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FOREST RESEARCH REPORT

No. 53 January, 1995

A Survey of Weevil Damage in White Pine Plantations in Nova Scotia

Introduction

Terminal feeding white pine weevils (*Pissodes strobi* Peck) are an important pest throughout much of North America. They feed on and breed in the phloem of conifers, particularly white pine (*Pinus strobus* L.). Infestations can result in deformed trees, a reduction in usable volume, and lower wood quality.

The consistent demand for quality white pine sawlogs has prompted a review to determine the extent of the weevil problem in white pine plantations in Nova Scotia. A plantation survey was conducted in 1991 and 1992 to determine:

- the extent of white pine weevil infestations,
- the influence of tree spacing on weevil damage, and
- the height at which pine is susceptible to attack.

Life Cycle of White Pine Weevil

Adult white pine weevils emerge from the duff and migrate to a host leader when temperatures begin to warm in late April or May (Rose and Linquist, 1973) (Figure 1). During the first week the females fly to various trees, feeding on, and searching for, the stoutest and longest leaders for oviposition (egg laying) (Wallace and Sullivan, 1985). Mating takes place during this time. Upon selection of a suitable leader a pattern of feeding and oviposition takes place for a month or more, with up to 200 eggs laid in a single leader (Wallace and Sullivan, 1985).

Larvae hatch in approximately 2 weeks and tunnel downward through the inner bark, merging to form a downward moving "feeding ring" around the circumference of the leader. The leader is rapidly girdled causing the newly developing shoots of the top whorl to wither, turn red, and bend downward to form a "shepherd's crook". At maturity the larva tunnel

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through the wood near the base of the attacked leader and pupate in the pith (Rose and Linquist, 1973). The new adults emerge in August and September, feed in the upper crown, and then hibernate in the duff under the infested tree.

As a result of attack, two years of height growth are lost. This is partially recovered upon replacement of the leader with an established lateral branch(s). Loss and replacement of the leader usually produces stem deformities such as crooks and multiple tops.

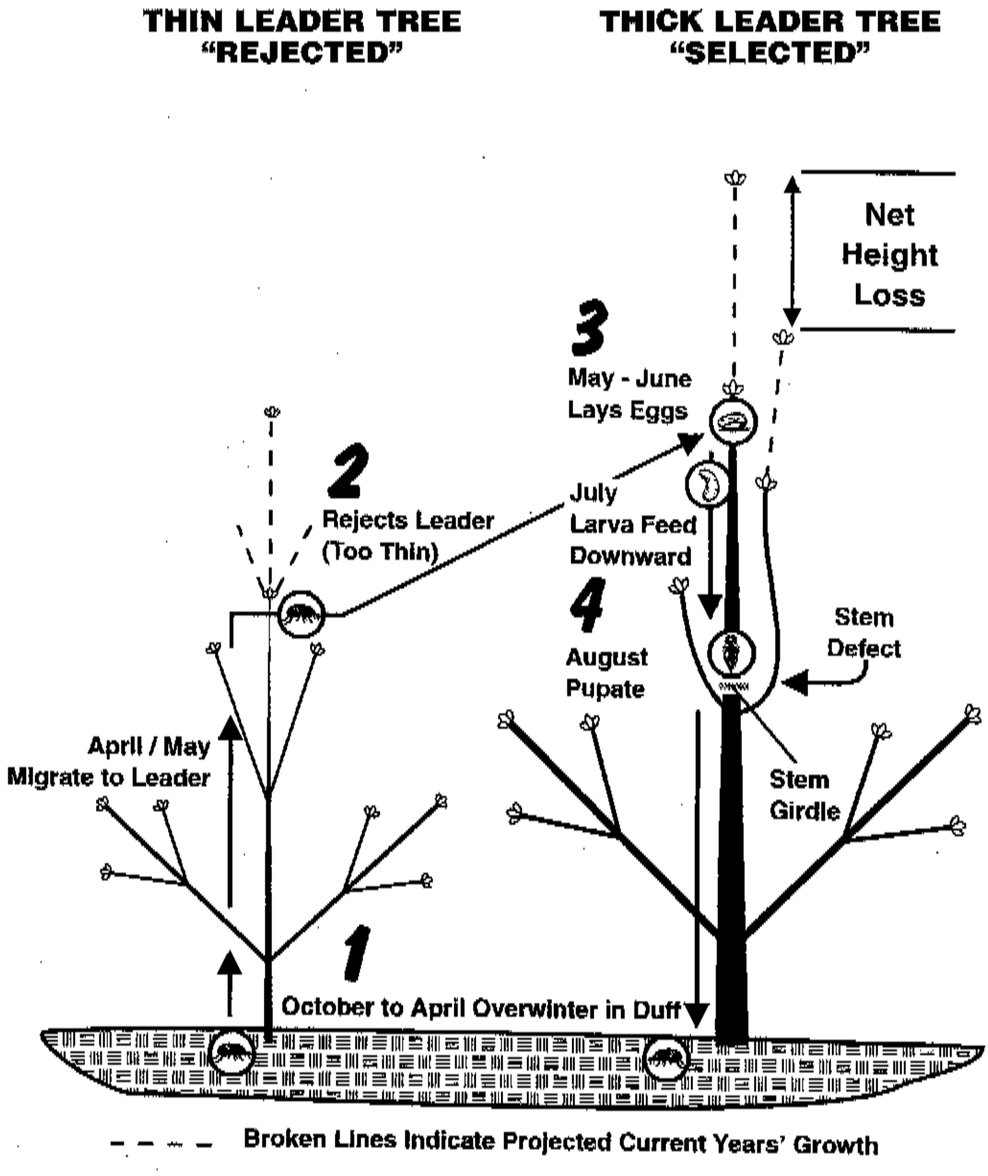

Figure 1. Life cycle of the white pine weevil.

Methods

Plantation Selection

Planting records were used to compile a list of over 80 older white pine plantations. Field checks determined that 25 met the selection criteria of being well stocked with a mean height of 5.8 m or taller. Eight were sampled in 1991 and 17 in 1992 (Appendix I). Of the rejected plantations, approximately 70% were too short, and 30% were inadequately stocked: both conditions usually resulting from establishment on poor sites (eg. barrens). A few were excluded because they were mixed plantations (several species), or could not be located.

Sampling Procedure

The plantations were systematically sampled using circular plots of 3.99 m radius (1/200th hectare) evenly spaced along pre-determined cruise lines. A minimum of 2 and maximum of 7 plots were established per plantation.

At each plot, original spacing was measured between and across rows. The state of health and the competition levels were assessed and recorded for each tree. Tree damage by agents, other than weevil, was recorded, as were the major species of vegetation. Weevil damage was evaluated for each tree by recording the number of internodes (up to a maximum of 3) exhibiting "weevil" type damage. This consisted of deformed stem growth consistent with leader loss.

The identification of weevil injury using external features is expected to yield reasonably accurate results, particularly in immature stands. In the destructive sampling of 60 to 90 year old mature white pine, Brace (1971) reported 51% accuracy in identifying "hits" in the 16 foot butt lengths, and 85% accuracy within ± 1 "hit". He further stated that weevil injury identification on standing trees would be considerably better if applied to smaller and younger trees.

A subsample was chosen at each plot, consisting of one tree from each weevil attack "class" (0,1,2, and 3+ "hits") present in the plot. These trees were measured to obtain total height, and diameter at breast height. At each "weevil attack" node, to a maximum of 3, a measurement was made of the attack height, number of lateral branches, and length of deformed stem (crook).

Data Analyses

Survey averages were calculated using individual stand summaries, thereby giving each plantation equal weight in the analyses regardless of stand size or number of sample plots.

Sample Description

Three plantations were located in the Western Region, 10 in the Central Region, and 12 in the Eastern Region (Figure 2). No qualifying plantations were found on Cape Breton Island.

Stand size varied from 0.2 to 12.1 hectares, and averaged 3.1 ha. The mean stand age was 23 years (15 to 57), and the mean height was 8.5 m (5.8 to 17.7). Eighty-eight percent of the plantations were less than 30 years old and 10 m in height or less. Mean stand spacing was 2.1 m and varied from 1.4 to 3.1 m (Appendix I).

In the selected stands, survival averaged 79%, and varied from 41 to 95%. Densities of live trees averaged 2,200/ha (1,100 to 4,000), of which 96% were considered healthy.

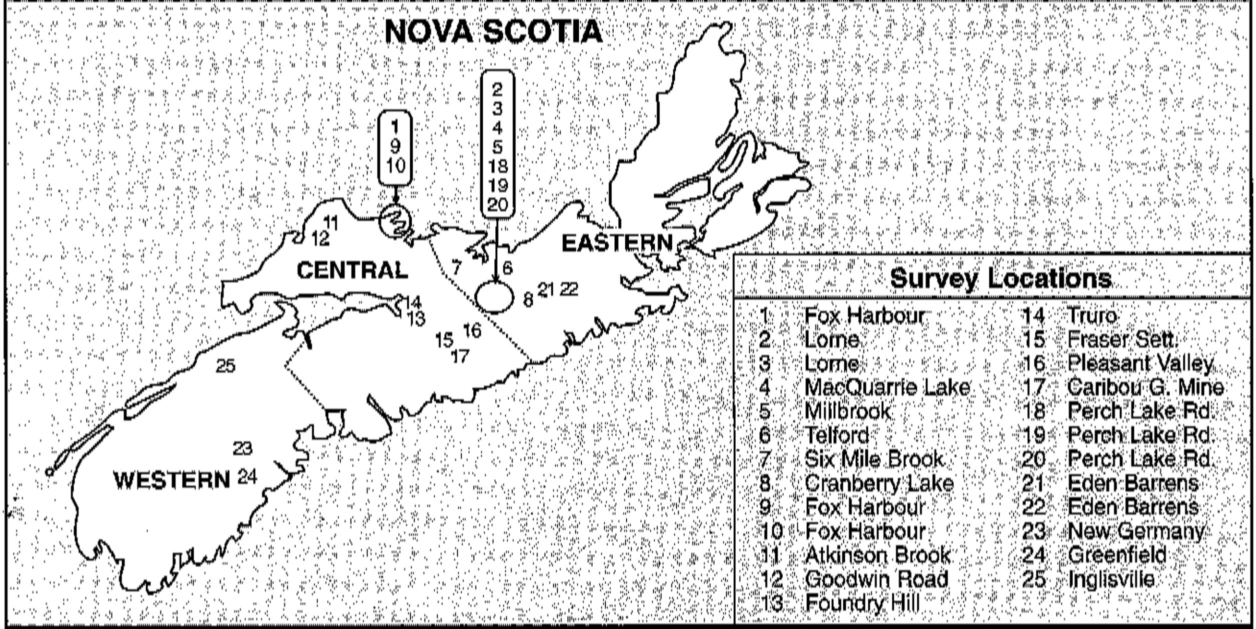

Figure 2. Location of surveyed white pine (*Pinus strobus* L.) plantations by region.

Results

Weevil Damage Levels

Overall

The incidence of white pine weevil attack was high. On average, 83% of the planted trees were attacked at least once, and 56% suffered multiple attacks (Figure 3). The levels were consistently high in virtually all plantations. Seventy-two percent of the plantations had 80% or more of the trees damaged, and a further 24 % had 60 to 79% damaged (Figure 4). The only stand exhibiting low levels of damaged trees (31%) was a 57 year old plantation (oldest surveyed), established at 1.4 m spacing, in which much of the external evidence of past weevil attacks may have been overgrown and difficult to detect (Brace, 1971).

Effect of Tree Spacing

Although it has been reported (Wallace and Sullivan, 1985; Anon, 1983) that weevil damage may be reduced by close spacing; in this survey no correlation could be found between plantation spacing, and either frequency of attack (eg. Figure 5), or length of defective stem resulting from attack. This may be due to limited representation of closely spaced plantations in the survey.

Numbers of Weevil Free Trees

The surveyed plantations averaged 360 "weevil-free" trees (no evidence of weevil type damage to the stem) per hectare, with a range of 0 to 1,800. Approximately two thirds of the plantations had more than 200 weevil-free trees/ha, one third had more than 400 weevil-free trees/ha, and one plantation had more than 900 weevil-free trees/ha (Figure 6). Their distribution within the plantations is unknown. It is expected that the number of weevil-free trees will decline in most plantations, since 87% of the surveyed trees were less than 10 m in height, and thus still within the preferred height range of weevils (Rose and Linquist, 1973; Brace, 1971). However, many of these weevil-free trees will likely continue to escape attack due to morphological characteristics, such as small leader size, which make them unsuitable for

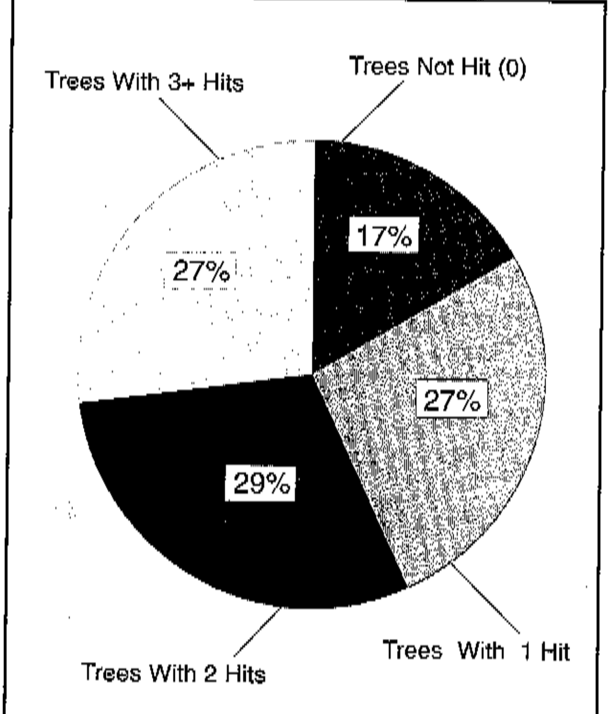

Figure 3. Frequency of weevil attacks (hits) per tree.

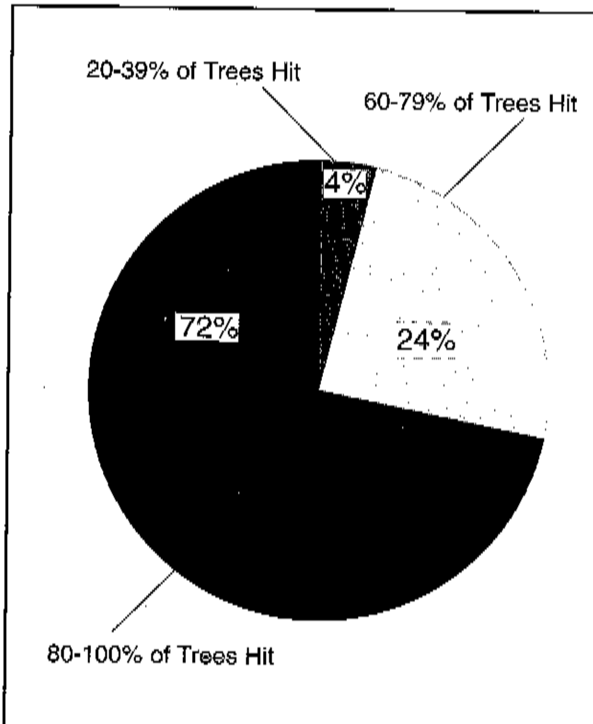

Figure 4. Frequency of plantations by the percentage of trees attacked (hit).

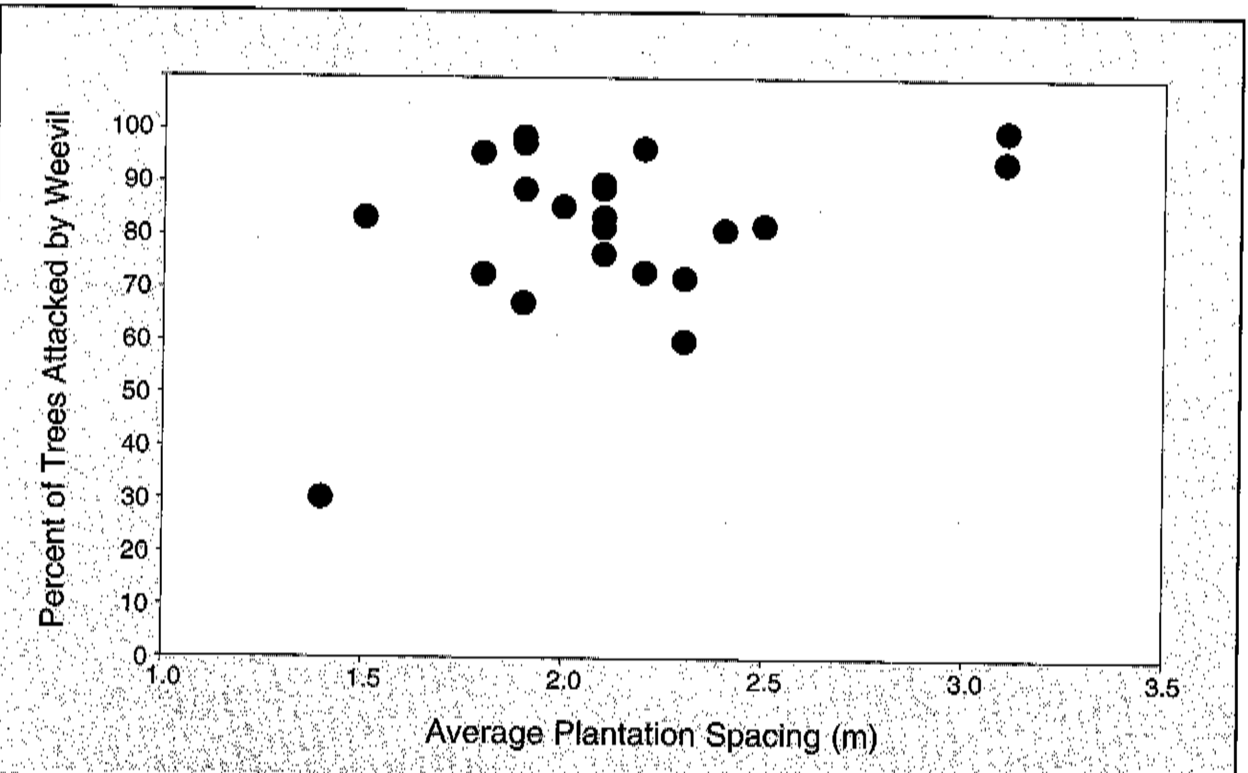

Figure 5. Percent of trees attacked by weevil versus average plantation spacing.

weevils (Wilkinson, 1983; Wallace and Sullivan, 1985). On average, weevil free trees were 7% shorter than weevil damaged trees, and 21% smaller in diameter (at breast height).

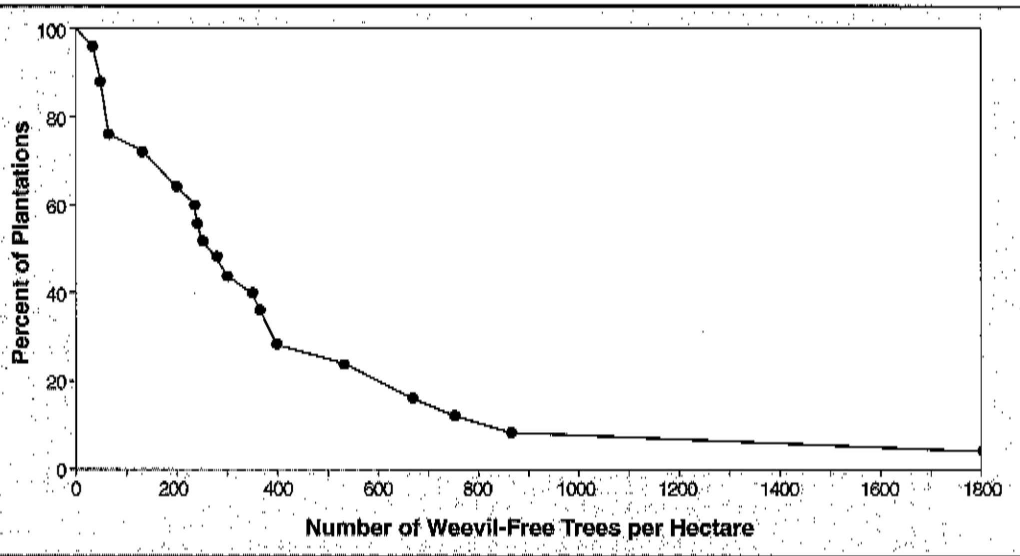

Figure 6. Frequency of plantations by the number of trees per hectare free of externally visible weevil damage (Weevil-Free).

Frequency of Weevil Attack by Tree Size and Vigour

Several researchers have reported tree size as the most important factor related to weevil attack (Wallace and Sullivan, 1985). Wilkinson (1983), found that the largest diameter, tallest, and fastest growing trees were attacked significantly more often than smaller, less vigorous trees. He also found a strong positive correlation between leader diameter, tree diameter and height.

In this survey, a comparison of the weevil attack frequency to relative tree diameter confirmed these findings, with the largest diameter stems (at least 10% larger than stand average) having an attack frequency almost 3 times as high as the smallest diameter stems (at least 10% smaller than stand average) (Figure 7). Similar trends occurred with tree height, however the magnitude was smaller due to the negative impact of repeated weevil attack on height growth.

This preference for the larger trees has a number of management implications:

• a reduction in the number and quality of potential crop trees; thereby limiting future stand improvement potential,

• underestimating land capability by affecting the height/age relationship of the dominant (tallest) trees in the stand (Brace, 1971).

Frequency of Weevil Attacks by Height of Attack

Figure 8 illustrates the frequency of all weevil attacks by attack height (up to and including the 3rd hit) for sampled trees taller than 5.5 m. Less than 8% of weevil attacks occurred below 2.5 m. The frequency of attack increased rapidly once the plantations surpassed 2.5 m in height. Beyond 2.6 m the intensity of attack was high and relatively constant to a height of 5 m. This pattern is consistent with that described by Brace (1971) who reported that the highest incidence of weevil injury occurred between 2.4 and 10 m, whereupon injury rates declined rapidly. Unfortunately the plantations in this survey were not tall enough to examine the trend beyond 5 m, thus a height at which injury rates decline could not be determined.

Weevil Attack Frequencies in Butt Logs

An average of 80% of the 8 foot butt logs were free of noticeable weevil damage (Table 1). For longer butt logs, 12 and 16 feet, the percentage that were weevil-free declined to 43 and 25% respectively.

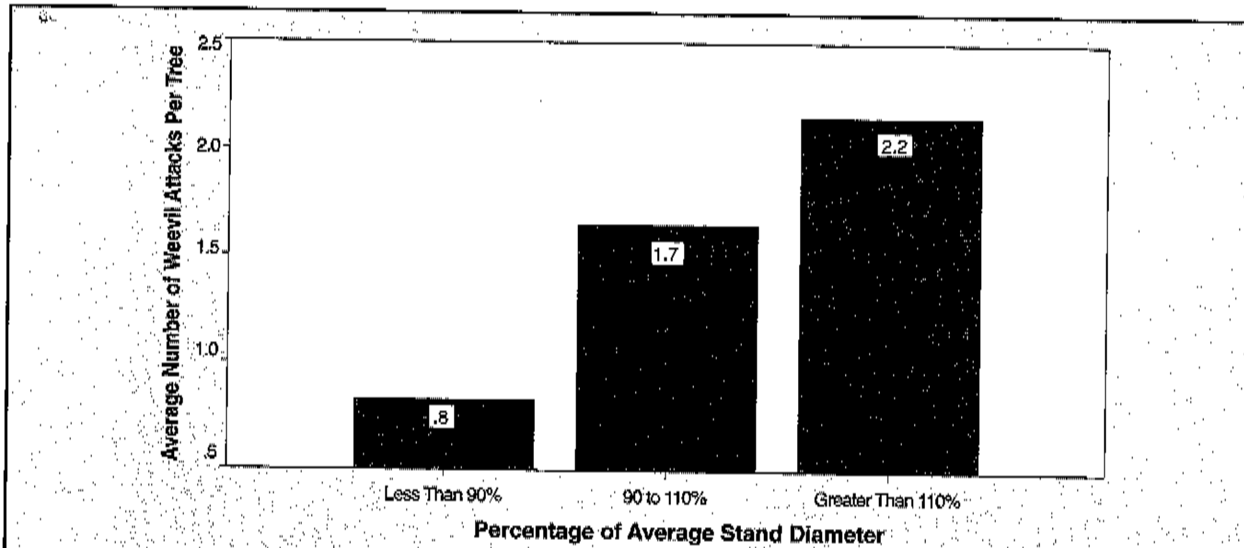

Figure 7. Average weevil attacks per tree in relation to relative stem diameter at breast height (tree diameter/average stand diameter x 100).

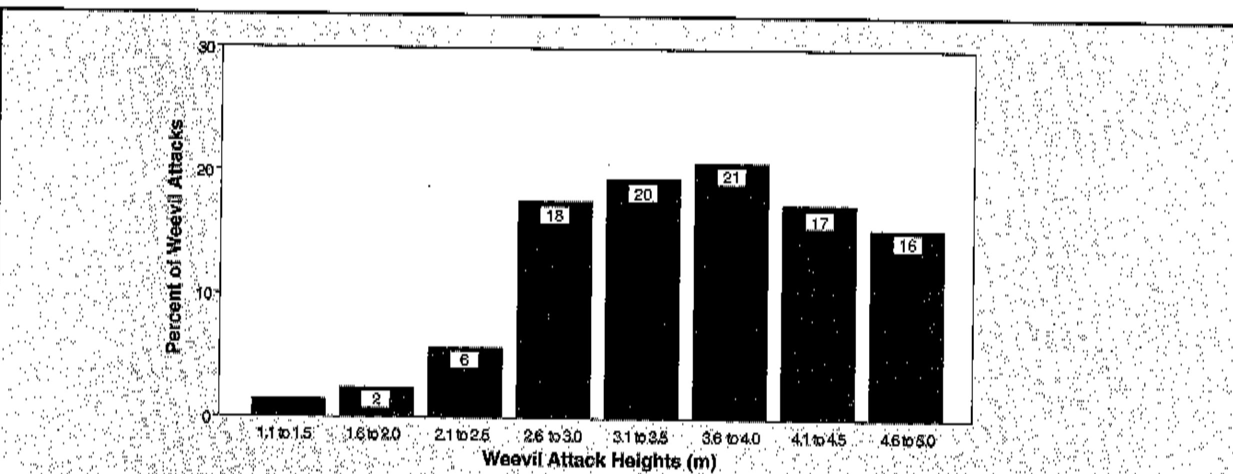

Figure 8. Frequency of Weevil attacks by attack height, up to 5 metres (to a maximum of 3 hits).

Table 1. Percentage of butt logs hit by the weevil.

Butt Log Length[1] (feet)	0 Hit (%)	1 Hit (%)	2 Hit (%)	3+ Hit (%)
8	80	18	1	0
12	43	42	12	2
16	25	35	25	13

[1] 1 foot allowed for stump and trim.

Distance Between Weevil Damaged Nodes

On the 56% of surveyed trees that exhibited more that one weevil "hit", the average distance between "hits" was 1.5 m (0.2 to 6.1 m). Forty-eight percent of the distances between "hits" were less than 1.3 m, 40% were between 1.3 and 2.5 m, and only 12% were greater than 2.5 m (8.2 feet) (Figure 9). This suggests that very few weevil free logs can be salvaged from between weevil damaged nodes.

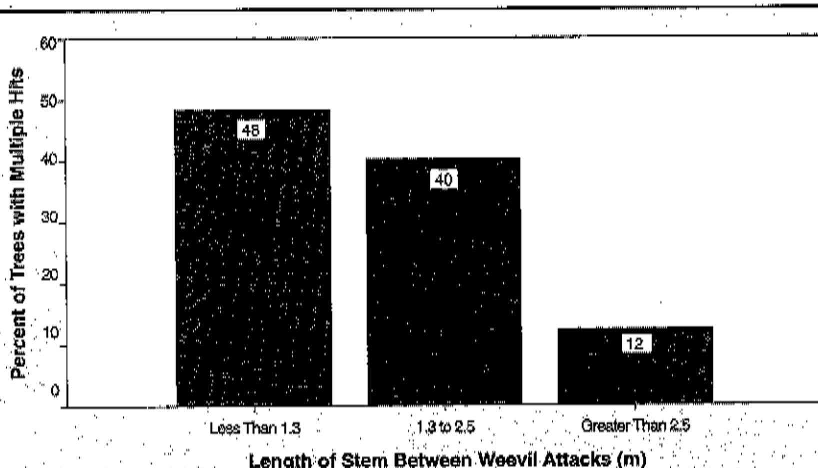

Figure 9. Distances between weevil attacks on stems of trees affected by multiple weevil attacks.

Crook Lengths

The length of "crooked stem" resulting from weevil attack averaged 0.24 m, ranging from 0.1 to 2 m (Figure 10). Twenty-eight percent of attacks resulted in crook lengths of 0.1 m, 44% yielded crooks of 0.2 m, 15% of crooks were 0.3 m, and 13% were greater than 0.3 m (1 foot) in length. It is speculated that these relatively short lengths of defect may be characteristic of plantation growth, in which heavy intraspecific competition and intense crowding at crown level encourages the development of straight stems after weevil attack.

Other Damaging Agents

Aside from weevils, porcupines were the only other damaging agent recorded in the survey. They caused a variety of damage including the loss of limbs in the live crown, large trunk scars (bare patches), and stem girdling causing topkill which destroyed the merchantable value of the tree. Some wounds developed secondary damage by fungi and insects.

Forty-four percent of the plantations suffered porcupine damage (Figure 11), resulting in injury to 11% of the live trees surveyed. In affected stands an average of 26% of trees (2 to 79%) were damaged, of which 21% suffered topkill.

Vegetation

Interspecific competition levels were low in most plantations with 84% of the stands having less than 20% of the crop trees affected by moderate to severe competition. Eight percent had 20 to 29%, and another 8% had greater than 30% of the crop trees affected by moderate to severe competition. Eight commercial tree species, other than white pine, were recorded in the plantations and these tended to dwell at or below the pine canopy height (Appendix II). The "other" vegetation was not prominent enough to be considered a nurse crop.

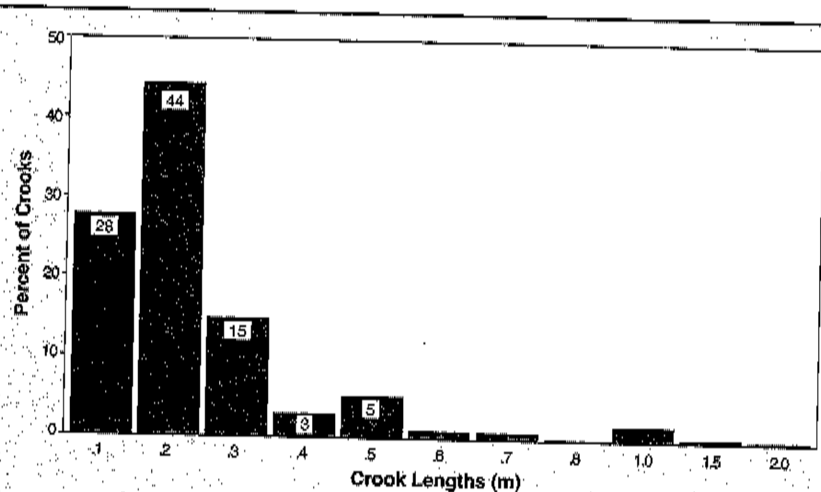

Figure 10. Frequency of crook lengths induced by weevil attack.

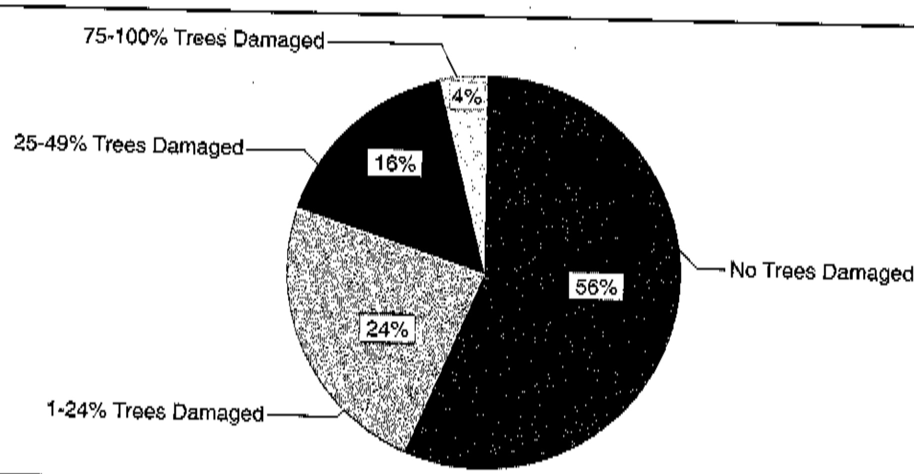

Figure 11. Frequency of plantations by percent of porcupine damaged trees.

Summary

Following are the major results of a survey conducted during 1991 and 1992 of 25 well-stocked white pine plantations that exceeded 5.8 m in height:

1. The incidence of white pine weevil damage was high, with an average of 83% of trees attacked at least once, and 56% with multiple attacks.

2. Ninety-six percent of the plantations had more than 60% of the trees attacked, and 72% of the plantations had in excess of 80% of the trees attacked.

3. Although it has been reported (Wallace and Sullivan, 1985; Anon, 1983) that weevil damage is generally lower in dense stands; in this survey no correlation could be established between plantation spacing and weevil damage levels. This may be due to the limited representation of closely spaced plantations in the survey.

4. The frequency of weevil attack was highest in the largest diameter, and tallest trees, due to the weevil's preferential selection of large leaders for egg laying. Large diameter trees (at least 10% larger than stand average) were attacked 3 times more frequently than small diameter trees (at least 10% smaller than stand average). Similar trends occurred with tree height.

5. Less than 8% of weevil attacks occurred below 2.5 m. A rapid increase in attack rates occurred above 2.5 m and then remained relatively constant to the limit of the survey data at 5 m. Other researchers found that weevil damage levels declined after stand height exceeded 10 m (Brace, 1971).

6. An average of 80% of the 8 foot butt logs were free of externally visible weevil damage (weevil-free). This percentage declined rapidly for 12 and 16 foot logs, to 43 and 25% respectively.

7. The surveyed plantations averaged 360 "weevil-free" trees per hectare (0 to 1,800). On average, weevil-free trees were 7% shorter, and 21% smaller in diameter. The overall number of weevil-free trees is expected to decline, since most trees in the survey are still within the preferred height range of weevils.

8. The degree of stem defect, as measured by the length of weevil induced stem crook, was fairly light, with 87% of crooks being 0.3 m (1 foot) or less in length. This may be characteristic of plantations, where significant crowding occurs at crown level.

9. Porcupines caused significant damage in 44% of the plantations. Eleven percent of the surveyed trees were damaged, including 2% which were girdled and topkilled. In affected stands, an average of 26% of trees (2 to 79%) were damaged.

10. Interspecific competition levels were low in most plantations, as was ingrowth of other tree species. None of the stands contained sufficient vegetation to examine possible nurse crop effects on weevil activity.

11. Further research, including the effect of white pine weevil damage on lumber grade, is required in order to fully assess the sawlog production potential of white pine plantations and develop appropriate management strategies.

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Appendix I
Summary of individual plantation statistics

Site[1] #	Size (Ha)	# of Plots	Age	Mean Height (m)	Mean Spacing (m)	Survival (%)	Live Trees/Ha	Mean Weevil Hits per Tree	Weevil Damaged Trees (%)	Porcupine Damaged Trees(%)
1	5.7	6	17	7.7	1.9	81	2900	1.7	98	0
2	0.2	2	56	14.0	1.4	50	2600	0.4	31	0
3	0.4	3	57	17.7	1.8	41	1500	1.2	73	0
4	4.9	6	17	6.5	1.9	80	2500	1.7	99	0
5	1.0	3	18	6.7	3.1	89	1100	2.4	94	0
6	3.0	6	20	8.5	2.5	93	2200	1.2	82	0
7	12.1	6	16	7.3	1.9	84	2000	1.9	89	0
8	3.2	6	28	7.9	2.2	60	1400	1.4	73	0
9	3.7	3	17	7.7	2.1	83	2300	1.5	76	38
10	0.6	3	17	7.9	2.3	92	2400	1.3	72	0
11	1.5	4	20	7.3	2.1	83	2200	1.7	89	7
12	2.0	4	17	6.5	1.9	86	2400	2.6	98	22
13	0.7	3	16	8.0	1.5	87	4000	1.5	83	0
14	1.0	3	15	7.1	1.8	85	3100	1.9	96	9
15	3.0	4	16	5.8	2.1	76	2000	1.3	82	5
16	10.9	7	17	6.9	2.1	76	2000	1.8	90	41
17	2.5	4	16	6.6	1.9	95	2800	1.9	98	2
18	4.6	5	17	6.2	2.1	74	1700	2.0	84	49
19	6.4	5	15	6.9	2.0	62	1700	1.9	86	79
20	2.0	4	17	7.0	2.1	78	1900	2.0	89	26
21	3.2	4	28	10.0	2.3	75	1900	1.1	61	5
22	0.8	2	28	8.9	2.4	70	1600	1.8	81	0
23	0.3	3	34	14.7	1.9	89	2700	1.3	68	0
24	2.0	3	23	9.3	2.2	88	1900	2.2	97	0
25	1.3	2	21	9.0	3.1	94	1600	2.6	100	0
Avg	**3.1**	**4**	**23**	**8.5**	**2.1**	**79**	**2200**	**1.7**	**83**	**11**
Min	**0.2**	**2**	**15**	**5.8**	**1.4**	**41**	**1100**	**0.4**	**31**	**0**
Max	**12.1**	**7**	**57**	**17.7**	**3.1**	**95**	**4000**	**2.6**	**100**	**79**

[1] **See Figure 2 for location.**

APPENDIX II
Classification and occurrence of "other" vegetation found in survey.

Species	Percent of Stands Occupied	Average Cover (%)	Average Height Ratio Veg:Pine (%)
No "other" Vegetation Present	24	—	—
Commercial Trees:			
Birch (*Betula* spp.)	48	8	75
Maple (*Acer* spp.)	28	9	78
Spruce (*Picea* spp.)	28	5	67
Aspen (*Populus* spp.)	24	6	100
Eastern Larch (*Larix laricina* [Du Roi] K.Koch)	12	5	88
Balsam Fir (*Abies balsamea* [L.])	8	5	90
Red Oak (*Quercus rubra* L.)	4	10	64
Beech (*Fagus grandifolia* Ehrh.)	4	5	44
Other Trees and Shrubs:			
Pin Cherry (*Prunus pensylvanica* L.f.)	12	7	62
Apple (*Malus* spp.)	4	2	51
Alder (*Alnus* spp.)	4	5	70
Mountain Ash (*Sorbus* spp.)	4	10	6
Striped Maple (*Acer pensylvanicum* L.)	4	2	27
Lambkill (*Kalmia angustifolia* L.)	4	30	4
Blueberry (*Vaccinium* spp.)	4	50	3
Ground Vegetation:			
Bracken Fern (*Pteridium aquilinum* (L.)Kuhn)	4	40	11
Reindeer Moss (*Cladonia* spp.)	4	25	1

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