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DAMAGE CAUSED BY THE BALSAM WOOLLY APHID IN YOUNG BALSAM FIR STANDS

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INTRODUCTION

The balsam woolly aphid[1] was discovered in Newfoundland in 1949 and has since become one of the most important insect pests attacking balsam fir.[2] Aphid attack causes tree deformity (Schooley and Oldford, 1971), reduces the quality and volume of wood produced (Page, Schooley, and Hudak, 1970) and predisposes trees to rapid mortality when they are subsequently attacked by other organisms (Otvos, Clark and Clarke, 1971; Hudak and Singh, 1970). Studies have shown that damage occurs on trees of all age classes but is most severe in older stands that are growing on fresh to dry sites at less than 600 feet elevation (Page, 1973). It has been estimated that volume losses in severely damaged stands approach 5% of the allowable cut at rotation age (60 years) or 18,000 cunits annually (unpublished data). However, losses in susceptible, overmature stands could be considerably higher. There is no Island wide estimate of such losses but 100% tree mortality has been recorded in localized areas, especially in western Newfoundland (Warren, Parrott and Cochran, 1967).

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[1] Balsam woolly aphid, Adelges piceae (Ratz.)

[2] Balsam fir, Abies balsamea (L.) Mill.

This report provides the results of a survey of aphid damage in young balsam fir stands of western Newfoundland and discusses the possible future development of such stands.

METHODS AND MATERIALS

Data on aphid damage in young stands was acquired from surveys conducted in 23 locations in western Newfoundland (Fig. 1). The stands were sampled during the years 1964 to 1970. Six stands were examined in 1964, six in 1965, two in 1968, six in 1969 and three in 1970. Twenty-two of the stands originated following clearcutting in aphid infested areas and one had developed where an overmature stand had been killed by the aphid. Two stands were sampled by tallying all trees on 6-foot-wide cruise strips. The other 21 were sampled by tallying all trees whose crowns were intersected by randomly located lines. Data collected from individual trees included species, age, crown class (dominant, codominant, intermediate or suppressed), total tree height and height growth during the five years prior to examination. All balsam fir trees were classified for aphid damage as shown in in Appendix 1. Recovery by trees from aphid damage and the incidence of mortality as a result of such damage was also recorded and the possibility of a relationship between stand age and density and the percentage of trees damaged was tested by Spearman's rank correlation coefficients.

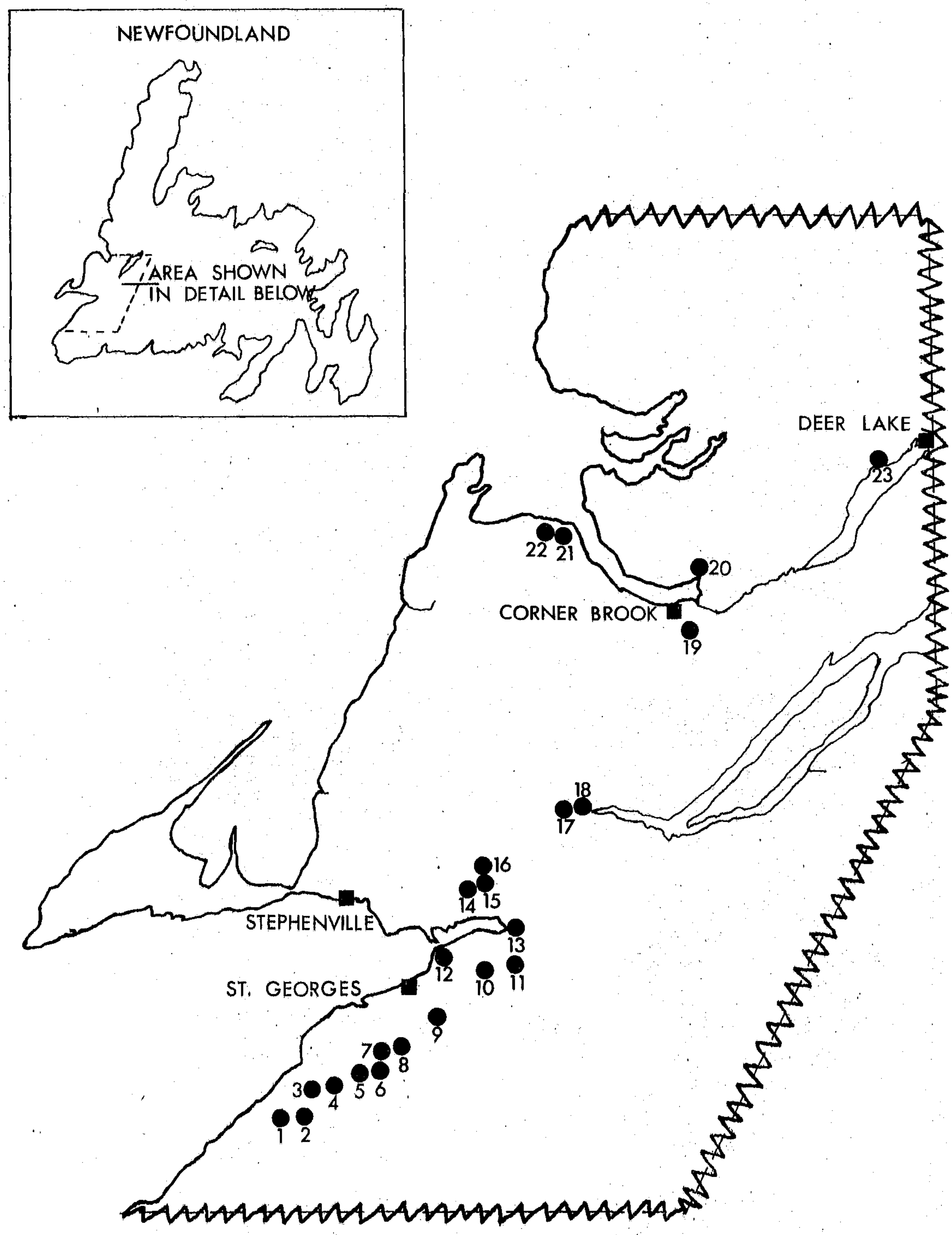

Figure 1: Location of stands sampled for balsam woolly aphid damage

RESULTS AND DISCUSSION

Stand Characteristics

As shown in Table 1, the stands were composed primarily of balsam fir. Other softwoods[3] amounted to a maximum of 14% of the trees tallied in any stand. Only three stands contained hardwood[4] species in excess of 30%; none exceeded 50%. Stand densities for all species were found to range from 6,000 to 76,000 stems per acre. Stand age of fir ranged between 8 and 30 years, but most stands were not over 15 years old.

Intensity of Damage

Results show that the percentage of trees damaged varied greatly between stands (Table 2). There was no evidence of balsam woolly aphid damage in three stands; 1 - 10% of the fir tallied was damaged in five stands; 11 - 50% in 10 stands; and the remaining five stands had more than 50% of trees damaged. There was gradation in the level of damage among trees up to the maximum level for any given stand. The maximum level of damage for stands was as follows: in one stand it was light; in two it was light-to-moderate; in four it was moderate; in three it was moderate-to-severe; and in 10 stands it was severe.

The data further suggests that as the percentage of damaged trees increased the level of damage increased. This relationship was significant (Chi sq. = 52.14 with 8 degrees of freedom, after Baily 1959) when the stands were grouped by the incidence of damage (Table 3).

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[3]Other softwoods, mainly black spruce, *Picea mariana* (Mill.) B.S.P. and white spruce, *P. glauca* (Moench) Voss.

[4]Hardwoods, mainly white birch, *Betula papyrifera* Marsh.

Table 1.- Age, density, and species composition of the stands surveyed.

Stand Number	Average age	Stems/ acre	Percentage composition		
			fir	other softwood	hardwood
1	12	18,000	51	7	42
2	11	22,000	90	1	9
3	11	29,000	79	1	20
4	8	36,000	68	1	31
5	6	52,000	82	1	17
6	11	37,000	88	1	11
7	12	32,000	84	1	15
8	6	76,000	94	0	6
9	*	8,000**	83	14	3
10	11	16,000	87	0	13
11	10	30,000	95	1	4
12	30	10,000	91	4	5
13	15	33,000	98	0	2
14	12	42,000	96	1	3
15	18	25,000	100	0	0
16	8	36,000	91	0	9
17	12	*	100	0	0
18	*	*	100	0	0
19	8	6,000	41	9	50
20	10	12,000**	76	7	17
21	14	12,000**	88	9	3
22	20	16,000	86	9	5
23	16	15,000	98	1	1

* Data not available.

** Suppressed trees not included in the tally.

Table 2.- Number of living and dead balsam fir trees examined and the percent of living trees with various levels of aphid damage.

Stand number	Year sampled	No. of living trees	No. of dead trees	Percent of living trees with various levels of aphid damage: undamaged	recovered	light	light-to-moderate	moderate	moderate-to-severe	severe
1	'65	353	1	57.5	1.7	9.3	11.6	11.9	5.9	2.0
2	'65	283	0	32.9	2.8	9.2	26.1	13.8	12.4	2.8
3	'69	332	0	21.7	19.0	20.2	29.0	4.8	3.6	1.8
4	'69	317	0	50.2	0.0	12.9	20.5	10.4	6.0	0.0
5	'69	421	0	91.7	0.0	4.8	2.6	0.5	0.2	0.2
6	'69	427	0	70.7	2.6	11.7	12.6	1.2	0.7	0.5
7	'69	389	0	68.6	6.2	12.6	11.1	1.5	0.0	0.0
8	'69	706	0	78.6	0.8	10.6	8.4	1.0	0.4	0.1
9	'64	60	0	96.7	0.0	3.3	0.0	0.0	0.0	0.0
10	'65	444	0	72.1	1.1	7.2	7.2	5.6	5.6	1.1
11	'70	791	0	63.3	0.0	19.2	14.7	2.4	0.4	0.0
12*	'68	374	17	64.4	10.7	3.2	7.8	2.1	2.9	8.8
13	'65	567	1	28.6	3.2	18.3	23.8	11.6	4.6	9.9
14	'65	936	0	97.7	0.0	1.0	1.1	0.3	0.0	0.0
15	'70	944	6	7.8	88.2	1.8	2.2	0.0	0.0	0.0
16	'65	688	0	94.5	1.0	0.7	1.3	0.7	0.3	1.5
17	'64	60	0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
18	'64	60	0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
19	'64	750	0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
20	'64	60	0	88.3	0.0	5.0	5.0	1.7	0.0	0.0
21	'64	59	0	16.9	0.0	27.1	23.7	32.2	0.0	0.0
22*	'68	341	0	72.1	13.5	5.9	7.6	0.6	0.3	0.0
23	'70	362	0	98.6	0.0	0.8	0.6	0.0	0.0	0.0

* Sampled with strip cruise procedure. All other samples were obtained with line transect procedure.

Table 3.- Contingency table relating the percentage of trees damaged in stands and the level of damage on trees (observed counts of damaged trees by damage class are main entries; expected counts in brackets).

% of trees damaged in stands	Damage Classes					Totals
	light	light-to-moderate	moderate	moderate-to-severe	severe	
1 - 10	39 (32)	32 (37)	10 (13)	3 (7)	11 (6)	95
11 - 50	467 (414)	468 (473)	148 (167)	86 (91)	48 (72)	1,217
> 50	230 (290)	341 (332)	140 (117)	73 (64)	70 (51)	854
Totals	736	841	298	162	129	2,166

The combined counts from all stands of fir trees in various aphid damage classes (Appendix I) are shown in Table 4. About one-third of the 9,724 trees tallied had been damaged by the aphid. Nearly 75% of the trees damaged (recovered trees omitted) were in the light and light-to-moderate damage classes. Trees in the moderate, moderate-to-severe and severe classes occurred much less frequently.

The trees tallied in 17 of the 23 stands were classified for crown dominance as well as aphid damage. The data (Table 5) show that the lowest number of damaged trees occurred in the dominant crown class (239) and increased in each crown class to the suppressed class (782). However, the data also show that damage occurred on about the same proportion of the trees in each of the crown classes. Therefore the probability of a tree having damage was the same regardless of crown class.

Table 4.- The number of fir trees tallied in all stands that had various levels of aphid damage and these counts expressed as a percent of the total (9,724) fir trees examined; as a percent of damaged (3,206) trees; and as a percent of damaged trees omitting those that had recovered (2,165).

	Level of Aphid Damage						
	undamaged	recovered	light	light-to-moderate	moderate	moderate-to-severe	severe
No. of trees tallied	6,518	1,041	736	840	298	162	129
% of total trees	67.03	10.70	7.57	8.64	3.06	1.67	1.33
% of damaged trees		32.47	22.96	26.20	9.30	5.05	4.02
% of damaged trees omitting those that recovered			34.00	38.80	13.76	7.48	5.96

Table 5.- The total number of trees tallied, the number and percentage of these that were damaged and the number and percentage that had recovered, by crown classes.

	Crown Class				
	dominant	codominant	intermediate	suppressed	Total
No. of trees tallied	1,108	1,913	2,403	3,293	8,717
No. of trees damaged (recovered trees omitted)	239	467	655	782	2,143
% of trees in each crown class damaged	21.6	24.4	27.3	23.7	
No. of trees recovered	54	198	296	493	1,041
% of trees in each crown class recovered	4.9	10.4	12.3	15.0	

Recovery of Aphid Damaged Trees

Recovery was observed on sample trees in 12 of the 23 stands. It exceeded 10% of the trees in four of the stands and reached a high of 88.2% in one (Table 2). This indicates that recovery is common in young stands but that the percentage of trees involved is highly variable between stands. On the whole about 1/3 of all trees with evidence of damage had recovered (Table 4). Evidence of recovery was highest in trees that had been damaged at the light-to-moderate damage level and lowest in trees that had been most severely damaged (Table 6).

Table 6.- Number and percentage of 1,041 fir trees examined that had recovered from various levels of aphid damage.*

	Level of damage from which trees recovered			
	light-to-moderate	moderate	moderate-to-severe	severe
No. of trees examined	535	222	184	100
% of trees examined	51.4	21.3	17.7	9.6

* Trees recovered from light damage class cannot readily be distinguished from undamaged trees so that they have been treated as undamaged trees and are not shown in this table.

The results of the survey also showed that some recovered trees had been reattacked by the aphid. Data from Stand 3 (Table 7) provides a good illustration of this condition. Tallies included 111 trees that had recovered but on 43.2% of these the recovery growth showed evidence of new damage. Renewed damage was most severe on those trees that had been classified as moderate-to-severe and severe before recovery occurred. These data indicate that recovered trees are not immune from renewed damage by the aphid and also that the most severely damaged before recovery tend to be the most severely damaged when damage is renewed.

Table 7.- For Stand 3; the number of trees that had recovered from different classes of aphid damage and the percentage of these trees that had various classes of new damage acquired since recovery.

Classification for previous damage*	Number of trees recovered	No new damage	New class of damage to recovered trees in %				
			light	light-to-moderate	moderate	moderate-to-severe	severe
Light-to-moderate	33	22.5	7.2	-	-	-	-
Moderate	28	17.1	8.1	-	-	-	-
Moderate-to-severe	27	6.3	9.9	7.2	0.9	-	-
Severe	23	10.8	2.7	5.4	0.9	0.9	-
Total	111	56.8	27.9	12.6	1.8	0.9	-

* Trees recovered from light damage class cannot readily be distinguished from undamaged trees so that they have been treated as undamaged trees and are not shown in this table.

The data from 17 of the 23 stands showed that occurrence of recovered trees increased with changes in crown class from 54 trees in the dominant to 493 trees in the suppressed classes (Table 5). Data also show that recovery did not occur on the same proportion of trees in each crown class. It increased from 4.9% in the dominant class to 15.0% in the suppressed class. This indicates that the probability of recovered trees occurring in the dominant crown class was lower than for any other crown class.

Tree Mortality

Aphid damage contributed to tree mortality in only four of the 20 stands with damaged trees. As shown in Table 2 only one dead tree was encountered in each of two of these stands; a third stand had six dead trees, and there were 79 dead trees in the oldest stand sampled (Stand 12). All the mortality in this latter stand was not attributed to aphid damage. Not more than one quarter of the dead trees died as a result of aphid attack (Table 2), the remainder were identified as having died from natural suppression. These results indicate that aphid injury is not a significant factor causing mortality in young balsam fir stands, but appears to be more important as stand age increases.

Relationship Between Aphid Damage and Stand Age and Stand Density

The survey data showed that there was no statistical relationship between stand age or stand density and the percentage of trees damaged ($r = 0.29$ and 0.15 respectively). However, one influence of stand age on damage may be expressed in the intensity of mortality; the aphid killed only about 0.5% of the trees in the younger stands as compared with about 5.0% in the 30-year-old stand (Table 2). Also an influence of stand density on the intensity of damage is indicated by Greenbank (1970), who showed that tree susceptibility increased in a Nova Scotia stand that was thinned.

Data collected in nine stands showed that there was also no relationship between stand vigor (as determined by average 5-year height growth of dominant trees, Table 8) and the incidence of aphid damage (r = 0.08).

Table 8.- Average 5-year height growth (inches) of dominant trees.

	Stand Numbers								
	5	6	7	8	10	11	14	16	23
Number of trees	36	51	36	58	55	90	108	120	99
Average 5-year height growth	43.4	48.6	54.2	42.4	54.1	46.0	41.3	61.2	68.8

SUMMARY AND CONCLUSIONS

A survey of 23 young stands in western Newfoundland has shown that the magnitude of aphid damage in these stands was highly variable. The incidence of damaged trees ranged from zero to more than 90 percent. The data also indicated that the level of damage increased with the incidence of damaged trees within stands. Half the damaged stands had at least a few severely damaged trees but in all stands more than 80 percent of injured trees were in the light, light-to-moderate or recovered damage classes. Mortality from aphid damage was rare except in a 30-year-old stand where about 5% of the trees had been killed by the aphid.

Evidence of recovery occurred in 60% of the stands that contained damaged trees but the incidence of recovery was usually low, exceeding 10% of the trees tallied in only four stands; it reached a high of 88.2% in one stand. The recovered portions of some damaged trees showed evidence of new damage indicating that recovered trees are not immune to further attack by the aphid. Results also indicated that renewed damage was most severe on those trees that were classified as moderate-to-severe and severe before recovery occurred.

The incidence of aphid damaged trees in the various crown dominance classes increased from the dominant to the suppressed classes (11% to 37% of damaged trees). However, the number of damaged trees in each crown class was in about the same proportion as the total number of trees occurring in each of the classes. This indicates that trees in the various crown classes had the same probability of having aphid damage. The incidence of trees that had recovered from such damage also increased from the dominant to the suppressed classes (5% to 47% of recovered trees) but the probability of recovery was not the same for trees in each crown class. It was lowest for trees in the dominant class, medium for trees in the codominant and intermediate classes and highest for trees in the suppressed crown class.

The results of the survey indicate that to date most young fir stands in western Newfoundland have not been seriously affected by the aphid, principally because mortality has been insignificant; most of the damage has been at the light or light-to-moderate levels; and more than one-third of the damaged trees have recovered. However, recovery cannot be relied on to reduce the influence of aphid damage in young stands because it tends to be less common on trees in the dominant crown class. Consequently, it must be concluded that if aphid damage persists, stand quality will probably be reduced at merchantable age. However, if there is no further aphid damage, it appears that past damage will have had little if any effect on most of the stands at maturity.

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APPENDIX I

Aphid Damage Classification

In Newfoundland the most prevalent form of aphid damage is caused by "twig attack" in the crowns of trees. The symptoms include swelling of nodes and inhibition of buds and shoots. Damage is first observed immediately below the cone-bearing branches and then it spreads, causing crown-dieback and eventual tree mortality.

Damage classification based on visual symptoms is as follows: -

Light - swelling apparent only on close examination.

Light-to-moderate - swelling of nodes distinct with some stunting and distortion of shoots.

Moderate - node swelling and shoot distortion very distinct; current shoots absent on some branches; no shoot dieback.

Moderate-to-severe - node swelling and shoot distortion pronounced; topmost branches dead or bare of needles.

Severe - node swelling and shoot distortion pronounced main stem terminal inhibited or dead; extensive dieback of branches.

Recovered - last two or more years of growth without damage symptoms but symptoms present on older growth. (Classified as recovered from previous damage that is categorized by the above system.)

Trees may support a small population of aphids without apparent damage. Therefore, it is important to emphasize that this classification is based on visual symptoms of injury. Also, damage is not equally weighted between classes.