EFFECT OF BALSAM WOOLLY APHID ATTACK ON BALSAM FIR TREE VOLUME RELATIONSHIPS IN WESTERN NEWFOUNDLAND

by
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Table of Contents

	Page
Introduction	1
Methods	1
Results	5
Volume Relationships	5
Height/Diameter Relationships	7
Discussion	8
Conclusions	12
Acknowledgements	13
Literature Cited	14

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Introduction

The balsam woolly aphid, Adelges piceae (Ratz.), a serious pest of balsam fir, was first discovered in Newfoundland in 1949, and since then has spread to most areas of the Island except the Northern Peninsula. Infested stands cover more than 6,000 square miles, with damage being most extensive in western Newfoundland.

The life cycle of the aphid (Balch and Carroll, 1958; Carroll and Bryant, 1960), the spread of infestation, and the effects of the aphid on crown, branch, and stem morphology (Warren, et al, 1967) and on cone and seed production (Schooley and Oldford, 1969) and fairly well documented, but little is presently known of the effects of the aphid on the volume production of balsam fir trees and stands at various stages of development. This report utilizes data from several sources to determine the impact of the aphid on the height/diameter/volume relationships of individual mature and semi-mature balsam fir trees.

Methods

Stem analysis data for 584 balsam fir trees were obtained from a number of earlier studies. All sample trees were from Forest Section B28b (Rowe, 1959) in western Newfoundland, and were classified for aphid damage as follows:

Class O: Undamaged trees from uninfested stands.

Class U: Undamaged trees from stands infested by the balsam woolly aphid.

Class L: Lightly damaged trees (nodal swelling present, some stunting and distortion of branches, leader remains erect).

Class M: Moderately damaged trees (pronounced nodal swelling and branch distortion, up to 12 inches of dieback on some branches, some lack of current shoot development, leader may be stunted but remains alive and more or less erect).

Class S: Severely damaged trees (very pronounced nodal swelling and shoot distortion, extensive branch dieback, leader dead).

Class D: Severely damaged dead trees (damage characteristics as for Class S, but no part of the tree remains alive).

This classification is based entirely on visual symptoms of injury, but is considered adequate for the investigation of volume relationships because changes in volume production can be expected to be associated with visual changes in stem and branch morphology. It should be noted that trees within any one damage class may support widely varying numbers of aphids. In addition, trees that are apparently undamaged may support a small population of aphids.

The stands from which sample trees were obtained were at a semi-mature or mature stage of development, and were situated on a wide variety of sites. All, except those from which class 0 trees were obtained, had been infested by the balsam woolly aphid for at least 10 years, and in most cases for 15 to 20 years, prior to measurement. The sample trees were from all levels of the stand canopy, and between 30 and 150 years of age.

For each sample tree, total volume and merchantable volume (from one-foot stump to 3-inch top diameter outside bark) were calculated using Smalian's formula. Total and merchantable volume relationships were then calculated for trees in each of the six damage classes, using a modification of the regression technique devised by Honer (1967).

Volume formulae were as follows:

(1) $V_t = D^2/(a + (b/H))$

(2) $V_m = D^2/(a + (b/H))$

where V_t = total stem volume (cubic feet)

V_m = merchantable stem volume (cubic feet)

D = breast height diameter (inches)

H = total height (feet)

a, b = regression coefficients

The volume equations were fitted using the refined curve-fitting method described by Wilson and Douglas (1969), and the linear form of the above expressions, thus:

$$D^2/V(t. \text{ or } m.) = a + b(1/H)$$

Tests were made to determine which of the volume relationships for the various damage classes differed significantly from those for Class 0 (control). The test statistic was as follows:

$$\frac{(n-4)}{2} \; \frac{S_{oj} - S_o - S_j}{S_o + S_j}, \quad \text{distributed as } F_{2,\, n-4}$$

where S_o = residual sum of squares for class 0 equation

S_j = residual sum of squares for class "j" equation

S_{oj} = residual sum of squares for a single equation fitted to pooled data for classes o and j

n = Total number of trees in the two classes.

This expression applies to linear equations, and is not necessarily exactly true for non-linear equations such as formulae (1) and (2) above. The F-tests therefore provide valid comparative evaluations of significance for each of the damage class equations in relation to class 0, but their absolute levels of significance must be considered as approximate only. Total and merchantable volume tables were computed for damage class 0 and for those other damage classes whose equations differed "significantly" from those for class 0.

It is not possible to establish percent accuracy in a rigorous way for the non-linear regressions or for the tables based on them. However, the "actual value" (with 95% probability) of the error for any given volume can be calculated. This "actual value" of the error is that value that would be obtained on repeated application by averaging the absolute values of the error (i.e. disregarding positive and negative signs). For convenience of application, an equation expressing cubic-foot error in terms of estimated volume has been derived for each volume table.

Results

Volume Relationships

On the basis of the computed equations, only damage class M differed significantly (at 1%) from class O in terms of total volume. In terms of merchantable volume classes M (at 1%), S (at 5%), and D (at 5%) differed significantly from class O. Total volume tables for damage classes O and M, and merchantable volume tables for classes O, M, S, and D are presented in Appendix 1. Class O total volume tables can be used for all other classes except class M, while class O merchantable volume tables can also be used for classes U and L.

The percentage increases or decreases in merchantable volume production for trees of classes M, S, and D, as compared to the control trees, are shown in Fig. 1. The percentage change in total volume production for trees in class M is the same as for merchantable volume in this class; the trend line for class M in Fig. 1 therefore applies to changes in both total and merchantable volume. For any given damage class, the percent increase or decrease in volume is the same for all diameter classes (this is determined by the form of the linear transformation of the volume equation) but varies with height. The degree of change is greatest in the smaller trees.

Only very few samples exceeded 50 feet in height in damage classes M, S, and D and little meaning can therefore be attached to the parts of the curves over 50 feet. The essential elements of the trends for all damage classes can be interpreted as follows:

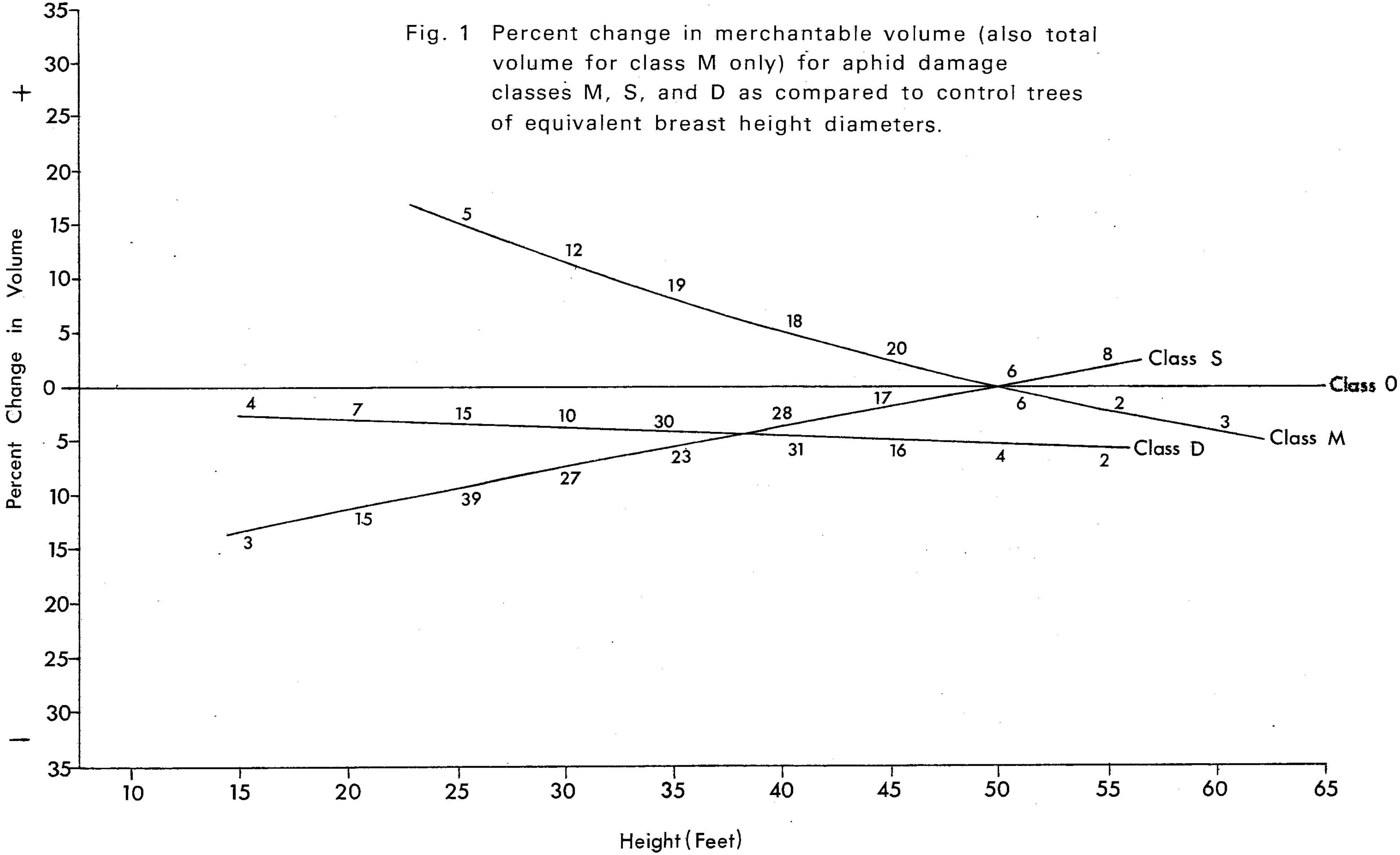

Fig. 1 Percent change in merchantable volume (also total volume for class M only) for aphid damage classes M, S, and D as compared to control trees of equivalent breast height diameters.

Classes U and L: There are no significant differences in total and merchantable volume relationships between trees of these two classes and those of class O.

Class M: Trees between about 45 and 60 feet in height have total and merchantable volumes similar to those of the control trees. Trees below about 45 feet in height have total and merchantable volumes greater than those of control trees of equivalent heights and diameters; 25-foot-high trees have approximately 15 percent more volume than the control trees.

Class S: There is no significant difference between Class S and Class O trees in terms of total volume relationships. For merchantable volume, trees between about 45 and 60 feet in height show little difference from the control, but those below 40 to 45 feet have smaller volumes than control trees of equivalent heights and diameters; twenty-five-foot trees in class S have about 10% less volume than the control trees.

Class D: There is no significant difference between Class D and Class O trees in terms of total volume relationships. At all heights, Class D trees have lower merchantable volumes than control trees of equivalent heights and diameters. The difference ranges from about 3 percent for 15-foot-high trees to about 6 percent for 55-foot-high trees.

Height/Diameter Relationships

The data also provide evidence of a marked change in the normal height/diameter relationships induced by aphid attack. Small diameter trees (about 3 to 5 inches dbh.) of all damage classes have greater heights in relation to their diameters than Class 0 trees (Fig. 2). The difference is most marked for trees of classes U, L, and M. Larger diameter trees (above about 7 inches dbh.) have lesser heights in relation to their diameters than class 0 trees, with trees of classes S and D showing the most marked differences.

Discussion

The significant differences in the tree volume relationships and the changes in height/diameter ratios can be explained in terms of the progression of aphid damage in semi-mature and mature balsam fir stands.

Dominant trees are usually the first to be attacked when the aphid invades a stand (Carroll and Bryant, 1960). Unpublished data indicate that as the aphid continues to feed on these trees, their vertical and lateral growth decreases and they become less competitive within the stand. Smaller trees are released, and respond by growing relatively more rapidly in height than in diameter (at breast height). As these trees reach upper canopy level they in turn become attacked, therefore giving less competition to the trees below them. This sequence of events may not occur in all infested stands because of the large number of factors affecting aphid populations. However, the data presented in this report suggest that, on the average, many of the smaller stems in infested stands do experience a period of release.

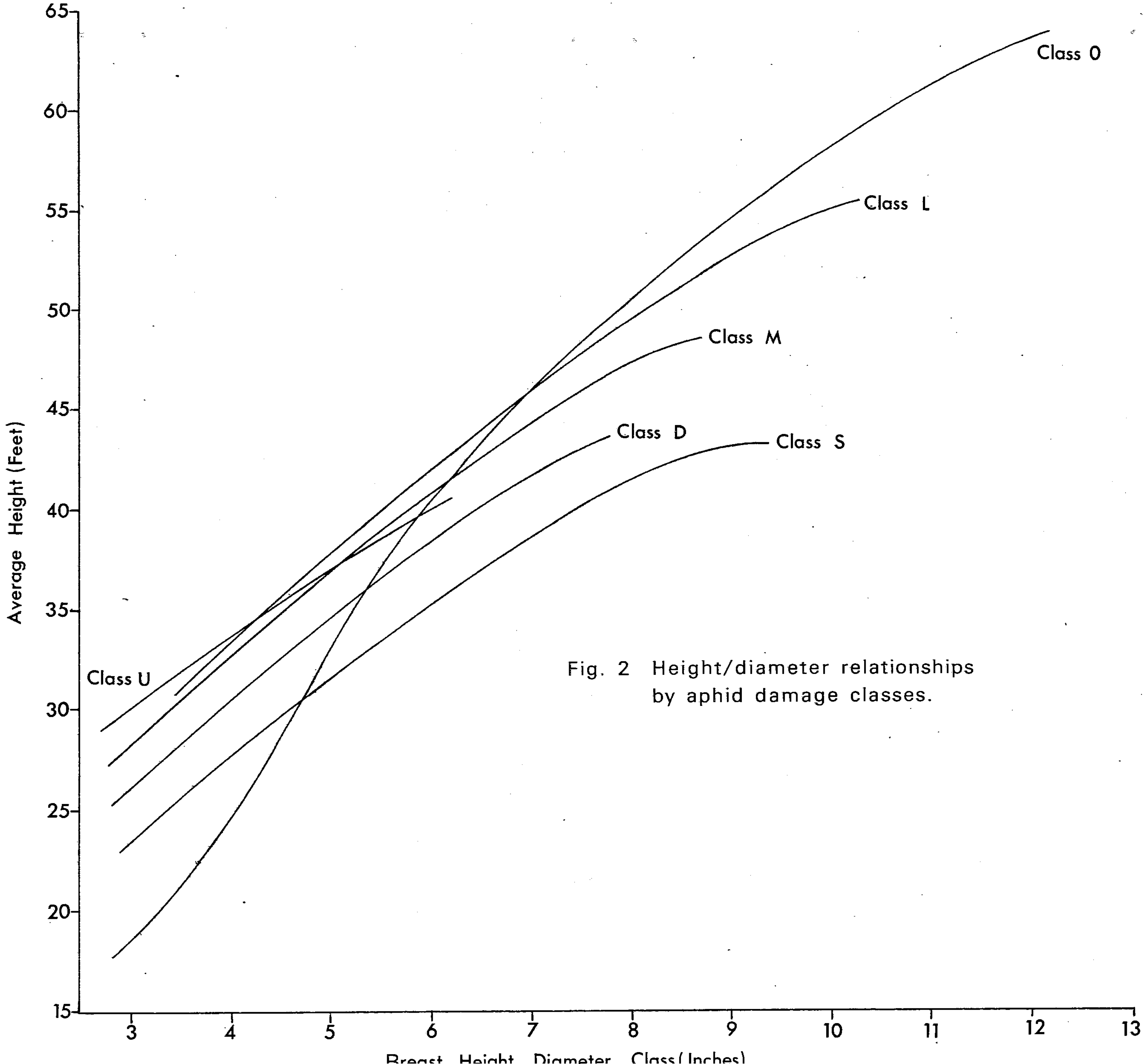

Fig. 2 Height/diameter relationships by aphid damage classes.

The sequence of events described above is clearly illustrated in Fig. 2. Height/diameter ratios of the smaller trees (approximately 3-5 inches dbh.) in the infested stands are greater than those of comparable trees in uninfested stands; the relative increase is dependent upon the severity of aphid damage, with undamaged trees showing the greatest increase and severely damaged trees the least increase. The larger trees, having originally occupied dominant positions in the canopy, do not show any release effects. Their height/diameter ratios are lower than those of the control trees, with those most severely damaged having the smallest ratios.

Lightly damaged trees exhibit only a mild degree of distortion due to aphid attack. Disproportionately rapid upper stem diameter growth (i.e. in the region where the aphid attack affects branch development)may occur as a result of aphid stimulation, but not to a sufficient extent to produce significant change in either total or merchantable volume content as compared to control trees of equivalent height and breast height diameter.

Moderately damaged trees show a greater degree of distortion caused by aphid attack, but all stem components remain alive. The aphid attack appears to induce disproportionately rapid upper stem diameter growth in trees of less than about 45 feet in height, resulting in greater total and merchantable volume contents as compared to control trees of equivalent height and breast height diameter. An increased volume content is not found in stems of more than about 45 feet in height; these stems are apparently unable to respond to a growth stimulus to the same extent as the smaller stems.

Severely damaged trees have dead leaders and many dead and deformed branches. Capacity for growth is decreased, with the most marked effects occurring, once again, in the upper stem region. Decreased diameter growth in this part of the tree (Warren et al, 1967) eventually nullifies the effects of the increased growth that occurs up to the level of moderate damage. In addition, death or severe deformation of the leader often results in the termination of height growth of the main stem. As a result of these two effects, the merchantable volume of severely damaged stems less than 40 to 45 feet in height is significantly lower than that of control stems of equivalent height and breast height diameter. As in the case of moderately damaged stems, the larger trees, most of which have probably passed the stage of most rapid growth, show no meaningful difference from the control trees. Total volume does not differ significantly between control trees and severely damaged trees. This is not, however, unexpected since volume estimation for the severely deformed portions of the stems is difficult and probably rather inaccurate.

Severely damaged dead trees had significantly smaller merchantable volumes than the control trees. The degree of response is similar for trees of all sizes, probably because all trees (including the larger stems) in this damage class were relatively young. The average breast height age of all trees in this class was about 47 years; in class S the smaller trees averaged about 58 years and the larger trees about 66 years; in class M the smaller trees averaged 65 years and the larger trees 70 years. The difference in volume as compared to the control is somewhat less for the smaller class D trees than for comparable class S trees. This, together with the younger average age of the class D trees, suggests that many of them may, for some reason, have died relatively soon after entering the severely damaged class. Hence the period of slower diameter growth was shorter, and the decrease in volume production less marked, than for many of the trees in class S. This apparent rapid death of the class D trees may have been due to very severe aphid attack possibly including stem attack, to the entry of *Armillaria* root rot, or to an inherent susceptibility of the trees themselves to being killed by the aphid.

Conclusions

(1) Normal height/diameter ratios are altered by aphid attack. Many of the smaller trees in aphid infested stands experience a period of release as a result of larger stems being damaged by the aphid. Release effects are more marked and/or more prolonged the smaller the trees (at least down to 3 inches d.b.h.), and result in increased height/diameter ratios. The height/diameter ratios are increased most for those small stems which are not attacked, or only lightly attacked, by the aphid. Larger stems do not experience a period of release, and have smaller height/diameter ratios as compared to the control trees. The more severe the aphid damage the smaller are the height/diameter ratios.

(2) Normal volume relationships are significantly altered for trees in damage classes M, S, and D (moderate and severe damage). All except the larger class M trees have total and merchantable volumes significantly

greater than those of control trees of equivalent height and diameter. All except the larger class S trees have significantly lower merchantable volumes than equivalent control trees; classes O and S do not differ significantly in terms of total volume. Class D trees all have lower merchantable volumes than equivalent control trees; total volumes do not differ significantly from the control.

(3) Results from earlier studies, together with those presented in this report, provide information on individual tree volume relationships, changes in height/breast height diameter ratios, and changes in stem and crown morphology for trees in aphid infested stands. However, the effects of aphid attack on the volume production of semi-mature and mature stands cannot yet be determined since no data are presently available on the effects of the aphid on breast height diameter growth, on the variation of aphid damage within a stand, or on the release response of other tree species. Studies in a number of aphid-infested stands in western Newfoundland are planned for the immediate future to determine these effects, and hence provide a means whereby volume tables presented in this report can be utilized in providing an answer to this important problem.

Acknowledgements

Thanks are due to Messrs. D. Bajzak, J.P. Bouzane and A.J. Robinson for supplying some of the data on which this report is based, and to Dr. A.L. Wilson and other members of staff of the Biometrics and Computer Science Branch, Ottawa, for their invaluable assistance in devising and carrying out the statistical analyses.

Literature Cited

Balch, R.J. and W.J. Carroll. 1958. The balsam woolly aphid. Can. Dept. Agric., Publ. 977. 8 pp.

Carroll, W.J. and D.G. Bryant. 1960. A review of the balsam woolly aphid in Newfoundland. For. Chron. 36(3): 278-290.

Honer, T.G. 1967. Standard volume tables and merchantable conversion factors for the commercial tree species of central and eastern Canada. Can. Dept. For. Rural Dev., For. Br., Information Report FMR-X-5. 21 pp. + App.

Rowe, J.S. 1959. Forest regions of Canada. Can. Dept. North. Aff. Nat. Res., For. Br., Bulletin 123. 71 pp.

Schooley, H.O. and L. Oldford. 1969. Effect of balsam woolly aphid damage on the reproductive potential of balsam fir. Can. Dept. Fisheries & Forestry, Can. For. Serv., Information Report N-X-35. 21 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. Rural Dev., For. Br., Information Report N-X-15. 63 pp.

Wilson, A.L. and A.W. Douglas. 1969. A note on non-linear curve fitting. The American Statistician, Oct. 1969: 37-38.

APPENDIX 1

TOTAL VOLUME TABLE

BALSAM FIR

(ABIES BALSAMEA (L.) MILL.)

DAMAGE CLASS 0

DBHOB CLASS	TOTAL HEIGHT CLASSES 15	20	25	30	35	40	45	50	55	60	65	70	75
1	.05	.07	.08	.09									
2	.21	.27	.32	.38	.42	.47							
3	.47	.61	.73	.85	.96	1.06	1.15						
4	.84	1.08	1.30	1.51	1.70	1.88	2.05	2.21	2.36				
5	1.31	1.68	2.03	2.35	2.65	2.94	3.20	3.45	3.69	3.91			
6	1.89	2.42	2.92	3.39	3.82	4.23	4.61	4.97	5.31	5.63	5.93	6.21	
7		3.30	3.98	4.61	5.20	5.76	6.28	6.76	7.22	7.66	8.07	8.46	8.82
8			5.20	6.02	6.80	7.52	8.20	8.83	9.44	10.00	10.54	11.04	11.52
9			6.58	7.62	8.60	9.52	10.37	11.18	11.94	12.66	13.34	13.98	14.59
10				9.41	10.62	11.75	12.81	13.80	14.74	15.63	16.46	17.26	18.01
11				11.39	12.85	14.21	15.50	16.70	17.84	18.91	19.92	20.88	21.79
12					15.29	16.92	18.44	19.88	21.23	22.50	23.71	24.85	25.93
13						19.85	21.65	23.33	24.92	26.41	27.83	29.16	30.43
14									28.90	30.63	32.27	33.82	35.29

VTCF = (DBHOB**2/(A+(B/H)))
A = +2.172
B = +253.607

ESTIMATED ERROR IN CF
+ OR – (.173+.0612*VTCF)

Basis: 84 trees from western Newfoundland

_____ Underlined values represent trees of dimensions actually sampled.

APPENDIX 1 (Cont'd)

TOTAL VOLUME TABLE

BALSAM FIR

(ABIES BALSAMEA (L.) MILL.)

DAMAGE CLASS M

DBHOB CLASS	TOTAL HEIGHT CLASSES 15	20	25	30	35	40	45	50	55	60	65	70	75
1	.06	.08	.09	.10									
2	.26	.32	.37	.42	.46	.49							
3	.58	.72	.84	.94	1.03	1.11	1.18						
4	1.04	1.28	1.49	1.67	1.83	1.97	2.09	2.21	2.31				
5	1.62	2.00	2.33	2.61	2.86	3.08	3.27	3.45	3.61	3.75			
6	2.34	2.88	3.35	3.76	4.12	4.43	4.71	4.97	5.19	5.40	5.59	5.76	
7		3.92	4.56	5.12	5.60	6.03	6.42	6.76	7.07	7.35	7.61	7.84	8.05
8			5.96	6.68	7.32	7.88	8.38	8.83	9.23	9.60	9.93	10.24	10.52
9			7.54	8.46	9.26	9.97	10.61	11.17	11.69	12.15	12.57	12.96	13.3[illegible]
10				10.44	11.43	12.31	13.09	13.79	14.43	15.00	15.52	16.00	16.44
11				12.63	13.83	14.90	15.84	16.69	17.46	18.15	18.78	19.36	19.89
12					16.46	17.73	18.85	19.86	20.77	21.60	22.35	23.04	23.67
13						20.80	22.13	23.31	24.38	25.35	26.23	27.04	27.78
14									28.28	29.40	30.42	31.36	32.2[illegible]

VTCF = (DBHOB**2/(A+(B/H)))
A = +3.754
B = +174.766

ESTIMATED ERROR IN CF
+ OR - (.110+.0096*VTCF**2)

Basis: 85 trees from western Newfoundland

APPENDIX 1 (Cont'd)

MERCHANTABLE VOLUME TABLE

BALSAM FIR

(ABIES BALSAMEA (L.) MILL.)

DAMAGE CLASS 0

DBOH CLASS	TOTAL HEIGHT CLASSES 15	20	25	30	35	40	45	50	55	60	65	70	75
1	.05	.06	.08	.09									
2	.20	.25	.31	.36	.40	.45							
3	.44	.57	.69	.80	.91	1.01	1.10						
4	.78	1.01	1.22	1.42	1.61	1.79	1.96	2.12	2.27				
5	1.22	1.58	1.91	2.22	2.52	2.80	3.06	3.31	3.55	3.77			
6	1.76	2.27	2.75	3.20	3.63	4.03	4.41	4.77	5.11	5.43	5.74	6.03	
7		3.09	3.74	4.36	4.94	5.48	6.00	6.49	6.95	7.39	7.81	8.21	8.59
8			4.89	5.69	6.45	7.16	7.84	8.48	9.08	9.66	10.20	10.72	11.22
9			6.19	7.20	8.16	9.07	9.92	10.73	11.49	12.22	12.91	13.57	14.20
10				8.89	10.08	11.19	12.25	13.24	14.19	15.09	15.94	16.76	17.53
11				10.76	12.19	13.54	14.82	16.03	17.17	18.26	19.29	20.27	21.21
12					14.51	16.12	17.63	19.07	20.43	21.73	22.96	24.13	25.24
13						18.91	20.70	22.38	23.98	25.50	26.94	28.32	29.63
14									27.81	29.57	31.25	32.84	34.36

VM = (DBOH**2/(A+(B/H)))
A = +2.012
B = +276.925

ESTIMATED ERROR IN CF
+ OR - (.491 +.00233*VM**2)

Basis: 84 trees from western Newfoundland

APPENDIX 1 (Cont'd)

MERCHANTABLE VOLUME TABLE

BALSAM FIR

(ABIES BALSAMEA (L.) MILL.)

DAMAGE CLASS M

DBOH CLASS	TOTAL HEIGHT CLASSES 15	20	25	30	35	40	45	50	55	60	65	70	75
1	.06	.08	.09	.10									
2	.24	.30	.35	.40	.44	.47							
3	.55	.68	.79	.89	.98	1.06	1.13						
4	.97	1.20	1.41	1.58	1.74	1.88	2.01	2.12	2.22				
5	1.52	1.88	2.20	2.47	2.72	2.94	3.13	3.31	3.47	3.62			
6	2.18	2.71	3.16	3.56	3.92	4.23	4.51	4.77	5.00	5.21	5.40	5.57	
7		3.69	4.31	4.85	5.33	5.76	6.14	6.49	6.80	7.09	7.35	7.59	7.81
8			5.63	6.34	6.96	7.52	8.02	8.48	8.88	9.26	9.60	9.91	10.20
9			7.12	8.02	8.81	9.52	10.16	10.73	11.24	11.72	12.15	12.54	12.91
10				9.90	10.88	11.75	12.54	13.24	13.88	14.46	15.00	15.48	15.93
11				11.98	13.17	14.22	15.17	16.02	16.80	17.50	18.15	18.74	19.28
12					15.67	16.93	18.05	19.07	19.99	20.83	21.59	22.30	22.94
13						19.87	21.19	22.38	23.46	24.44	25.34	26.17	26.93
14									27.21	28.35	29.39	30.35	31.23

VM = (DBOH**2/(A+(B/H)))
A = +3.726
B = +191.253

ESTIMATED ERROR IN CF
+ OR - (.574 -.0977*VM+.0141*VM**2)

Basis: 85 trees from western Newfoundland

APPENDIX 1 (Cont'd)

MERCHANTABLE VOLUME TABLE

BALSAM FIR

(ABIES BALSAMEA (L.) MILL.)

DAMAGE CLASS S

DBOH CLASS	TOTAL HEIGHT CLASSES 15	20	25	30	35	40	45	50	55	60	65	70	75
1	.04	.06	.07	.08									
2	.17	.22	.28	.33	.38	.43							
3	.38	.50	.62	.74	.86	.97	1.08						
4	.68	.90	1.11	1.32	1.52	1.73	1.92	2.12	2.31				
5	1.06	1.40	1.73	2.06	2.38	2.70	3.00	3.31	3.60	3.90			
6	1.53	2.02	2.50	2.97	3.43	3.88	4.33	4.76	5.19	5.61	6.02	6.43	
7		2.75	3.40	4.04	4.67	5.28	5.89	6.48	7.06	7.63	8.20	8.75	9.29
8			4.44	5.28	6.10	6.90	7.69	8.46	9.23	9.97	10.70	11.42	12.13
9			5.62	6.68	7.71	8.73	9.73	10.71	11.68	12.62	13.55	14.46	15.35
10				8.24	9.52	10.78	12.02	13.23	14.41	15.58	16.73	17.85	18.96
11				9.97	11.52	13.05	14.54	16.00	17.44	18.85	20.24	21.60	22.94
12					13.72	15.53	17.30	19.05	20.76	22.44	24.09	25.70	27.30
13						18.22	20.31	22.35	24.36	26.33	28.27	30.17	32.03
14									28.25	30.54	32.78	34.99	37.15

VM = (DBOH**2/(A+(B/H)))
A = +0.705
B = +342.792

ESTIMATED ERROR IN CF
+ OR – (.417 – .111*VM+.0198*VM**2)

Basis: 166 trees from western Newfoundland

APPENDIX 1 (Cont'd)

MERCHANTABLE VOLUME TABLE

BALSAM FIR

(ABIES BALSAMEA (L.) MILL.)

DAMAGE CLASS D

DBOH CLASS	TOTAL HEIGHT CLASSES 15	20	25	30	35	40	45	50	55	60	65	70	75
1	.05	.06	.07	.09									
2	.19	.24	.29	.34	.39	.43							
3	.43	.55	.66	.77	.87	.96	1.05						
4	.76	.98	1.18	1.37	1.54	1.71	1.86	2.00	2.14				
5	1.19	1.53	1.84	2.14	2.41	2.67	2.91	3.13	3.35	3.55			
6	1.71	2.20	2.65	3.07	3.47	3.84	4.18	4.51	4.82	5.11	5.38	5.64	
7		2.99	3.61	4.18	4.72	5.22	5.70	6.14	6.56	6.95	7.32	7.67	8.01
8			4.72	5.47	6.17	6.82	7.44	8.02	8.56	9.08	9.56	10.02	10.46
9			5.97	6.92	7.80	8.64	9.42	10.15	10.84	11.49	12.10	12.69	13.24
10				8.54	9.64	10.66	11.62	12.53	13.38	14.18	14.94	15.66	16.34
11				10.33	11.66	12.90	14.06	15.16	16.19	17.16	18.08	18.95	19.78
12					13.88	15.35	16.74	18.04	19.27	20.43	21.52	22.55	23.54
13						18.02	19.64	21.17	22.61	23.97	25.26	26.47	27.62
14									26.23	27.80	29.29	30.70	32.04

VM = (DBOH**2/(A+(B/H)))
A = +2.391
B = +279.544

ESTIMATED ERROR IN CF
+ OR – (.426 –.0733*VM +.0107*VM**2)

Basis: 119 trees from western Newfoundland