Armillaria Root Rot Damage in Softwood Plantations in Ontario

by

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Abstract

Armillaria root rot, caused most likely by *Armillaria obscura* (Pers.) Herink, killed 6- to 21-year-old white spruce, black spruce, jack pine and red pine saplings in each of 49 plantations examined in northern Ontario. Annual mortality in the four species over the last 2 to 6 years averaged 1.4%, 1.5%, 0.5% and 0.2%, respectively. In all but one of 25 white spruce and red pine plantations (43 to 58 years old) in eastern and southern Ontario, *Armillaria* root rot was associated with mortality. Accumulated mortality in white spruce and red pine (initially recorded in 1978) averaged 7.6% and 11.7%, respectively, as of 1986. Current annual mortality for all plantations ranged from 0% to 16%.

Key words: root rot, *Armillaria obscura*, white spruce, black spruce, jack pine, red pine.

Résumé

Le pourridié-agaric, causé fort probablement par *Armillaria obscura* (Pers.) Herink, est à l'origine de la mortalité d'Epinettes blanches, d'Epinettes noires, de Pins gris et de Pins rouges âgés de 6 à 21 ans dans 49 plantations situées dans le nord de l'Ontario. Au cours des 2 à 6 dernières années, les taux de mortalité annuels moyens ont été respectivement de 1.4%, 1.5%, 0.5% et 0.2% chez les quatre espèces. La mortalité des arbres est due au pourridié-agaric dans 24 des 25 plantations d'Epinettes blanches et de Pins rouges (âgés de 43 à 58 ans) évaluées dans l'est et le sud de l'Ontario. Les taux de mortalité cumulatifs moyens des Epinettes blanches et des Pins rouges (calculés depuis 1978) étaient respectivement de 7.6% et de 11.7% en 1986. À l'heure actuelle, le taux de mortalité annuel varie de 0% à 16% dans toutes les plantations.

Mots clés: pourridié-agaric, *Armillaria obscura*, Epinette blanche, Epinette noire, Pin gris, Pin rouge

Introduction

Armillaria root rot-induced mortality has been observed in all conifers planted in Ontario (Anon. 1970-1983). *Armillaria mellea* (Vahl. ex Fr.) Kummer² was the main root-rotting fungus in dying conifer saplings of natural regeneration at several locations throughout Ontario (Whitney and Myren 1978). Huntley *et al.* (1961) found that up to 29% of planted white pine (*Pinus strobus* L.) and red pine (*P. resinosa* Ait.), growing near hardwood stumps, were killed by *A. mellea* 21 years after planting. The same study reported that 55% of the trees were dead 31 years after planting. Forest Insect and Disease Survey records (Anon. 1970-1983) show up to 27% mortality in red pine plantations. Many plantations of white

spruce (*Picea glauca* [Moench] Voss), black spruce (*P. mariana* [Mill.] B.S.P.), jack pine (*Pinus banksiana* Lamb.), white pine (*P. strobus* L.), lodgepole pine (*P. contorta* Dougl.) and Scots pine (*P. sylvestris* L.) have also shown mortality as a result of the presence of *Armillaria* root rot.

Since the discovery of the complex of *Armillaria* species and related biological forms by Korhonen (1978) in Europe and by Anderson and Ullrich (1979) in North America, a measure of uncertainty has been created about the identity of the species/forms of *Armillaria* present in Ontario. The species that is known to attack conifers in Ontario and is being discussed in this report is most likely *A. obscura* (Pers.) Herink.³

Surveys based on systematic tree selection from a random start in "high-value" Ontario plantations indicate that low proportions (1-2%) of trees are killed, and that many plantations have no *Armillaria* root rot at all (H.L. Gross and P.D. Syme, Great Lakes Forestry Centre, Sault Ste. Marie, Ont., unpublished data). It seems that the occurrence of *Armillaria* root rot is sporadic and results in groups of dead trees. Stocking of the desired species can be far from adequate where large openings (10-30 m diameter) occur in the forest, or where groups of 5 to 10 dead trees are frequent. This makes

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²Probably *A. obscura* (Pers.) Herink.

³Isolates of *Armillaria* from the roots of white spruce and black spruce from some 60 plots in natural stands across northern Ontario were identified by Dr. D. Morrison (Pacific Forestry Centre, Victoria, British Columbia) as *Armillaria ostoyae* (Romagn.) Herink, which is now considered synonymous with *A. obscura* (Pers.) Herink. (Roll-Hansen 1985). Pairings of single-spore isolates from northern Ontario sporophores by Dr. M.T. Dumas (Great Lakes Forestry Centre, Sault Ste. Marie, Ontario) have confirmed that the northern Ontario samples are *A. obscura* and have also identified that this species is present in 60-year-old red pine in southern Ontario.

it difficult to estimate damage resulting from the disease. This study was undertaken in an attempt to improve our knowledge of losses caused by *Armillaria* root rot in conifer plantations in Ontario.

Methods

One plot was located in each of 49 plantations planted between 1960 and 1980, and in each of 25 older plantations established between 1925 and 1940.

Young plantations (planted between 1960 and 1980) of white spruce ($n = 15$), black spruce ($n = 11$), jack pine ($n = 15$) and red pine ($n = 11$) were selected in widely separated areas in northern and eastern Ontario. The investigations extended from Nipigon in the west to Temagami in the eastern part of the province. Moderately well stocked stands aged 6 to 21 years were sampled. In a selected area considered to be representative of the plantation, a 0.2-ha plot (20 m $\times$ 100 m) was laid out, marked with wooden plot corner posts, and located on a map. All living and dead trees were tallied. Wherever root rot was suspected as the killing agent, the basal bark of dead trees was peeled back and a few roots were excavated or exposed. Tree death was attributed, at least in part, to *Armillaria* root rot when mycelial fans or rhizomorphs were observed under root bark or under bark in the root collar area (Fig. 1), or when *Armillaria* sporophores were seen attached to the base of dead trees (Fig. 2). Trees in which mortality or damage was attributable to other causes were excluded from the tally. Dead trees were located and marked with paint to avoid retallying them at the next 2-year evaluation. Initial mortality counts were made in the plantations at various times between 1979 and 1983. Following the initial assessment, additional *Armillaria*-caused mortality was tallied every two years except in a red pine plantation in Davis Twp. Thus, plots established in 1979 were reassessed for mortality in 1981, 1983 and 1985. Those established in 1983 were reassessed only once — in 1985.

Older plantations (planted between 1925 and 1940 in eastern and southern Ontario) of white spruce and red pine were also sampled. Plots (0.2 ha) were established in 1983 for biennial examination. Plots at Petawawa were an exception, as they were superimposed on .08-ha plots, usually square. Bark of the lower bole, root collar and larger roots of older, dead trees was removed; the presence of mycelial fans or rhizomorphs on the cambium was considered to be a sign of *Armillaria* root rot (Fig. 3). The cause of death of older trees was not easily determined in many cases. The older dead trees with *Armillaria* root rot infection frequently revealed signs of bark beetles⁴, as indicated by galleries and exit holes.

Results

Young Plantations (Planted between 1960 and 1980)

In chlorotic or recently dead trees of all species, mycelial fans of *Armillaria* usually encircled the base of the tree. However, in trees dead for about 3 years, only fragments of the mycelial fans were observed in most cases.

In 15 white spruce plantations aged 6 to 20 years, mortality from *Armillaria* root rot at the time of plot establishment ranged from 0.3% to 17.3% (an average of

Figure 1. Mycelial fans of *Armillaria* spp. girdled the base of chlorotic 7-year-old jack pine, causing chlorosis.

3.7%) of total trees planted (Table 1). Dead trees were mostly scattered throughout the plantation, but groups of two or three dead trees were often observed. Occasionally, larger groups of dead trees were observed, forming gaps in the stand. Additional mortality over three subsequent 2-year periods ranged from 0 to 10.1% per period. Mortality after the plots were established (at various times) averaged 1.4% per year. These dead trees were most frequently found adjacent to trees killed earlier. Accumulated mortality, including that observed during the initial assessment, averaged 10.2% of white spruce trees per plot (Table 1).

On the 11 black spruce plantations, initial mortality due to *Armillaria* root rot ranged from 0 to 13.0% (avg 5.0%) of total trees (Table 2). Most dead black spruce were also scattered. Mortality over three additional 2-year periods averaged 2.6%, 3.5% and 3.5%, respectively, so that average annual mortality was 1.5% (Table 2), a rate almost identical to that for white spruce. Average accumulated mortality from *Armillaria* root rot in black spruce was 14.6% per plot after the initial assessment in 1979.

Figure 2. Eight-year-old black spruce near Chipman Lake, Ontario, infected with *Armillaria* spp. Left, an infected, living tree; right, a dead tree with sporophores around its base.

⁴Identified as *Ips pini* (Say) by P.D. Syme, Entomologist, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario.

Figure 3. Mycelial fans of *Armillaria* spp. at the base of chlorotic 45-year-old red pine, York County Forest, Ontario.

Initial mortality in young jack pine due to *Armillaria* root rot ranged from 0.6% to 10.2% (an average of 2.5%) in 15 plantations (Table 3). Subsequent mortality in jack pine over three ensuing 2-year periods ranged up to 4.2% per period. Accumulated average mortality in all jack pine plantations over the survey period was 6.2%. Average annual mortality was only 0.5% (Table 3). Dead jack pine were usually scattered throughout the stands in a manner similar to that of the spruces.

Young red pine plantations showed the least mortality owing to *Armillaria* root rot. Initial mortality ranged from 0.2% to 13.7% of all trees killed (Table 4). Average annual mortality 2 years later was below 1% in all plantations, with the exception of Kennedy Creek plantation near Wawa, where annual mortality was 16%.

Regression analyses indicated that plantation density and year of sampling had no influence on mortality caused by *Armillaria* root rot. Among the younger plantations, however, plantation age significantly affected the proportions of white spruce trees killed by this disease. Figure 4 indicates that more *Armillaria*-killed trees were found in the youngest (6 and 7 years old) plantations than in plantations 10 to 20 years old. However, the correlation is low ($r = .54$). Examination of individual plantations in Tables 1 and 2 showed that there was a downward trend in *Armillaria*-caused mortality over a 5- or 6-year period in about 25% of the plots. This was most common in stands of white spruce, and several black spruce plantations showed the opposite trend.

Older Plantations (Planted between 1925 and 1940)

Table 5 shows that *Armillaria*-caused mortality ranged from 0.3% to 15.4% of the stand in nine older (45-53 yr) red

Table 1. Mortality of 6- to 20-year-old white spruce saplings caused by *Armillaria* root rot on 0.2-ha plots in 15 northern Ontario plantations.

Location	Year of plot establishment	Age	Density (trees per ha)	Trees killed by <i>Armillaria</i> root rot (%) (based on 180-700 trees per plot)				
				Initial examination ^a	2 yr later	4 yr later	6 yr later	Annual avg ^b
Chapleau Manning Twp	1979	8	2 400	1.7	1.3	0.8	0.2	0.4
Geraldton Cedar Mtn	1979	11	1 300	3.1	1.2	0.4	0.0	0.3
Gretal Cr	1979	11	1 325	3.2	1.2	0.8	0.8	0.5
Greta Rd No. 1	1982	8	2 400	2.9	2.1	3.9		1.5
No. 2	1982	8	2 100	2.9	2.5	7.4		2.5
No. 3	1982	8	2 000	6.7	7.5	8.0		3.9
Florrie Rd No. 1	1981	8	3 500	0.3	0.9	0.4		0.3
Hearst Ritchie Twp	1979	11	1 500	2.6	1.4	0.4	0.4	0.4
Hillsport No. 1	1981	17	2 000	17.3	2.8	1.9		1.2
No. 3	1981	6	2 800	4.4	9.1	5.3		3.6
No. 4	1981	6	3 100	5.1	8.9	10.1		4.8
Temagami Gillies Twp	1983	14	1 750	1.7	0.0			0.0
White River Kenshoe L. No. 1	1980	20	1 000	2.5	0.0	0.0	0.5	0.1
Kenshoe L. No. 2	1980	20	900	0.5	0.0	1.1	1.7	0.5
Ylo Lake	1980	11	1 800	1.4	0.6	0.8	0.6	0.3
Average				3.7	2.9	3.0	0.6	1.4
Accumulated avg mortality							10.2	

^a mortality recorded at time of plot establishment

^b for periods after the initial measurement only

Table 2. Mortality of 7- to 20-year-old black spruce saplings caused by Armillaria root rot on 0.2-ha plots in 11 Ontario plantations.

Location	Year of plot establishment	Age	Density (trees per ha)	Trees killed by Armillaria root rot (%) (based on 160-940 trees per plot)				
				Initial examination ^a	2 yr later	4 yr later	6 yr later	Annual avg ^b
Geraldton								
Florrie Rd No. 5	1982	9	4 700	5.5	4.1			2.1
Florrie Rd No. 6	1981	8	3 200	3.2	0.3	2.6		0.7
Oly Lake	1980	10	1 700	13.0	3.0	3.5		1.6
Hillsport No. 2	1981	14	2 000	5.4	2.4	2.5		1.2
Kapuskasing								
Opasatica Twp	1979	9	3 800	0.0	0.0	3.7	4.3	1.3
Wawa								
Kennedy Cr No. 3	1980	7	1 400	5.8	8.8	11.8	8.1	4.8
White River								
Cupa Lake								
Elsie Lake No. 2	1980	12	2 200	2.7	0.9	1.2	1.0	0.5
Elsie Lake No. 3	1980	8	1 500	6.2	2.6	2.6	2.7	1.3
Elsie Lake No. 4	1980	8	1 750	6.9	4.2	5.3	6.0	2.6
Kenshoe Lake No. 2	1980	8	1 650	5.4	2.2	0.7	2.6	0.9
	1980	20	800	1.2	0.0	0.6	0.0	0.1
Average				5.0	2.6	3.5	3.5	1.5
Accumulated avg mortality							14.6	

^arecorded at time of plot establishment.^bfor periods after the initial measurement only.

pine plantations in 1983. In most cases, the dead trees were in small groups of two to five trees. Occasionally, larger groups of trees were also killed (Fig. 5). Mycelial fans were abundant between bark and xylem tissues. In some recently dead trees, mycelial fans were found as high as 2-3 m up the trunk, and sporophores were produced from this region. Sporophores and small amounts of subcortical mycelium at ground level or slightly above ground level were also observed on some trees

that showed no symptoms of decline in the crown (Fig. 6). Average annual mortality due to Armillaria root rot in older red pine plantations varied from 0.0% to 4.5% in 1984 and 1985 (Table 5).

Twelve of the 14 older white spruce plantations examined were in the well-studied experimental plantations at Petawawa. As with red pine, there was considerable variation

Table 3. Mortality of 6- to 21-year-old jack pine saplings caused by Armillaria root rot on 0.2-ha plots in 15 Ontario plantations.

Location	Year of plot establishment	Age	Density (trees per ha)	Trees killed by Armillaria root rot (%) (based on 60-840 trees per plot)				
				Initial examination ^a	2 yr later	4 yr later	6 yr later	Annual avg ^b
Espanola								
Dunlop Twp	1983	21	550 ^c	2.9	0.9			0.5
Mandamin Twp	1983	21	300 ^c	3.3	0.0			0.0
Moses Twp	1983	20	2 450	10.2	2.1			1.0
Nairn Twp No. 1	1983	20	2 130	2.1	1.0			0.5
Nairn Twp No. 2	1983	20	750 ^c	2.0	0.0			0.0
Tennysen Twp No. 1	1983	13	2 500	1.4	2.0			1.0
Temagami								
Gamble Twp	1983	14	2 700	1.8	0.2			0.1
McGiffin Twp	1983	12	2 700	1.7	0.2			0.1
Wawa								
Challenger Twp	1980	9	4 200	1.7	0.8	0.7	1.6	0.5
Kennedy Cr No. 1	1980	6	3 000	3.1	1.9	1.1	0.9	0.7
Kennedy Cr No. 2	1980	6	1 000	2.6	4.0	0.0	3.7	1.3
Kennedy Cr No. 3	1980	6	2 000	1.5	3.5	4.2	1.1	1.5
White River								
Elsie Lake No. 2	1980	8	850	1.2	1.3	0.6	1.2	0.5
Elsie Lake No. 3	1980	8	4 000	0.8	1.3	0.9	0.3	0.4
Elsie Lake No. 4	1980	8	2 350	0.6	0.4	0.2	0.0	0.1
Average				2.5	1.3	1.1	1.3	0.5
Accumulated avg mortality							6.2	

^arecorded at time of plot establishment.^bfor periods after the initial measurement only.^cnatural-seeded on a red pine plantation.

Table 4. Mortality of 6- to 21-year-old red pine caused by Armillaria root rot on 0.2-ha plots in 11 Ontario plantations.

Location	Year of plot establishment	Age	Density (trees per ha)	Trees killed by Armillaria root rot (%) (based on 250-450 trees per plot)			
				Initial examination ^a	2 yr later	4 yr later	Annual avg ^b
Espanola							
Dunlop Twp	1983	21	1 400	2.5	0.4		0.2
Mandamin Twp	1983	21	1 250	0.8	0.0		0.0
Moses Twp	1983	20	1 600	0.6	0.0		0.0
Nairn Twp No. 2	1983	20	1 350	2.2	0.8		0.4
Weeks Twp	1983	21	1 250	1.6	0.0		0.0
Temagami							
Biggs Twp	1983	13	1 700	0.3	0.0		0.0
Gilles Twp	1983	14	2 000	0.2	1.0		0.5
Hagar							
Davis Twp No. 1	1986	6	1 445	2.4			
No. 2	1986	6	1 780	2.2			
No. 3	1986	6	2 255	2.4			
Wawa							
Kennedy Cr No. 2	1982	8	2 200	13.7	25.2	38.7	16.0
Average ^c				1.5	0.3		0.2
Accumulated avg mortality ^c					1.8		

^arecorded at time of plot establishment.
^bfor periods after the initial measurement only.
^cexcluding plot at Kennedy Cr No. 2.

Figure 4. Percentage of white spruce and black spruce saplings killed annually by Armillaria root rot (Y) at various ages (X) in Ontario plantations.

in mortality as a result of Armillaria root rot in older white spruce. Mortality ranged from 0% in plantation 67D to 19.4% in plantation 14A (Table 6). Average annual mortality in 1984 and 1985 varied from 0% (in five plantations) to 2.7% of stems killed at Durham, .

Discussion

Armillaria root rot killed trees in all but one of 72 conifer plantations examined (67D at Petawawa). In plantations less than 25 years old, diagnosis of root rot was certain because it was not confounded by the presence of other pests or declines. Where fewer than 1% of trees were killed annually in young plantations, losses were insignificant, as long as the mortality was evenly distributed in the stand. However, where the root rot occurred in patches, understocking resulted. Understocking was evident in six of 15 white spruce, seven of 11 black spruce, four of 15 jack pine and one of eight red pine plantations. After a detailed study in radiata pine (*Pinus radiata* D. Don) plantations in New Zealand, Van der Pas (1981) concluded that, rather than increasing radially, infection centres delineated root systems of old-growth stumps and other root systems that supplied Armillaria inoculum. This association of killed trees with below-ground inoculum seems to be present in Ontario as well.

Whether the current rate of mortality from Armillaria root rot will increase, decrease, or remain constant in a plantation is unpredictable on the basis of present knowledge. Examples of all three conditions in plantations can be seen in the data presented. However, only initial trends can be established on the basis of two or three observations per plantation made to date.

Both jack pine and red pine saplings sampled seemed less susceptible to Armillaria than the spruces. Of the pines, red pine saplings were attacked less than jack pine, except at Kennedy Creek. The high proportion of red pine killed by Armillaria root rot at Kennedy Creek was comparable to that observed earlier by Huntley *et al.* (1961) in 31-year-old trees.

Table 5. Mortality of 43- to 53-year-old semimature red pine caused by *Armillaria* root rot on 0.2-ha plots (except at Petawawa)^a in 11 southern and eastern Ontario plantations.

Location	Age	Density (trees per ha)	Trees killed by <i>Armillaria</i> root rot (%) ^b (based on 180-700 trees per plot)		
			Initial examin- ation ^c	2 yr later	Annual avg ^d
Durham No. 1	51	600	15.3	6.4	3.2
Durham No. 2	53	450	6.7	9.0	4.5
Larose No. 77A	46	900	6.6		
Larose No. 94W	46	900	2.7	0.6	0.3
Minden No. 1	44	650	10.6	5.9	3.0
Minden No. 2	48	550	5.3	6.5	3.2
Petawawa No. 18	43	1 150	0.7	0.0	0.0
Petawawa No. 70	48	1 900	0.3	0.6	0.3
York No. 1	48	550	7.0	1.0	0.5
York No. 2	48	850	15.4	8.2	4.1
York No. 3	48	700	7.3	7.5	3.8
Average			7.1	4.6	2.3
Accumulated avg mortality (%)				11.7	

^aPlots in Petawawa plantations were 0.08 ha.

^bSome dead trees were also infested with bark beetles.

^crecorded at time of plot establishment in 1983.

^dfor period after initial measurement only.

In the earlier study, the high rate of infection of planted trees was attributed to their proximity to hardwood stumps that were suspected of *Armillaria* infection. In Kennedy Creek plantations, apparently a similar situation prevails, even though the stumps are of softwood species.

In other parts of Canada, Morrison (1981) found that *Armillaria* root rot results in death of 2% to 3% of young western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) 5 to 25 years of age in coastal British Columbia forests. Hiratsuka (1987) considers this root rot to be important in plantations or highly managed stands in the Prairie Provinces, where it tends to kill young trees in groups and thus creates undesirable gaps in stands. In Newfoundland, Singh and Richardson (1973) found that the percentage of trees infected by *Armillaria* sp. ranged from 1.8% to 79.0% among 17 conifers (mostly exotics) tested in experimental plantations.

According to Wargo and Shaw (1985), a critical evaluation of disease impact and of forest management objectives is required to ensure that the level of loss justifies

any control measures. In the present investigations an attempt was made to assess the damage, and it appears that reduction of inoculum sources may be the most suitable means of controlling the disease. Morrison (1981) recommended stump removal and root raking to remove *Armillaria*-infested material before regenerating disease-affected areas in the interior of British Columbia. He also suggested that, if possible, planting or regenerating the most susceptible species (*Abies* spp., Douglas-fir, and western hemlock) be avoided. There is some evidence from this study that jack pine and red pine may be less susceptible to the disease than white spruce and black spruce. To avoid losses to *Armillaria* root rot in Newfoundland, Singh and Richardson (1973) recommended seeding non-stocked forest land (or

Figure 5. Forty-year-old red pine near Midhurst, Ontario, killed by *Armillaria* root rot.

Figure 6. Sporophore of *Armillaria* spp. at the base of 40-year-old, healthy-appearing red pine. Midhurst, Ontario, 23 October 1985.

Table 6. Mortality of 43- to 58-year-old semimature white spruce caused by Armillaria root rot on 0.08 (Petawawa) to 0.2-ha plots in 14 southern and eastern Ontario plantations.

Location	Age	Density (trees per ha)	Trees killed by Armillaria root rot (%) ^a (based on 110-580 trees per plot)		
			Initial examin- ation ^b	2 yr later	Annual avg ^c
Durham	53	2 900	2.1	5.4	2.7
Minden	44	1 600	0.6	2.9	1.5
Petawawa					
Hudson (3a)	53	5 500	3.6	0.0	0.0
Branstead (6)	58	1 700	7.9	0.3	0.1
Headquarters (12)	57	1 400	5.8	2.0	1.0
Woermke (14A)	57	3 000	15.8	0.0	0.0
Woermke (16)	57	4 400	4.6	0.0	0.0
Halliday (20)	56	2 400	8.2	4.6	2.3
Halliday (31)	48	2 450	19.4	5.1	2.6
Hudson (37A)	48	2 200	6.8	0.6	0.3
Hudson (37B)	48	1 800	3.1	0.7	0.4
Hudson (37C)	48	1 800	3.5	0.4	0.2
Woermke (42)	43	3 300	3.0	0.0	0.0
Branstead (67D)	48	2 600	0.0	0.0	0.0
Average (weighted)			6.0	1.6	0.8
Accumulated avg mortality (%)				7.6	

^aSome dead trees had also been infested with bark beetles.

^brecorded at time of plot establishment in 1983.

^cfor period after initial measurement only.

perhaps container planting) rather than planting bare-root stock, and using native species in reforestation.

In one older plantation (Larose 94W), annosus root rot (Myren 1973) was present as well as Armillaria root rot, and this disease is known to damage pine plantations in southern Ontario (ibid.). Limestone-induced chlorosis (Ellis and Whitney 1975) is associated with mortality in older red pine plantations in eastern Ontario. In some plantations at Petawawa, heavy snow (e.g., in the winter of 1978-1979 [Stiell 1980]) had caused broken tops, and the damaged trees were dying and becoming invaded by Armillaria. These trees were not included in Tables 5 and 6, as the snow breakage was considered the primary cause of death. Armillaria root rot, however, may have hastened death. Broken tops contribute to stress in trees, and some researchers (Patton and Vasquez Bravo 1967) contend that this would increase their susceptibility to Armillaria attack.

Armillaria-associated root rot in red pine at Petawawa plantations was considerably less severe than in red pine plantations at the other four eastern and southeastern Ontario locations. Furthermore, the older red pines in the Petawawa plantations appeared to be damaged much less than white spruce. This difference confirmed the findings for these species in younger plantations. In the older white spruce plantations, mostly at Petawawa, mortality due to Armillaria root rot varied considerably, ranging from 0% to 19.4% as evaluated in 1983.

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