Armillaria root rot in aphid-damaged balsam fir in Newfoundland

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The balsam woolly aphid, *Adelges piceae* (Ratz.), a pest of true firs, *Abies* spp., was discovered in Newfoundland in 1949. The aphid feeds by inserting its stylets into the cortical tissue, causing damage to the branches and stems of trees. Small numbers of aphids may be present for 2 or 3 years before symptoms of feeding become apparent. The symptoms include: inhibited shoot growth, pronounced swelling of nodes, thinning of the foliage, production of wood with an abnormally high lignin content, and die-back of the crown. Trees with these symptoms usually remain stagnated for several years prior to death (Carroll and Bryant 1960).

Since its discovery on the Island, the aphid has spread over 6,000 square miles (15,500 km²) of balsam fir (*Abies balsamea* (L.) Mill.) forest. The most extensive infestations occur in western Newfoundland where fir comprises more than 70% of the softwood stands. Warren et al. (1967) estimated an average of 12% tree mortality in merchantable stands that had been damaged by the aphid for a period of 10 to 15 years.

Studies in Newfoundland have shown that aphid damage pre-disposes trees to infection by *Armillaria mellea* (Vahl ex Fr.) Kummer, a fungus that has a worldwide distribution (Hudak and Singh 1970). Our paper compares the incidence and intensity of *Armillaria* root rot in trees in different aphid damage classes on representative balsam fir sites in western Newfoundland and indicates how losses may be minimized.

Description of study areas

Investigations were conducted in southwestern Newfoundland in six merchantable 60- to 70-year old balsam fir stands located at Serpentine Lake, Codroy Pond, Bottom Brook, St. Fintans, Crabbes River and Flat Bay Brook. Although some trees may have been infested with the aphid, there was no evidence of damage in the stand at Serpentine Lake; damage was extensive in the other stands.

The most productive site occurred at Codroy Pond where the average site index was 46 ft (14 m) at 50 years of age (Page 1968). The soil was a

Le sapin baumier à Terre-Neuve: interrelations entre les effets du Pourridié-Agaric et du puceron lanigère. Les auteurs étudièrent le rapport entre le Pourridié-Agaric et les dommages causés par le puceron lanigère du sapin en six endroits éloignés dans la partie occidentale de l'île de Terre-Neuve. La qualité de la station n'avait apparemment pas d'effet sur la présence et l'intensité de la maladie. Les dommages causés par le puceron constituèrent le facteur primaire de la forte présence du Pourridié-Agaric dans les arbres examinés. Cette maladie devient plus importante à mesure que les aires d'infestation du puceron s'agrandissent et que les dommages causés par celui-ci augmentent.

moist, sandy colluvial till and was classified as gleyed dystic brunisol (National Soil Survey Committee of Canada 1970). The pH varied from 3.8 in the humus layer to 5.2 in the B horizon. The amount of organic matter was 44% in the humus layer, 0.9% in the A horizon and 1.9% in the B horizon. The poorest site occurred at Flat Bay Brook where the average site index was 38 ft (11.5 m) at 50 years of age. The soil was a well drained sandy loam orthic ferro-humic podzol. The pH in the LFH, A and B horizons was 3.9, 4.2 and 4.9 respectively. The percentage of organic matter in these horizons was 55%, 1.0% and 10.7%. Although the soil characteristics in the other locations showed some differences the variation was slight, the site indices ranging from 40 ft (12.2 m) at Crabbes River and Serpentine Lake to 42 ft (12.8 m) at Bottom Brook and St. Fintans.

Sampling methods

In each study area trees over 3.5 inches (9 cm) dbh were sampled for aphid damage and *Armillaria* root rot along a randomly selected 8-ft (2.4-m) wide strip. Visual symptoms of aphid damage in the crowns were used to separate trees into five damage classes as follows:

undamaged — no apparent symptoms of aphid attack

light — nodal swelling and branch distortion present, few branch tips inhibited

medium — nodal swelling and branch distortion pronounced, branch tips inhibited, few branches bare up to 12 inches (30 cm)

severe — very pronounced nodal swelling and shoot distortion, many branches bare for 12 inches (30 cm) or more

dead — similar symptoms as in the severe damage class but all branches bare of green needles and inner bark dead at breast height.

Sampling in each of the damaged stands was continued until 10 trees were examined in each class. In the undamaged stand the first 40 trees were sampled.

Three main roots of each tree were exposed for their entire length and a 3-ft (0.9-m) section nearest to the root collar was checked for characteristic symptoms and signs of the root rot. These included

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TABLE 1. Site index of the study areas and percentage of trees with *Armillaria* root rot in the five balsam woolly aphid damage classes

Location	Site index (ft)	(m)	Damage class %					Average
			Undamaged	Light	Moderate	Severe	Dead	
Flat Bay Brook.....	38	11.5	—	0	0	30	90	30.0
Serpentine Lake.....	40	12.2	2.5	—	—	—	—	2.5
Crabbes River.....	40	12.2	—	10	30	40	70	37.5
Bottom Brook.....	42	12.8	—	10	20	30	100	40.0
St. Fintans.....	42	12.8	—	0	30	30	100	40.0
Codroy Pond.....	46	14.0	—	0	20	30	80	32.5
Average			2.5	4	20	32	88	30.4
Average (light to severe damage class)								18.6
Average (light to dead damage class)								36.0

discoloration of the bark, resin exudation and mycelial fans under the bark. The mycelial fans along the length and circumference of roots were measured. Circumference measurements were taken where the fans covered the largest proportion of root perimeter. Disease incidence was expressed as a percentage of infected trees and disease intensity as a percentage of infected roots and as percentages of longitudinal and perimetric extent of mycelial fans on infected roots.

Extent of damage

Percentages of trees infected with *A. mellea* in the five aphid damage classes are presented in Table 1 in increasing order of site index for the study areas. The disease was present in all areas and analysis of variance showed that disease incidence was not related to site at the 5% probability level, but increased significantly with aphid damage. The lowest level of infection, 2.5%, occurred in undamaged trees and infection in damaged trees averaged 4% in the light, 20% in the moderate, 32% in the severe and 88% in the dead class.

The percentage of infected roots increased from 2.0% in the light damage class to 14.6% in the severe, while the longitudinal extent of mycelial fans on infected roots varied from 26.8% to 63.7% (Table 2). The average percentage of root circumference covered by mycelium in living trees also increased from 10.0% to 80.0% as aphid damage increased from light to severe. Percentage of infected roots and percentage extent of mycelial fans were

higher in dead trees than in any other damage class.

Management implications

A. mellea infected both undamaged and aphid-damaged trees but disease incidence and intensity increased markedly with increasing levels of aphid damage regardless of differences in forest site. Therefore, it is concluded that damage caused by the aphid was the primary factor responsible for the high incidence and intensity of the root rot in damaged trees. Aphid damage to balsam fir stands is known to vary with elevation and soil moisture regime (Page 1973), consequently site may have an indirect effect on disease incidence in stands. However, the fungus is common in most forest soils in Newfoundland and stands with the most aphid damage are expected to have the highest percentage of infected trees. In addition the intensity of the disease, expressed as the percentages of root length and circumference covered by mycelial fans, indicates that *A. mellea* is an important factor contributing to the mortality of mature trees severely damaged by the aphid. As there are no practical biological or chemical methods for controlling either balsam woolly aphid or *Armillaria* root rot it is suggested that forest managers harvest aphid-infected stands on the shortest economically feasible rotation to reduce losses in wood fibre production. The highest priority should be placed on utilizing mature stands severely damaged by the aphid. This practice would yield an additional benefit as experience has shown that such stands die rapidly after they are attacked by defoliating insects.

TABLE 2. Incidence and intensity of *Armillaria* root rot in balsam fir in five aphid damage classes

Damage class	No. trees examined	Trees infected		No. roots examined	Roots infected		Percent extent of mycelial fans	
		Number	Percent		Number	Percent	Lengthwise	Perimetric
Undamaged	40	1	2.5	120	1	0.8	11.1	8.0
Light	50	2	4.0	150	3	2.0	26.8	10.0
Moderate	50	10	20.0	150	11	7.3	36.3	39.0
Severe	50	16	32.0	150	22	14.6	63.7	80.0
Dead	50	44	88.0	150	104	69.6	77.3	90.0

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