference between species as determined by ANOVA (P = 0.05).

MFRC Biological Interface Project

By

I.W. Varty

Maritimes Forest Research Centre
Fredericton, New Brunswick

MFRC Biological Interface Project
(For Spruce Protection Workshop, Bangor, Maine, Oct. 23, 1984)

The Biological Interface program at the Maritimes Forest Research Centre, Canadian Forestry Service, was initiated in 1982 to intensively study the biological and spray practice parameters influencing spruce budworm mortality on both balsam fir and red spruce.

The initiative was made by the New Brunswick Spray Efficacy Research Group (NBSERG) as part of multidisciplinary approach to explain the mechanisms determining the degree of sucess or failure of operational sprays.

Sub-objectives of the project include :

1. Identification of spray deposit needed to attain a target percentage larval mortality :
   - optimal droplet size and density (fenitrothion) ;
   - minimal quantity deposited per budworm habitat ;
   - defined target surface ;
   - receptivity of various foliages (host species, age of foliage).

2. Toxicology (determination of best insecticide, formulation, dosage) :
   - mode of entry of fenitrothion (dermal, stomach, tracheal) ;
   - lethal and sublethal dosages ;
   - residue persistence.

3. Determination of optimal timing (larval instar, bud development, damage reduction, population density).

4. Larval vulnerability relative to post-spray weather (silking behavior).

5. Definition of effective swath width in biological terms.

Efficacy is measured by larval fallout under sample trees which are intensively sampled for deposit. The sampling unit is the budworm habitat, an arbitrarily selected 4 cm of the previous year's growth and the adjacent buds on current year's shoot.

It is hypothesized that larval vulnerability to residues of fenitrothion on both balsam fir and red spruce depends largely on deposit homogeneity and on post-spray weather. Studies of budworm silking and feeding behavior relative to instar, weather, shoot development and host species are among the most profitable areas of research because they determine the probability of toxic contact.

Examination of data collection in five experimental sprays are being collated and analyzed in an attempt to relate larval and shoot development/weather/larval activity/larval vulnerability factors with droplet density and measures of efficacy in order to improve spray timing, especially on red spruce.

I.W. Varty

Study of Spruce Budworm and Spruce Coneworm Behavior on Red Spruce

By

Charles J. Spies

Eco-Analysts, Inc.
Bath, Maine

Study of Spruce Budworm and Spruce Coneworm Behavior on Red Spruce

The behavior of spruce budworm and spruce coneworm, *Dioryctria reniculelloides* (Mutt. and Mon.), was studied on red spruce in Maine. Two data collection methods were utilized. Method one uses direct observations of caged and uncaged insects made from platforms placed in the midcrowns of mature trees. Method two uses data collected from pruned branches of red spruce taken from both sprayed and unsprayed stands. Both methods considered the following: species, instar, bud index, damage location, damage extent, stem severing, type of concealment and amount of concealment (see indices). Observations and sampling periods corresponded with peak budworm instars on balsam fir. This allowed comparisons between our observations and the usual methods of timing budworm control.

Platform Observations

A late project start and bad weather delayed caging of insects, therefore observations from platforms began when budworm reached peak fifth instar on fir. At this time spruce buds were swollen but still wholly encased in the bud capsule (mean bud index = 3). Mean concealment of both budworm and coneworm ranged from 50%-90%. The budworm showed a preference for feeding at bud bases either by mining or on the surface. Coneworm also prefered basal feeding but by mining only (Tables 1 and 2). Basal feeding could be more destructive than apical feeding because activity is closer to the central axis. This leads to a greater chance of axil severing and loss of shoot growth.

At peak sixth instar, platform observations were made on "wild" uncaged insects. This allowed better precision and a larger number of observations than was possible with the caged insects. At this time, buds were slightly elongated with bud caps broken free of bud bases (mean bud index = 5). Mean body concealment of both species was approximately 40%, except in less developed buds where it was about 70%. Both species were most frequently observed feeding either basally or along the entire length of the bud (Tables 3 and 4). The mean extent of damage to occupied buds was approximately 70% for budworm and 55% for coneworm.

Detailed examination of caged branchlets after larval development was complete showed that budworm attacked an average of 9.4 buds and that coneworm attacked an average of 9.0 buds from the time they were caged as 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% bud destruction was the most common type of bud damage tallied for both species. Extensive damage also resulted form surface feeding by both species. The usual outcome of bud attack was stem severing and complete bud loss.

Branch Samples

Branch samples were frozen on the same day pruned. This stopped development and allowed examination in a controlled manner. Only one third of the samples have been examined thus far so only preliminary results are given here. Descriptive statistics are given in Table 5. These data are for occupied buds only, actual numbers per branch are higher. Sample periods

1-4 correspond with peak budworm instars 3-6 respectively. Sample period 5 corresponds with peak coneworm fifth instar which occurs when budworms are pupating. The ratio of budworm to coneworm is about 1:1 throughout the season, indicating that in the area studied coneworm contributed significantly to the damage observed.

Table 6 shows the mean number of bud types encountered for every thirty vegetative buds counted. The percentage of vegetative buds attacked increased notably between sample periods 1 and 2. Values for sample period 5 are also notable with 53%-78% of the midcrown buds being attacked by the end of the season. Contrary to general belief, dormant buds were not commonly found. However, we did find the basal bracts of buds destroyed in earlier years. These look similar to a viable bud but are darker and when dissected usually are hollow with only pitch, severed stumps of old bud axils or just bud scars inside. We believe that these structures may have been mistakenly called dormant buds in the past. They are referred to as killed buds in this study. Numbers of killed buds and flower buds encountered have been variable.

Budworm and coneworm showed no preference for flower buds vs. vegetative buds (Figures 1 and 2). The most frequent location of bud damage for both species changed from apical in the early season to all over in the mid to late season (Figures 3 and 4). Feeding by mining was greatest early in the season then declined steadily as the season progressed. Coneworm persisted in mining longer than the budworm (Figures 5 and 6). The incidence of stem severing increased for both species over time until sample period 5 when bud elongation was beginning (Figures 7 and 8).

Concealment data from bagged branches is difficult to assess since some larval movement undoubtedly occurs during pruning and pre-freezer storage. But, one quarter of all larvae occupying buds were found to be 100% concealed in spite of sampling trauma. We think that direct observations at all instars may show that this number is higher before disturbance occurs.

In summary, our preliminary data indicate that budworm and coneworm both played important roles in damaging red spruce on the sites studied. Most damage occurs when the new growth is still in the bud stage on red spruce. The damage is most frequently caused by mining. When buds are attacked, mining or surface feeding usually leads to stem severing and total shoot destruction. Damage assesment techniques successfully used on balsam fir do not work well on spruce and have led to underestimation of damage in the past. Better, more accurate, ways of measuring damage on spruce need to be developed. Assessment of relative spray efficacy from treated and untreated stands will be done when all data are collected.

Table 1. Number (percentage) of spruce budworm larvae found in four feeding position categories at each site during L5 sample period.

	Feeding position			
Site	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 2. Number (percentage) of spruce coneworm larvae found in four feeding position categories at each site during L5 sample period.

	Feeding position			
Site	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 3. Number (percentage) of spruce budworm larvae found in four feeding position categories at each site during L6 sample period.

Site	Basal mining	Basal surface feeding	Apical surface feeding	Feeding along entire bud
		Feeding position		
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 4. Number (percentage) of spruce coneworm larvae found in four feeding position categories at each site during L6 saple period.

Site	Basal mining	Basal surface feeding	Apical surface feeding	Feeding along entire bud
		Feeding position		
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 5. Descriptive statistics for mean numbers of insects found occupying buds on 45cm branch tips of red spruce.

PLOT-BT

SAM. PER.	# BRANCHES	INSTAR BW	INSTAR CW	BUD INDEX	# BW	# CW	# OTHER	TOT.ALL SPECIES	DEFOL. INDEX
1	12	3.0	2.0	2.0	6*	7*	4.5*	17.5*	2.0
2	12	3.5	3.0	2.5	13	18.5	1.5	35.0	2.0
3	10	4.5	3.5	3.5	9.5	18.5	1.5	29.0	2.5
TREATED (6/15/84)									
4	10	6.0	5.0	6.0	5.5	4.5	0.5	10.0	3.5
5	20	6.0	5.0	6.0	1.0	4.0	0.5	5.0	4.5

PLOT-ZECTRAN

SAM. PER.	# BRANCHES	INSTAR BW	INSTAR CW	BUD INDEX	# BW	# CW	# OTHER	TOT.ALL SPECIES	DEFOL. INDEX
1	5	2.5	2.0	2.0	6.0*	4.0*	4.0*	13.0*	1.5
TREATED (6/3/84)									
2	20	3.5	2.0	2.5	4.0	4.5	1.5	9.5	1.5
3	0	-	-	-	-	-	-	-	-
TREATED (6/16/84)									
4	0	-	-	-	-	-	-	-	-
5	20	6.5	5.5	6.0	0.5	6.5	0.5	7.0	4.0

PLOT-CONTROL

SAM. PER.	# BRANCHES	INSTAR BW	INSTAR CW	BUD INDEX	# BW	# CW	# OTHER	TOT.ALL SPECIES	DEFOL. INDEX
1	0	-	-	-	-	-	-	-	-
2	15	4.5	3.0	3.0	6.5	7.5	1.5	15.0	1.5
3	10	5.0	3.5	4.5	9.0	8.0	1.5	18.0	2.0
4	15	5.5	4.5	6.0	3.5	4.0	0.5	7.5	2.5
5	20	6.0	5.5	6.0	0.5	3.5	0.5	4.0	3.5

* VALUE DOES NOT INCLUDE NEEDLE MINING INSECTS.

Table 6. Mean bud types encountered for every 30 vegetative buds counted on 45cm branch tips of red spruce.

PLOT-BT

SAM.PERIOD	% BUDS ATTACKED	DORMANT	KILLED	FLOWER
1	8.0	N/A	11.0	0.5
2	21.0	N/A	7.5	2.5
3	35.0	N/A	9.0	0.0
TREATED (6/15/84)				
4	50.0	0.0	4.5	2.5
5	77.5	0.5	2.5	11.0

PLOT-ZECTRAN

1	2.0	N/A	10.5	10.5
TREATED (6/3/84)				
2	11.5	N/A	2.0	6.5
3	-	-	-	-
TREATED (6/16/84)				
4	-	-	-	-
5	61.5	0.0	7.5	5.5

PLOT-CONTROL

1	-	-	-	-
2	12.5	N/A	12.0	0.0
3	15.5	N/A	4.0	1.5
4	34.5	0.0	4.5	0.0
5	53.5	0.5	8.0	3.5

Figure 1.

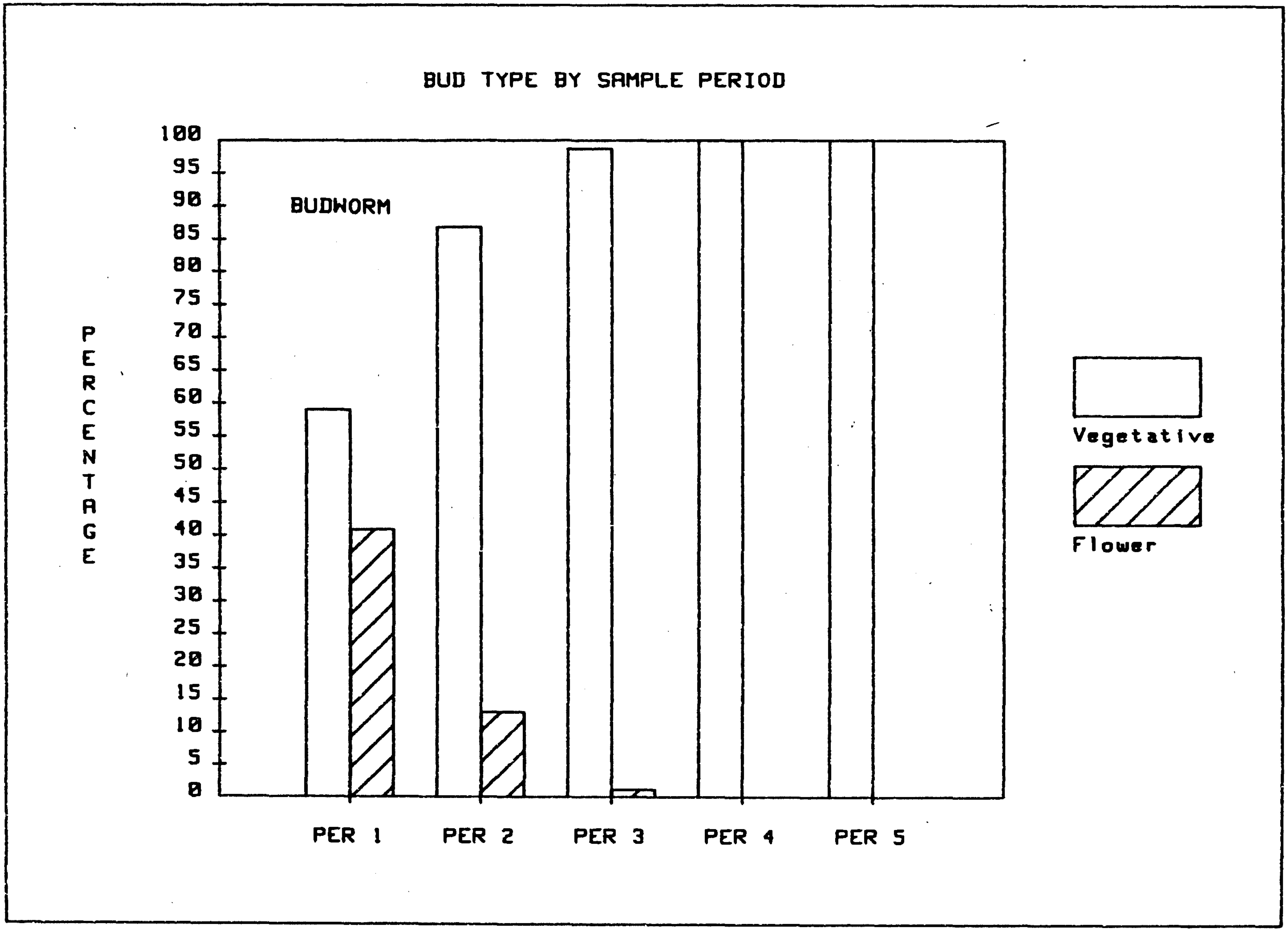

BUD TYPE BY SAMPLE PERIOD
BUDWORM
PERCENTAGE
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
PER 1
PER 2
PER 3
PER 4
PER 5
Vegetative
Flower

Figure 2.

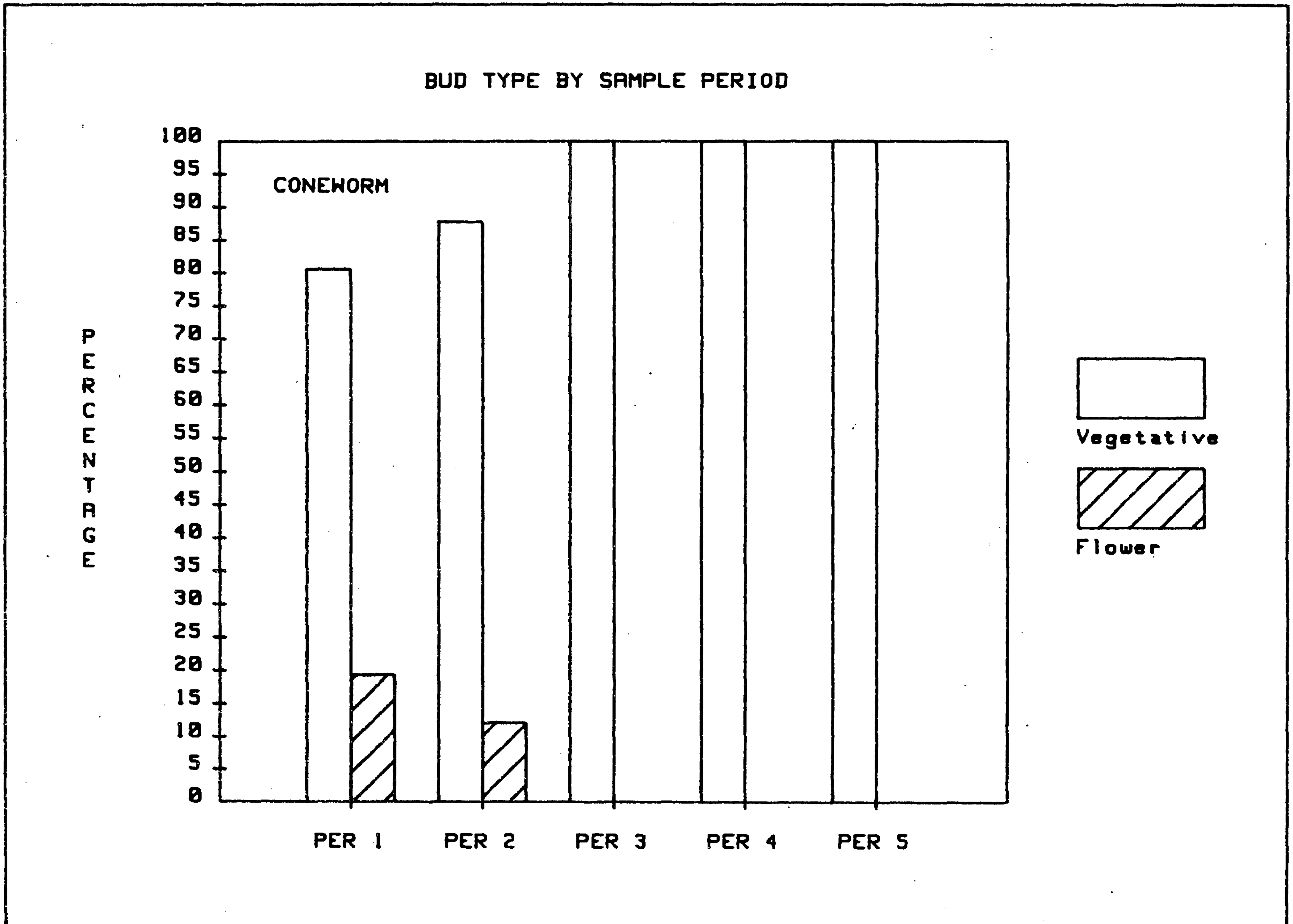

BUD TYPE BY SAMPLE PERIOD
CONEWORM
PERCENTAGE
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
PER 1
PER 2
PER 3
PER 4
PER 5
Vegetative
Flower

Figure 3.

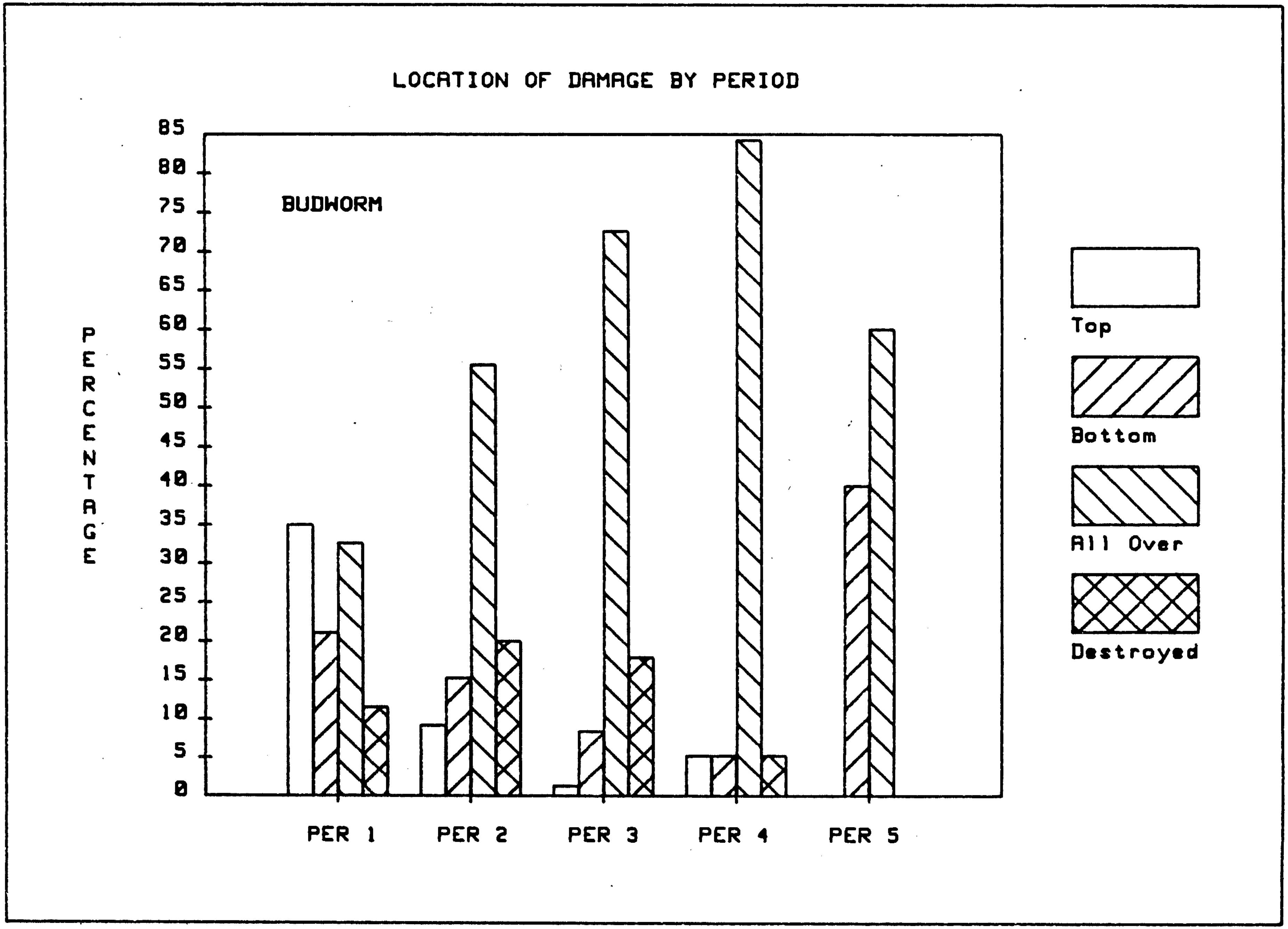

LOCATION OF DAMAGE BY PERIOD
BUDWORM
PERCENTAGE
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
PER 1
PER 2
PER 3
PER 4
PER 5
Top
Bottom
All Over
Destroyed

Figure 4.

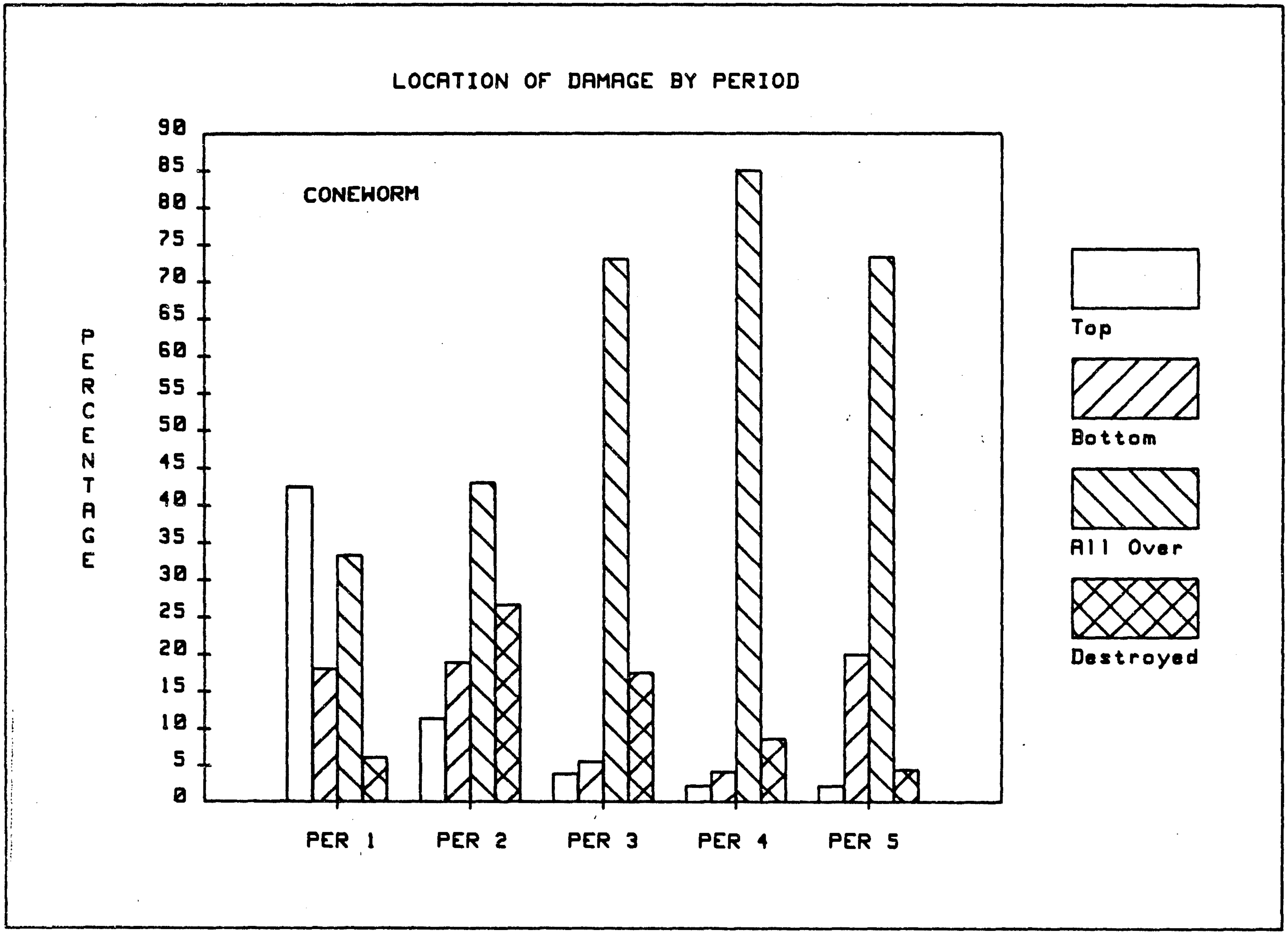
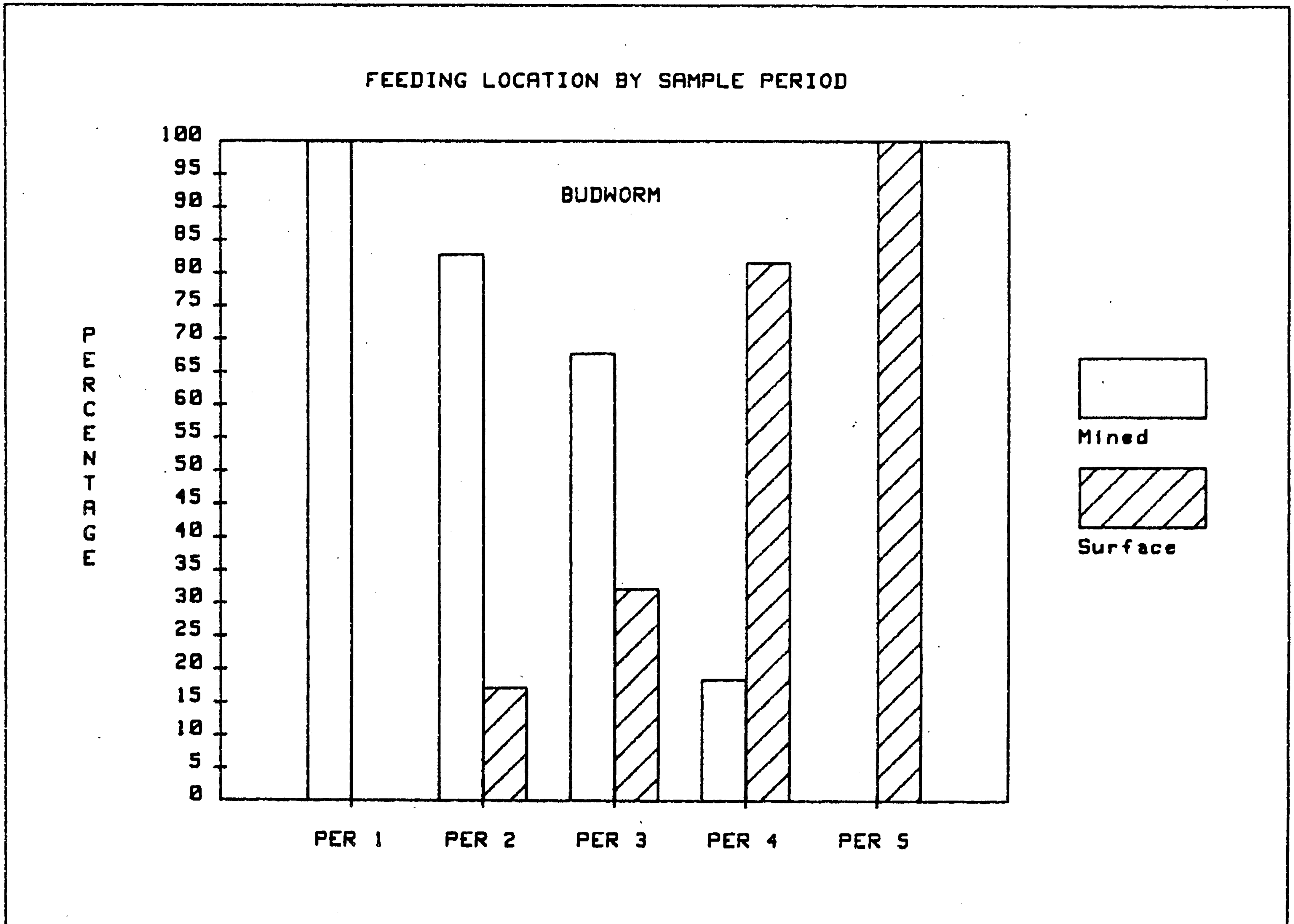

LOCATION OF DAMAGE BY PERIOD
CONEWORM
PERCENTAGE
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
PER 1
PER 2
PER 3
PER 4
PER 5
Top
Bottom
All Over
Destroyed

Figure 5.



FEEDING LOCATION BY SAMPLE PERIOD
BUDWORM
PERCENTAGE
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
PER 1
PER 2
PER 3
PER 4
PER 5
Mined
Surface

Figure 6.

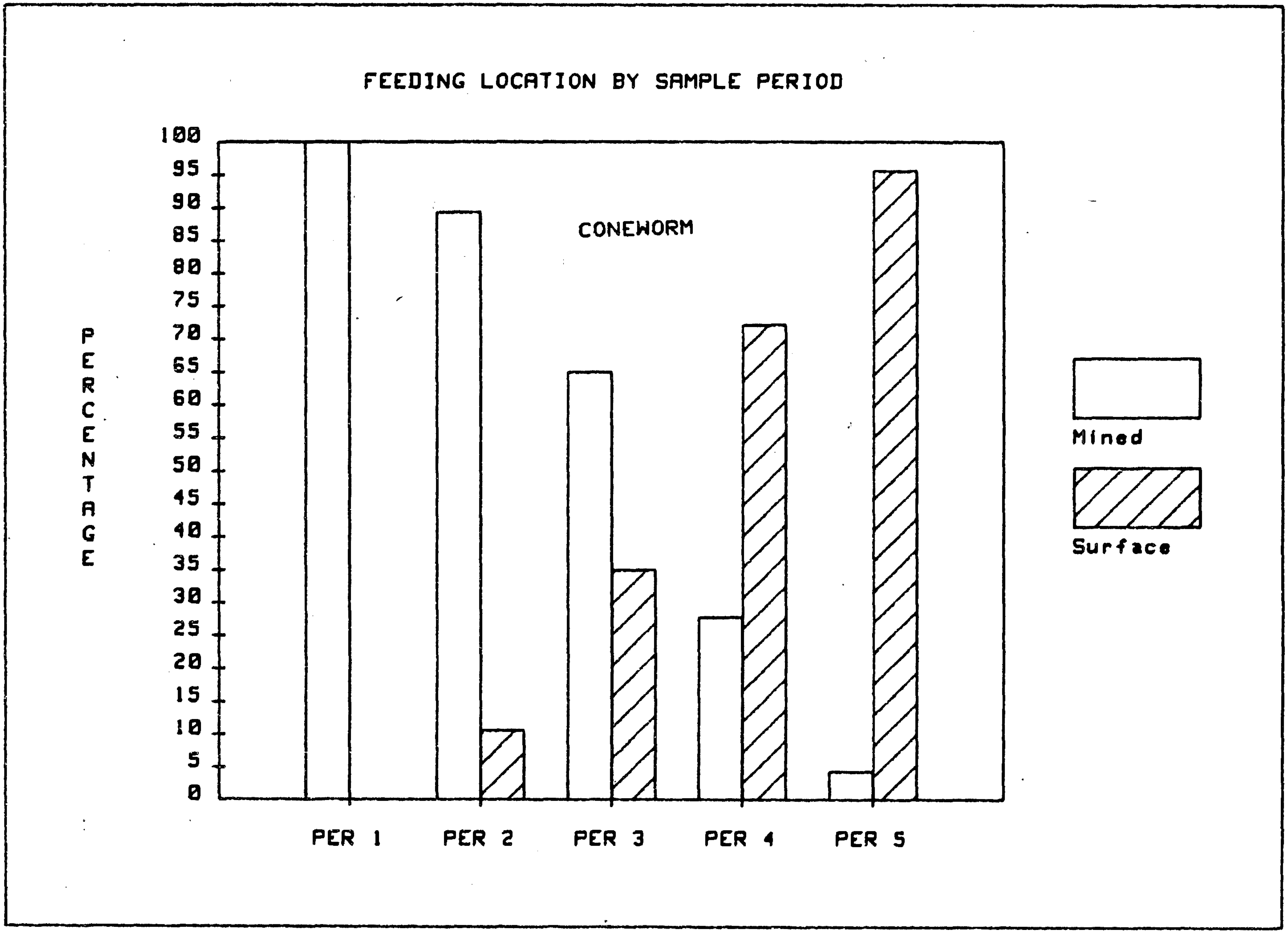

FEEDING LOCATION BY SAMPLE PERIOD
CONEWORM
PERCENTAGE
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
PER 1
PER 2
PER 3
PER 4
PER 5
Mined
Surface

Figure 7.

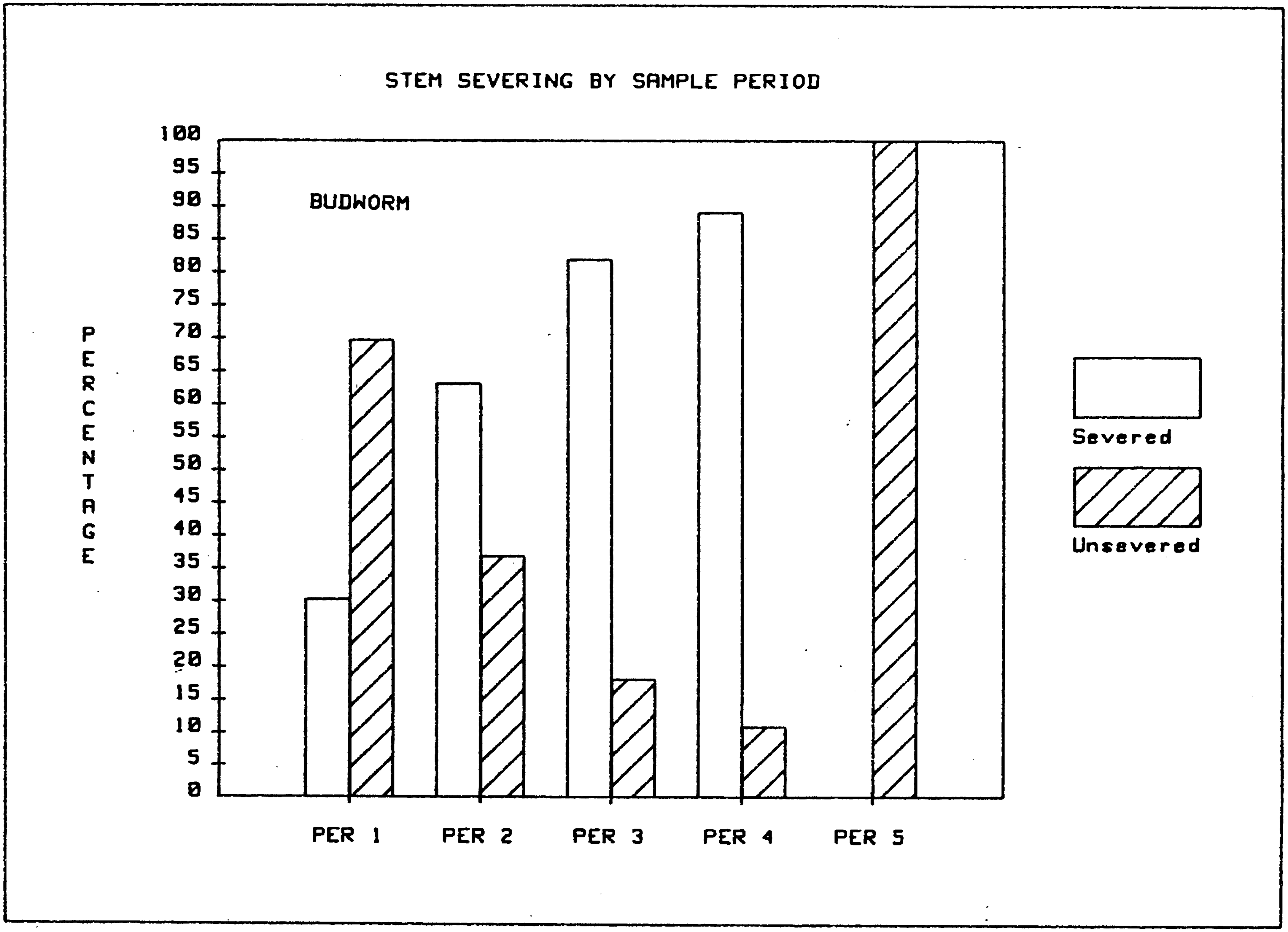
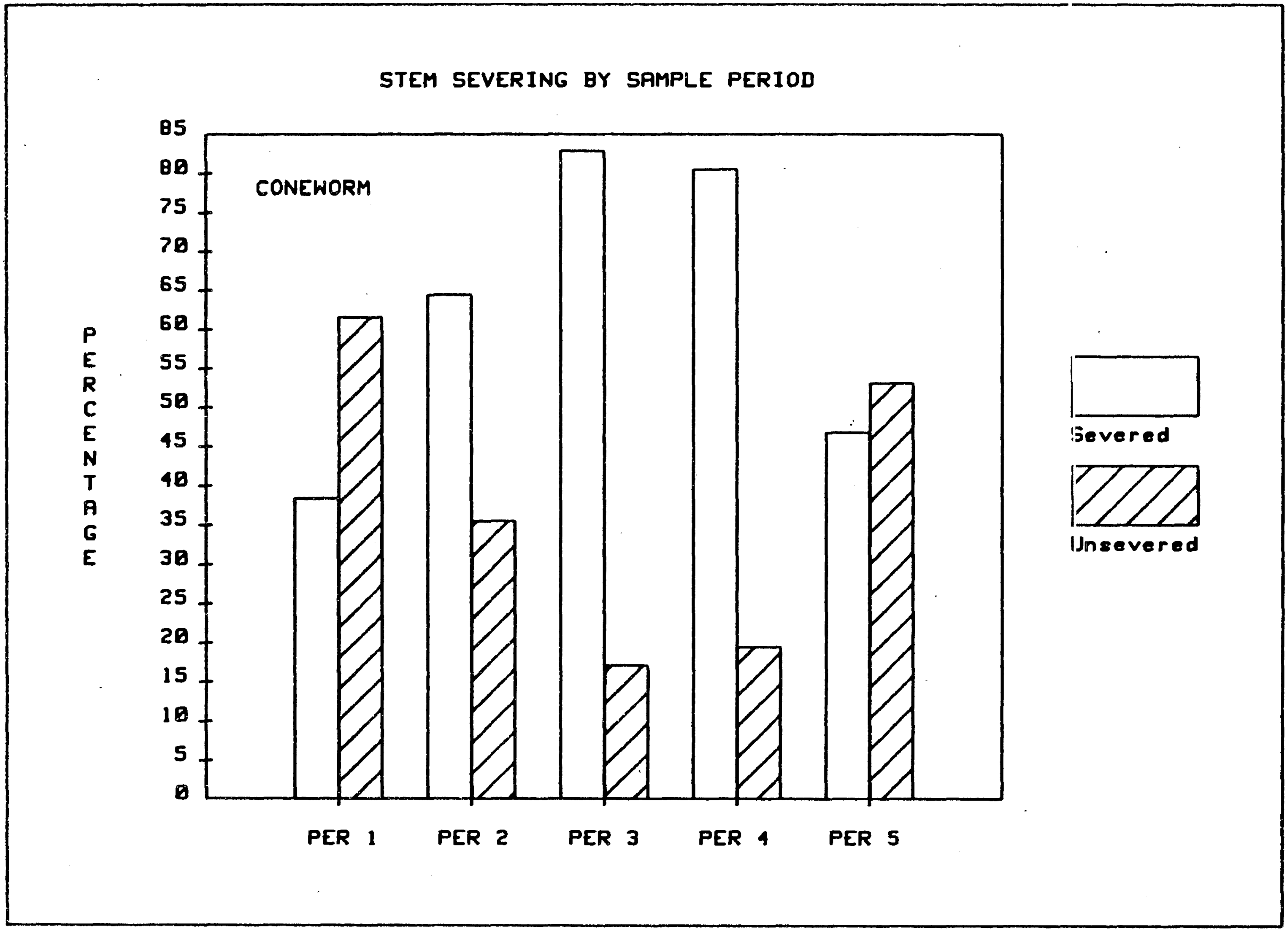

STEM SEVERING BY SAMPLE PERIOD
BUDWORM
PERCENTAGE
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
PER 1
PER 2
PER 3
PER 4
PER 5
Severed
Unsevered

Figure 8.


STEM SEVERING BY SAMPLE PERIOD
CONEWORM
PERCENTAGE
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
PER 1
PER 2
PER 3
PER 4
PER 5
Severed
Unsevered

INDICES - A

Bud Development Index 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	Shoot elongated, bud capsule separated from bud base
6	Bud capsule lost completely

DAMAGE INDEX

LOCATION	TYPE	EXTENT	STEM CUTTING
1= TOP	1= MINING	1= 0-20%	1= NONE
2= BOTTOM	2= SURFACE	2= 21-40%	2= BASAL
3= ALL OVER		3= 41-40%	3= APICAL
4= DESTROYED		4= 61-80%	
		5= 81-100%	

INDICES - B

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 / 175% 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

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