Environment
Canada

Forestry
Service

BALSAM WOOLLY APHID DAMAGE TO THE CROWNS OF BALSAM FIR TREES

by H.O. Schooley and L. Oldford

NEWFOUNDLAND FOREST RESEARCH CENTRE

ST. JOHN'S, NEWFOUNDLAND

INFORMATION REPORT N-X-121

JUNE 1974

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

BALSAM WOOLLY APHID DAMAGE TO THE CROWNS OF BALSAM FIR TREES

by

Hugh O. Schooley and L. Oldford

INTRODUCTION

The balsam woolly aphid[1] is an important pest attacking all age classes of balsam fir[2], the most abundant pulpwood species on the Island of Newfoundland. A salivary substance injected into the tree by the aphid reacts on the cambium resulting in the formation of enlarged annual rings of brittle, reddish-brown wood, "red-wood". When aphid attack is concentrated on the shoots and twigs, "twig attack", it causes a swelling of the nodes "gout", inhibition of the buds and eventually, a dying back of the branches. This condition is the most prevalent symptom found on aphid injured trees in Newfoundland. Tree mortality usually occurs only after a long period of such attack. When aphids are concentrated on the stem and/or the base of branches, "stem attack", the attack is recognized by white wax threads covering the feeding nymphs and adults. This condition is not common in Newfoundland, but when it does occur, it can cause death of infested trees in a period of only 2 or 3 years. Damage symptoms increase on trees under persistant attack. However, if the aphid infestation collapses, the trees released from damaging effects usually recover and resume normal growth.

---

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

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

Studies concerning the impact of the aphid on balsam fir stands have been conducted by the Newfoundland Forest Research Centre for several years. Results of these studies have shown that cone and seed production is not effectively reduced until damage becomes severe. Even then, it has been concluded that stands damaged by the aphid will probably produce adequate viable seed for stand replacement (Schooley and Oldford, 1969). Most young fir stands have not been seriously affected by the aphid, principally because damage has not been severe enough to cause appreciable mortality and many damaged trees have recovered and resumed normal growth (Schooley and Oldford, 1974). Page (1973) summarized work that showed aphid damage does not adversely affect the productivity of semi-mature stands unless there is a high proportion of severely damaged trees. It has been estimated (Page _et al._ 1974), that volume losses in such damaged stands approach 5% of the allowable cut at rotation age (60 years in Newfoundland). 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 _et al._ 1967).

This report describes the distribution of aphid damage in the crowns of fir trees and the effect of such damage on crown production.

METHODS

The Stand Studied

The trees examined in this study were taken from the upper part of the Hughes Brook watershed near Corner Brook (48°30'N, 58°15'W). The area supported a second growth stand of sub-merchantable to merchantable balsam fir with scattered black spruce[3] and white birch[4] on a "Dryopteris-Hylocomium balsam fir site", as described by Damman (1967). The stump age of the fir trees in the stand ranged from 32 to 70 years and averaged 46.8 years; heights ranged from 32 to 49 feet and averaged 40.3 feet; and diameters at breast height varied from 4.3 to 9.3 inches and averaged 6.3 inches. The first aphid infested trees were found in the area in 1956 (Parrott and Clarke, 1957). By 1965 the infestation had spread throughout the watershed and damage had intensified; 16% of the trees had severe damage (unpublished data). In 1972 the frequency of damaged trees was the same as in 1965 but most of the injured trees were showing evidence of recovery. The progress of the infestation, and the development of damage on trees are fairly typical of many aphid infested stands of this age class in western Newfoundland.

The Classification of Aphid Damaged Trees

This study is concerned only with "twig attack" the most prevalent form of balsam woolly aphid damage found in Newfoundland. Typically, damage first occurs immediately below the cone-bearing branches in the sub-apical quarter of the crown and then spreads upward and downward in the crowns if the infestation persists.

---

[3]Black spruce, *Picea mariana* (Mill.) B.S.P.

[4]White birch, *Betula papyrifera* (Marsh.)

The damage classification used in this study is based on visual symptoms as follows:

<u>Light</u> - swelling of nodes apparent only on close examination.

<u>Light-to-moderate</u> - swelling of nodes distinct with some stunting and distortion of shoots.

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

<u>Moderate-to-severe</u> - node swelling and shoot distortion pronounced; top most branches dead or bare of needles.

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

<u>Recovered</u> - 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. Also, damage is not equally weighted between classes.

Branching Habits of Balsam Fir Trees

In this study, tree crowns were stratified by their branching habits to facilitate the collection of data on aphid damage. The system of branching on balsam fir trees is shown in Fig. 1. A tree annually

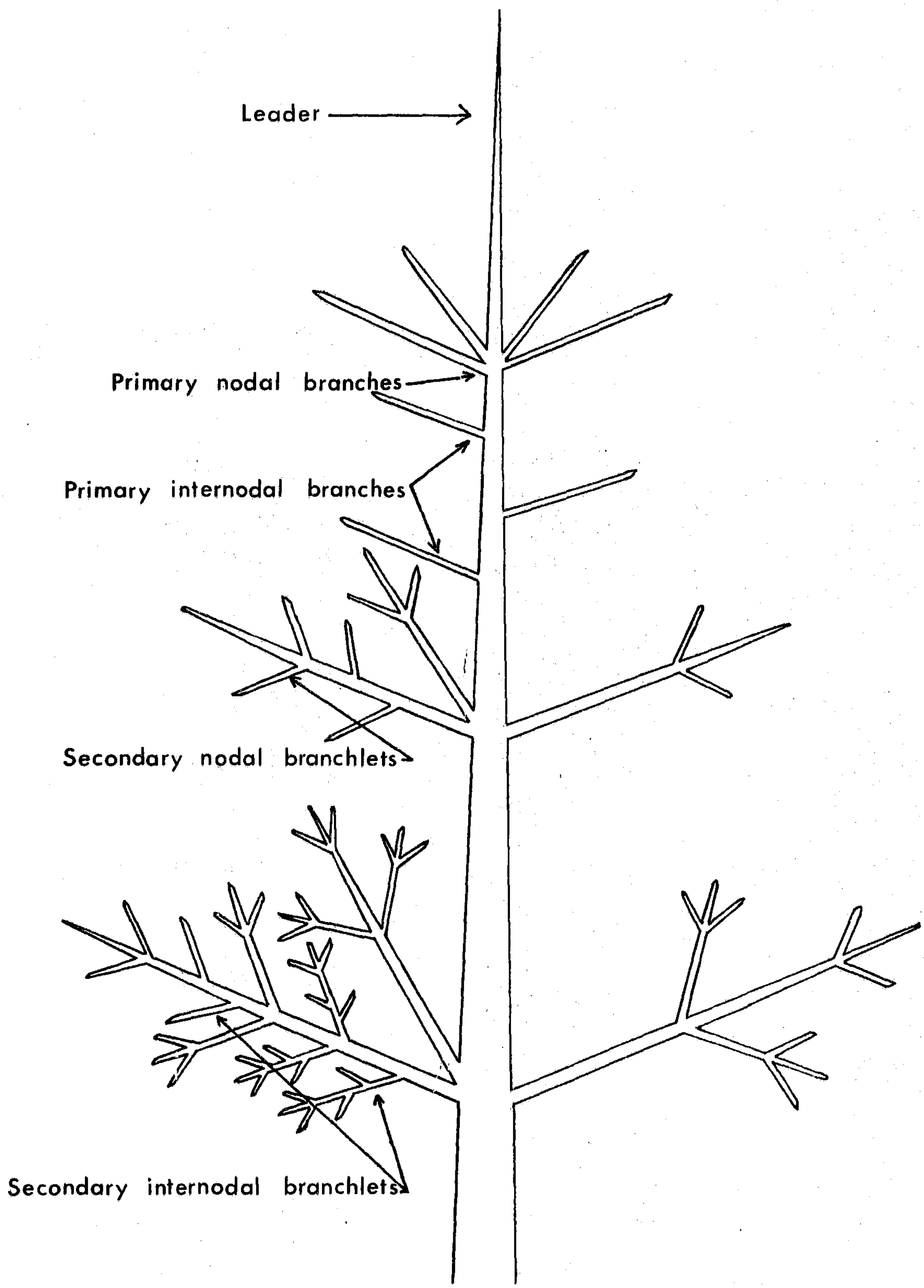

Figure 1: Branching characteristics of balsam fir.

produces on its main stem, four or five primary branches in a whorl at the terminal node and an irregular number of primary branches along the most apical internode. Each branch annually produces a whorl of two or three secondary branchlets at its terminal node and also internodal branchlets. Branchlets, of the third and succeeding orders, arise in the same pattern.

Collection of Data

A total of 50 trees were randomly selected from the stand for study. At the time the trees were examined, 10 were undamaged; 10 had light damage; 7 had light-to-moderate damage; 7 had moderate damage; 8 had moderate-to-severe damage; and 8 were severely damaged.

The uppermost or apical section of the crown containing 11 complete years of radial increment were removed from each of the trees for detailed measurements as follows: (a) the presence or absence of swelling from aphid injury "gout" was recorded for each main stem node and for the nodes on one branch randomly chosen from each whorl of primary branches; (b) the annual linear growth was recorded for the main stem section and for each of the selected primary branches; (c) the number of primary whorl and internodal branches were recorded by year of initiation; (d) the number of secondary whorl and internodal branchlets from each randomly selected primary whorl branch selected for (a) were recorded by year of initiation, but the lengths of these branchlets were not determined.

The student's "t" was used to test differences between mean values for linear growth increments and for the numbers of branches produced on undamaged trees and on trees in the various damage classes. This method of analysis gives a 99% confidence level for comparing trees in individual damage classes but only 94% confidence level for comparing all damage classes simultaneously.

RESULTS

"Gout" in the Crowns of Damaged Trees

Main stem and primary branch nodes in the 11-year-old crown segment of the 50 sample trees were examined for "gout" formed as a result of aphid injury. Figs. 2 and 3 show the percentage of nodes that exhibited "gout". There was no evidence of "gout" on the trees classified as undamaged and the percentage of nodes with "gout" was lowest for trees in the light damage class. With each successive increase in the level of damage there was an increase in the percentage of nodes having "gout". These figures also show that the intensity of "gout" varied with the age of the nodes depending on the severity of damage. For example, "gout" was present on 100% of the nodes for the years 2 to 10 on the main stem of severely damaged trees (Fig. 2). A similar condition occurred on 2- to 5-year-old primary branch nodes (Fig. 3). On trees in the light damage class the highest frequency of "gout" was only 70% and this occurred on only 5- and 6-year-old main stem nodes. The frequency of "gout" reached only about 45% on primary branch nodes that were 6 to 8 years old.

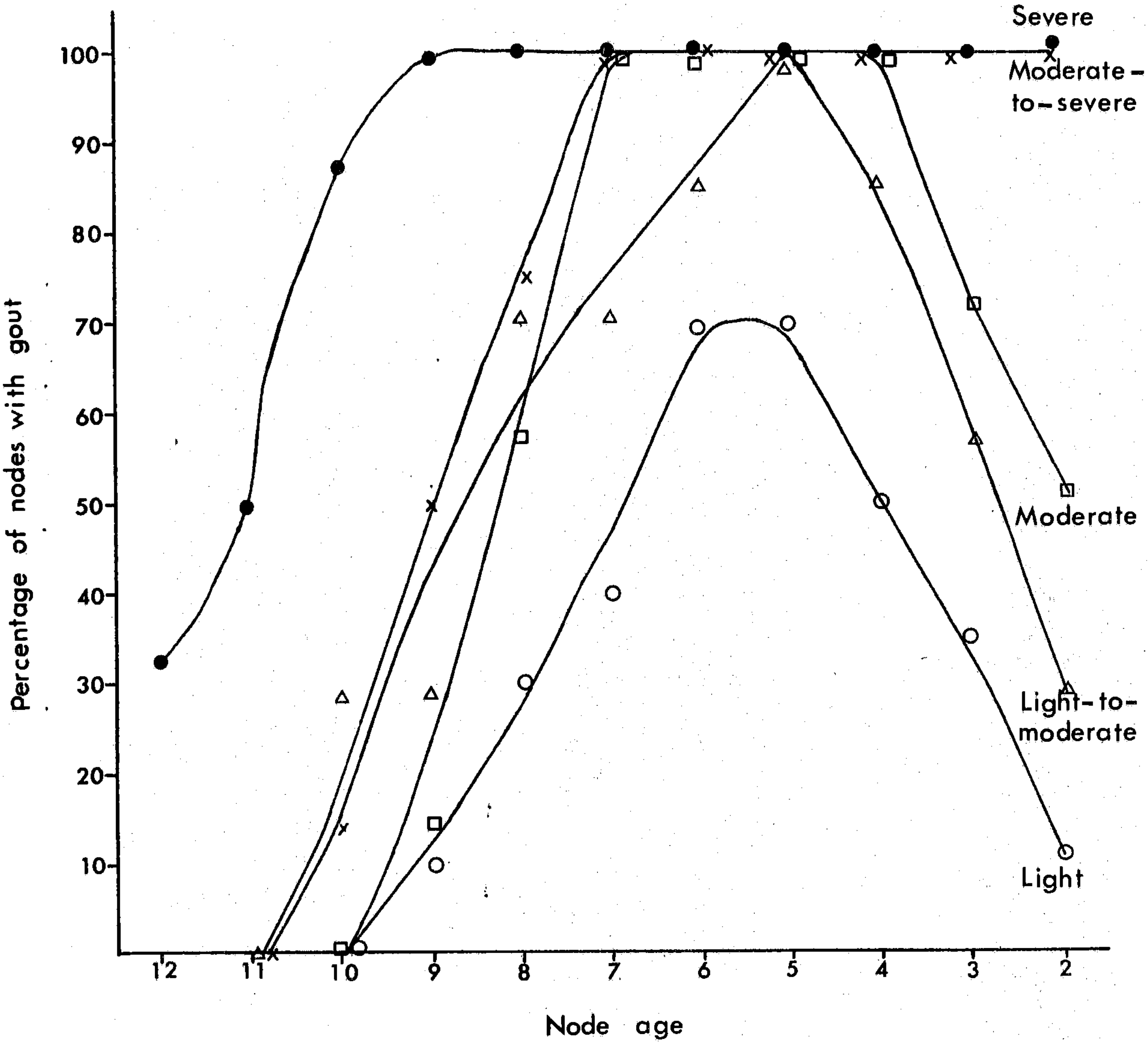

Figure 2: Percentage of primary nodes on the main stem gouted.

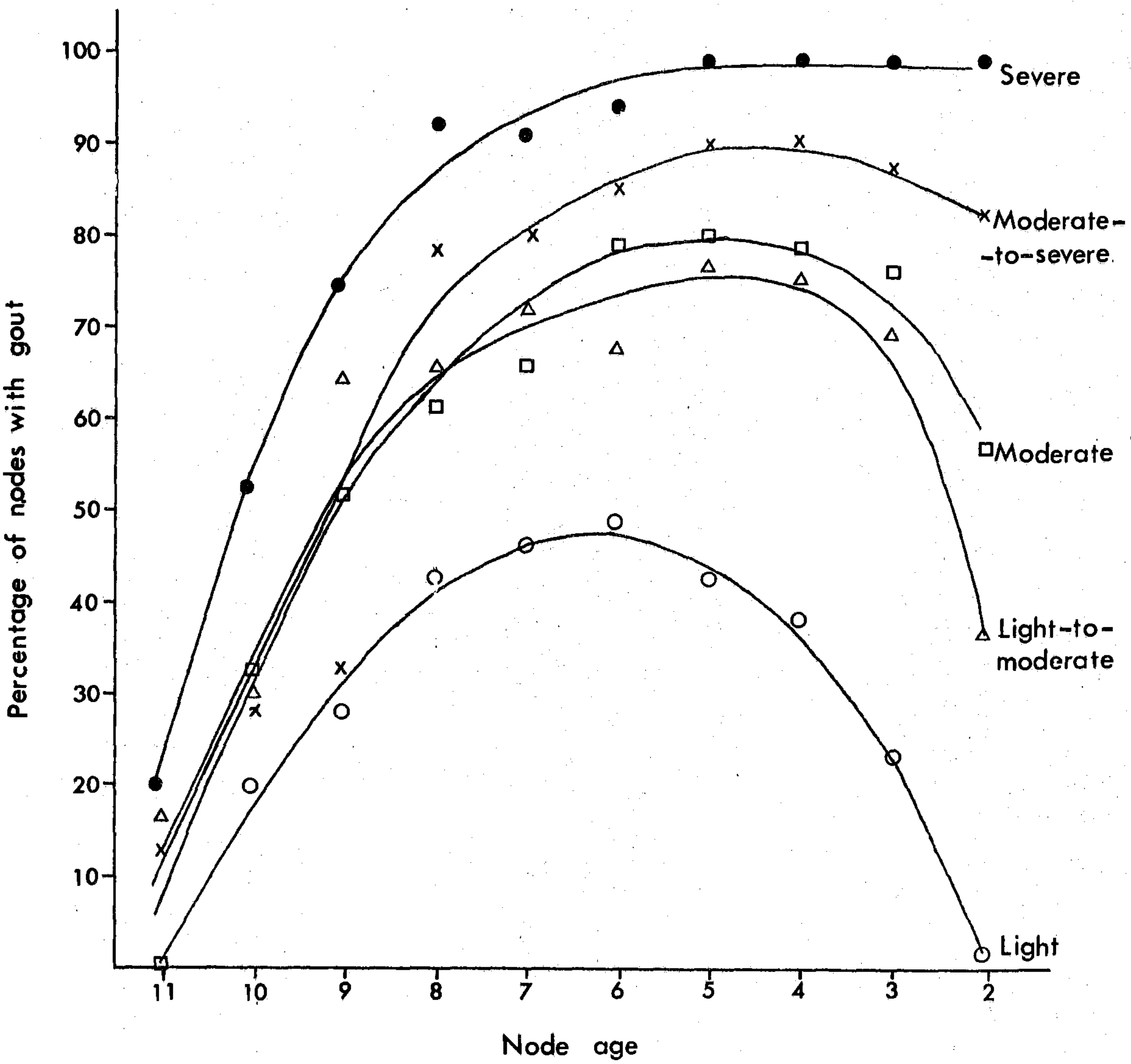

Figure 3: Percentage of secondary nodes on branches gouted.

Fig. 4 illustrates the distribution of "gout" throughout the crowns of trees in the various damage classes. In trees in the light damage class the highest frequency of "gout" occurred on the 4-year-old nodes of the 5-year-old branches. The area of intense "gout" formation increased in all directions in the crown with increasing levels of damage. It reached its greatest impact on trees in the severe damage class where "gout" occurred on nearly all nodes regardless of age.

Effect of Aphid Damage on the Height Development of the Main Stem

Height growth - Table 1 shows that all trees up to the moderate level of damage produced leaders each year, however 13 of the 23 trees in those damage classes above this level did not produce any leader growth during the latter years of development. This condition occurred during the last 2 years in the moderate and moderate-to-severe damage classes and over the last 4 years in the severe damage class.

Table 1.- Percentage of the trees that produced main stem leaders in different years.

Age of main stem internode	Percentage of trees that produced main stem growth					
		Damaged				
	Undamaged	Light	Light-to-moderate	Moderate	Moderate-to-severe	Severe
1 year	100	100	100	71	62	0
2	100	100	100	86	88	0
3	100	100	100	100	100	38
4	100	100	100	100	100	50
5 and older	100	100	100	100	100	100

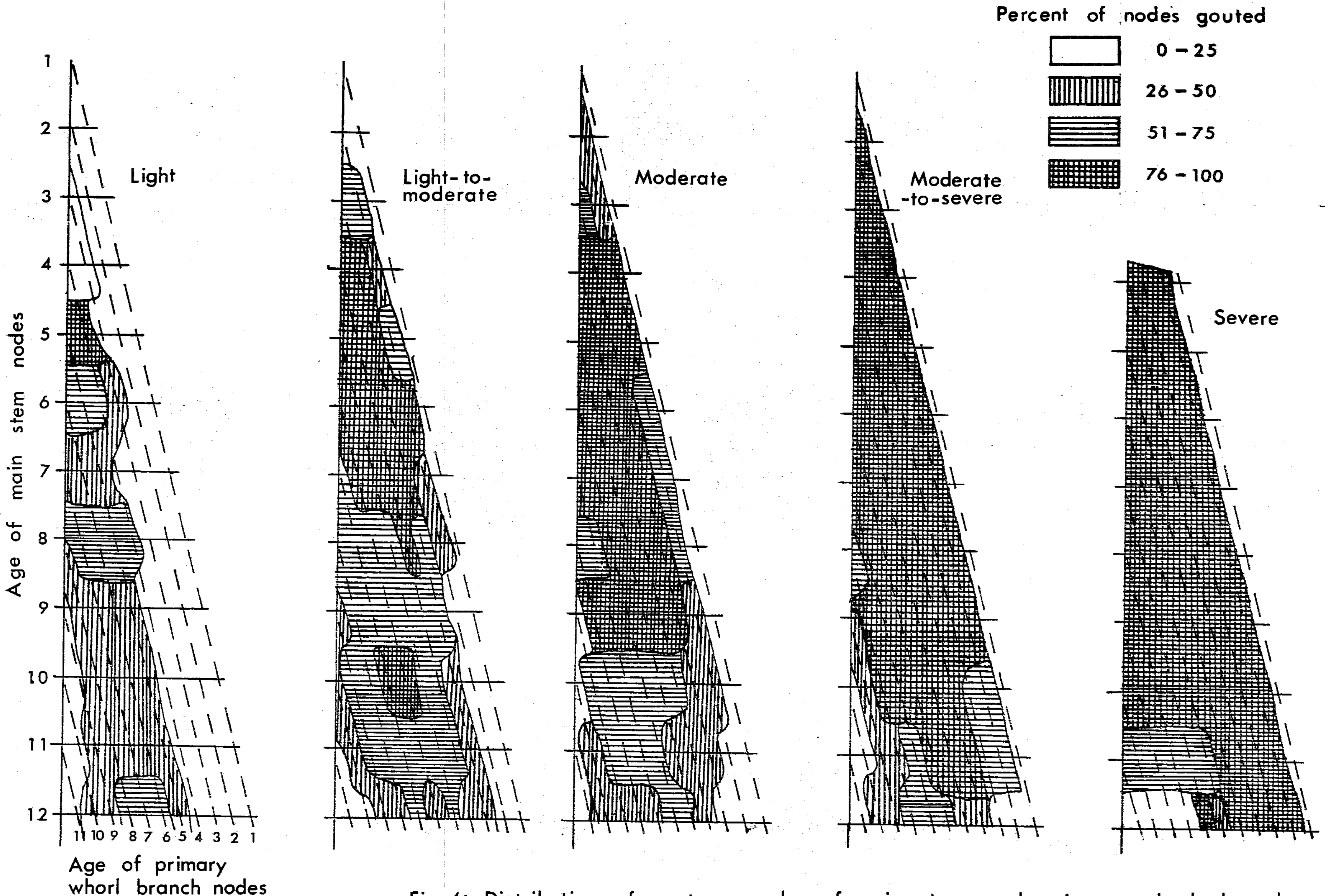

Fig. 4: Distribution of gout on nodes of main stem and primary whorl branches at top of damage classified trees.

In addition, the mean annual increase in the length of the main stem of undamaged trees varied between 7.35 and 12.25 inches during the 11 years included in the sample (Table 2). Significantly ($P = 0.01$) shorter increments were produced during the last year of growth on trees with moderate damage, during the last 4 years on trees with moderate-to-severe damage, and during the last 6 years on severely damaged trees. The main stem elongation on trees in the light and light-to-moderate damage classes was slightly shorter than on the undamaged trees for the last 5 or 6 years; however, these differences were not statistically significant.

The average length of the 11-year-old main stem segment on undamaged trees was 9.4 feet. However, the average length of 11-year-old main stem segment was only 8.4 feet on trees in the light, light-to-moderate and moderate damage classes; 6.5 feet on trees in the moderate-to-severe damage class; and to only 4.3 feet on severely damaged trees (Fig. 5) showing a marked reduction in the growth of the main stem as damage increased.

Dieback - Dieback, including up to 6 years of main stem growth, was found on 38% of the severely damaged trees. However, this had little influence on the living length of affected stems because, as shown above, aphid attack had already caused the stems to be much shorter even before dieback occurred.

Table 2.- Mean annual main stem elongation[1].

Age of main stem internode	Mean main stem elongation in inches					
		Damaged				
	Undamaged	Light	Light-to-moderate	Moderate	Moderate to-severe	Severe
1 year	7.35	5.80	5.14	3.29*	1.40**	0.00**
2	10.30	7.85	8.14	6.43	2.65**	0.00**
3	9.95	8.10	8.29	8.57	5.64*	0.88**
4	10.78	8.00	9.14	9.64	6.66*	1.77**
5	8.55	7.89	8.00	9.29	6.84	5.35*
6	10.69	7.94	9.92	9.00	7.28	5.91*
7	11.44	10.60	10.57	10.93	9.49	7.42
8	12.25	10.60	10.93	11.57	11.03	8.40
9	10.95	9.94	10.21	11.58	8.30	7.56
10	9.89	10.25	10.86	10.57	8.71	7.04
11	11.00	12.88	11.58	10.90	10.51	7.04

[1]Whole year growth segments missing as result of aphid caused inhibition of buds were included in the computation as zeros.

*Where mean growth of undamaged trees was significantly different from damaged trees with a $P \leq 0.01$.

**$P \leq 0.001$.

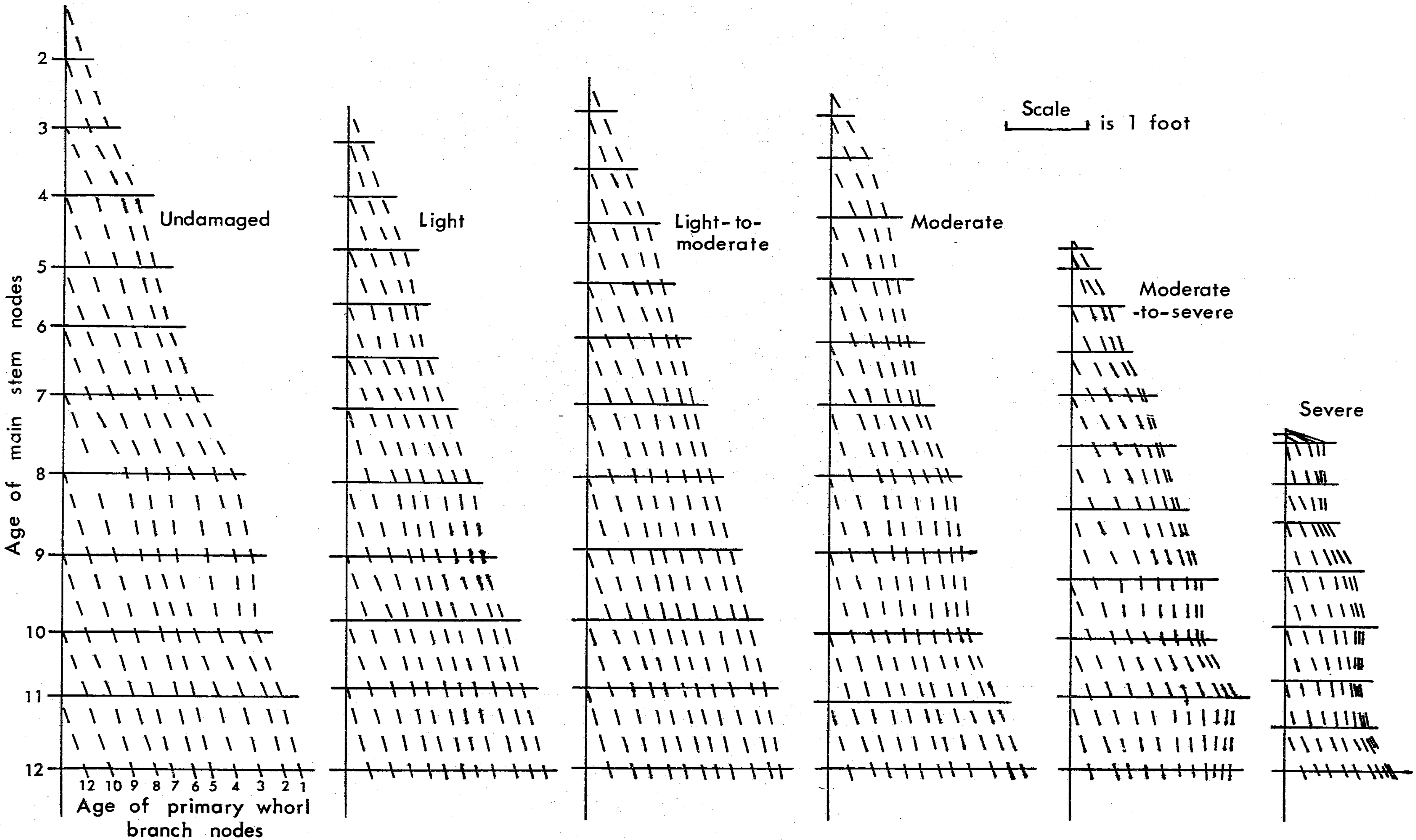

Fig. 5: Annual elongation of the main stem and primary whorl branches at the top of damage classified trees.

Effect of Aphid Damage on Branch Production

Number of primary whorl branches - The data in Table 3 show that four or five branches usually occurred at each primary whorl of the 11-year-old segments of the undamaged trees. There was no significant difference in the number of branches occurring up to the moderate-to-severe damage class. However, there were significantly fewer branches occurring on trees (P = 0.01) on the last 2 years in the moderate-to-severe damage class, and on the last 3 years in the severe class. During these periods, trees in the moderate-to-severe damage class averaged two branches and trees in the severe damage class averaged less than one branch per whorl.

Number of secondary whorl branchlets - The data in Table 4 show that about three secondary branchlets were produced at each whorl on the primary branches of undamaged trees. However, the number of secondary branchlets decreased significantly (P = 0.01) in most trees damaged by the aphid for the last 7 years of growth. Furthermore the number of branchlets decreased as aphid damage increased. For example, there was an average of 2.64 secondary whorl branchlets on the undamaged trees in the last year of growth and this number was reduced in each of the succeeding damage classes reaching a low average of 0.20 branchlets on trees in the severe damage class.

Table 3.- Mean number of primary whorl branches originating in different years.

Age of main stem whorl	Mean number of primary whorl branches					
		Damaged				
	Undamaged	Light	Light-to-moderate	Moderate	Moderate-to-severe	Severe
1	4.60	4.00	4.14	3.14	1.25**	0.00**
2	4.00	3.33	3.86	3.43	2.50*	0.88**
3	4.00	3.44	3.86	4.00	3.29	1.12**
4	4.10	3.55	3.86	4.00	3.80	2.38
5	4.30	3.90	4.14	3.83	3.50	3.88
6	4.33	4.10	4.00	3.57	4.28	3.38
7	4.20	3.90	3.43	4.43	3.75	3.88
8	4.30	4.22	4.00	3.83	3.86	3.62
9	4.30	3.78	4.17	3.71	3.33	3.14
10	4.67	4.20	3.86	4.14	3.86	3.38*
11	4.50	4.25	4.00	4.60	3.42	3.00*

*Where mean number of primary branches of undamaged trees was significantly different from damaged trees with a P = 0.01.

**P = 0.001.

Table 4.- Mean number of secondary whorl branchlets originating in different years.

Age of secondary whorl	Undamaged		Damaged									
			Light		Light-to-moderate		Moderate		Moderate-severe		Severe	
	Number of whorls	Mean number of secondaries	Number of whorls	Mean number of secondaries	Number of whorls	Mean number of secondaries	Number of whorls	Mean number of secondaries	Number of whorls	Mean number of secondaries	Number of whorls	Mean number of secondaries
1 year	88	2.64	90	2.37*	63	2.30**	64	2.06**	75	0.96**	76	0.20**
2	85	2.67	88	2.31**	61	2.41*	60	2.17**	68	1.65**	68	0.43**
3	75	2.77	78	2.47**	55	2.44**	54	2.37**	58	1.84**	60	0.85**
4	66	2.42	68	2.21	48	2.12*	47	2.38	53	2.06*	52	1.04**
5	56	2.98	59	2.49**	40	2.60*	40	2.55**	45	2.42**	44	1.75**
6	45	2.47	47	2.15	34	2.23	32	2.31	37	2.35	36	1.75**
7	36	2.94	39	2.51*	26	2.42**	26	2.38**	29	2.55	28	2.14**
8	26	2.62	29	2.59	20	2.40	19	2.47	21	2.29	20	2.25
9	16	2.38	19	2.32	13	2.23	12	2.33	14	2.14	13	1.92
10	7	2.57	9	2.56	6	2.50	5	2.80	7	2.43	5	2.60

*Where mean number of secondary branches from nodes on primary whorl branches of undamaged trees was significantly different from damaged trees with a $P \leq 0.01$.

**$P \leq 0.001$.

<u>Number of secondary internodal branchlets</u> - The data in Table 5 show that about two secondary branchlets occurred on the internodes of the primary branches of undamaged trees each year. However, this number decreased as damage increased but only significantly so (P = 0.01) in the last 2 to 4 years of growth and most predominantly on the severely damaged trees.

<u>Number of primary internodal branches</u> - The data in Table 6 show that about nine internodal branches occurred each year on the main stem of undamaged trees. The data also show that this number decreased as aphid damage increased. This decrease was significant (P = 0.01) only in moderate-to-severe and the severe damage classes and then only in the last 3 and 4 years of growth respectively.

<u>Linear growth of branches</u> - Linear growth was determined only on one branch from each whorl of the primary branches from the 11-year-old apical segment of each sample tree. Table 7 shows a highly significant decrease (P = 0.01) in the average length of these branches with an increase in aphid damage. This decrease was most pronounced in the younger portions of the branches, up to 4 years of age in all damage classes except for trees in the severe class where the decrease was evident for 10 years. This condition is diagramatically illustrated in Fig. 5.

As a result of the reductions in annual increments the average total length of primary branches of a given age on damaged trees was much shorter than the length of branches of the same age on undamaged trees. For example, a 3-year-old branch on undamaged trees had an average length

Table 5.- Mean number of secondary branchlets supported on primary whorl branch internodes of different ages.

Age of supporting primary branch internode	Mean number of secondary internodal branchlets					
		Damaged				
	Undamaged	Light	Light-to-moderate	Moderate	Moderate-to-severe	Severe
2	.57	.37	.21*	.11**	.07**	.00**
3	1.59	1.01	.84**	.58**	.66**	.06**
4	1.09	.81	.98	.54*	.55*	.13**
5	1.18	.91	.92	1.00	.94	.29**
6	.54	.36	.67	.28	.69	.25
7	1.49	1.57	1.53	1.22	1.51	.77*
8	.86	.82	1.12	.42	1.00	.57
9	1.69	2.55*	2.30	1.63	2.10	.65**
10	1.31	2.26	2.31	.75	1.14	1.00
11	1.14	1.89	1.67	.80	.86	1.00

*Where production of secondary internodal branches by undamaged trees was significantly different from trees with a $P \leq 0.01$.

**$P \leq 0.001$.

Table 6.- Mean number of primary internodal branches of different ages.

Age of internodes	Mean number of primary internodal branches					
		Damaged				
	Undamaged	Light	Light-to-moderate	Moderate	Moderate-to-severe	Severe
2 years	8.90	7.90	8.00	5.29	0.75**	0.00**
3	12.40	11.00	10.71	10.57	5.62*	0.62**
4	10.56	9.70	11.00	9.43	5.62*	1.37*
5	6.70	6.30	8.57	8.67	5.12	3.50*
6	9.33	9.33	12.00	8.50	5.29	6.25
7	8.88	11.00	12.00	8.71	9.00	8.12
8	9.62	10.20	11.00	10.86	9.62	8.25
9	8.66	9.44	13.14	10.33	7.29	8.00
10	8.11	9.44	11.57	10.43	7.57	8.00
11	10.12	13.12	11.50	13.00	8.86	8.43
12	10.00	12.80	11.00	11.00	8.50	7.83

*Where mean number of primary branches of undamaged trees was significantly less than damaged trees with a P = 0.01.

**P = 0.001.

Table 7.- Mean annual primary branch elongation.

Age of branch internode	Mean primary branch elongation in inches					
	Undamaged	Light	Light-to-moderate	Moderate	Moderate-to-severe	Severe
1	2.13	1.72**	1.84**	1.45**	0.60**	0.02**
2	3.51	2.48**	2.53**	2.19**	1.36**	0.32**
3	3.63	2.73**	2.88**	2.51**	2.25**	0.76**
4	3.52	2.61**	2.82**	2.62**	2.37**	1.18**
5	2.85	2.27**	2.29**	2.67	2.49	1.49**
6	3.80	2.96*	3.04*	3.19*	3.19*	2.06**
7	3.58	2.82*	2.78*	2.77*	3.11	2.14**
8	3.75	3.18	2.98*	2.98*	3.34	2.36**
9	3.48	3.22	3.11	3.03	2.87	2.08**
10	3.47	3.42	3.42	3.08	3.07	2.06**
11	3.21	3.67	3.50	3.20	3.04	2.56*

*Where mean growth of undamaged trees is significantly different than damaged trees with a P = 0.01.

**P = 0.001.

of 11 inches; branches on trees in the light, light-to-moderate and moderate classes averaged about 8.5 inches; they were about 6 inches long on trees in the moderate-to-severe class; but only 2 inches long on trees that were severely damaged. This reduction in average length of branches, caused by aphid damage to trees in classes beyond the moderate level is influenced in part by failure of some branches to produce annual linear growth from the bud stage. For example, whereas 1-year-old branches were present on all primary whorl branches of undamaged trees, they were absent on 60% of trees in the moderate-to-severe damage class and on 98% of trees in the severe damage class (Table 8).

Table 8.- Percentage of the expected number of primary whorl branch segments of different ages, absent from moderate-to-severe and severe damaged trees where aphid caused inhibition of growth occurred.

Age of branch internode	Damage class	
	Moderate-to-severe % absent	Severe % absent
1	60.9	98.2
2	27.9	81.8
3	14.8	58.7
4	3.7	38.6
5	0.0	21.6
6		2.5
7 and older		0.0

Effect of Aphid Damage on the Size and Shape of the Crown

The overall effects of shortened or missing main stem and primary branches on crown shape and crown volume are illustrated schematically in Fig. 5. Trees in the light, light-to-moderate and moderate damage classes were similar in profile to undamaged trees. However, trees in moderate-to-severe and severe damaged classes had crown profiles that were more like cone frustrums than the typical conical form of undamaged trees. Decreases in the number of branches and branchlets reduced the branch density of crown as damage advanced. Reduced main stem and branch elongation in the successive years resulted in trees with considerably smaller crowns. The average volume[5] of the 11-year-old crown segment examined in undamaged trees was 130 cubic feet. Volumes of crowns of trees in the light, light-to-moderate and moderate damage classes were about 95 cubic feet, but those in the moderate-to-severe damage classes averaged 70 cubic feet and those in the severe damage class averaged only 25 cubic feet.

SUMMARY AND CONCLUSION

Data collected from all damage classes of trees indicates that "gout" was distributed throughout the apical portion of crown (11 years in this study) early in the cycle of damage. On trees in the light damage class "gout" was found to have been most intense in the area around the 5-year-old branches. As the damage cycle continued, this area of intense

[5] $\text{Volume} = 4\pi \, \frac{(\text{schematic area of cross-section})}{3}$

"gout" enlarged, so that it occupied one-half the apical section on trees in the moderate damage class, three-quarters on trees in the moderate-to-severe damage class and nearly the whole crown section on trees in the severe class.

As the level of damage increased it prevented the development of normal tree height; undamaged trees averaged 9.4 feet in the 11-year-old section of crown examined as compared with only 4.3 feet on severely damaged trees. This condition was caused by the reduction of annual growth and inhibition of terminal bud growth. In addition to these height losses, dieback caused some further reduction of living crown length on 38% of the trees in the severe damage class.

It was also found that as aphid damage progressed, the number of branches produced was substantially reduced. At the top of the trees the average number of primary whorl branches on undamaged trees was 4 or 5, but decreased to 1 or 2 on trees in the moderate-to-severe damage class and no branches were produced in trees in the severe damage class. A similar but less pronounced effect was found as the age of the apical section of crown increased. Primary internodal branch and secondary, whorl and internodal branch production was affected in the same way.

In addition to reductions in branch numbers, increasing damage also resulted in smaller annual increments to the length of branches; only primary whorl branches were measured. For example, a 3-year-old branch on an undamaged tree had a length of 11 inches but this was reduced to an average length of only 2 inches on a severely damaged tree.

The gross effects of shortened and missing portions of main stems and branches resulted in a substantial reduction in the volume of living crown as damage increased. The average volume of the 11-year-old segment examined was 130 cubic feet on undamaged trees; this was slightly reduced up to the moderate level of damage but only averaged 25 cubic feet for trees in the severe damage class.

As this study only included 11 years of apical growth on trees, it is impossible to predict what total impact the physical changes caused by the aphid would have on the eventual volume of wood in damaged merchantable trees. However, it would appear that there would not be any appreciable effect until trees are in the moderate-to-severe or severe damage classes. This conclusion agrees with the findings of Page (1973) who points out that aphid damage does not adversely affect the productivity of semi-mature stands unless there is a high proportion of severely damaged trees.

LITERATURE CITED

Damman, A.W.H. 1967. The forest vegetation of western Newfoundland and site degradation associated with vegetation changes. Ph.D. Thesis, Univ. of Mich. U.S.A. 319 pp.

Page, G. 1973. Impact of balsam woolly aphid damage on fir stands in Newfoundland. Can. Dept. Environment, Can. For. Ser., Information Rep. N-X-94. 35 pp.

Page, G., W.C. Wilton and Tony Thomas. 1974. Forestry in Newfoundland. Newfoundland Forest Research Centre, St.John's, Nfld.

Parrott, W.C. and L.J. Clarke. 1957. Annual report of forest biology rangers, Newfoundland, 1956. Forest Biology Laboratory, Corner Brook, Newfoundland.

Schooley, H.O. and L. Oldford. 1969. Effect of balsam woolly aphid damage on the reproductive potential of balsam fir. Can. Dept. Fisheries and Forestry, Can. For. Serv., Information Rep. N-X-35. 21 pp.

Schooley, H.O. and L. Oldford. 1974. Damage caused by the balsam woolly aphid in young balsam fir stands. Environment Canada, Can. For. Serv., Information Rep. N-X-115. 19 pp.

Warren, G.L., W.C. Parrott, and S.G. Cochran. 1967. Balsam woolly aphid dispersal and damage in balsam fir stands in Newfoundland. Can. Dept. For. and Rural Devel., For. Br., Information Rep. N-X-15. 63 pp.