# ROOT ROT FUNGI
# IN FOUR ONTARIO CONIFERS

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## ABSTRACT

A survey of root rots of several species of conifers was carried out in Ontario by personnel of the Forest Insect and Disease Survey Unit of the Canadian Forestry Service, Sault Ste. Marie, Ontario during 1971 and 1972. A total of 215 balsam fir (*Abies balsamea* [L.] Mill.), 144 black spruce (*Picea mariana* [Mill.] B.S.P.), 150 white spruce (*Picea glauca* [Moench] Voss), and 104 jack pine (*Pinus banksiana* Lamb.) were sampled. Plots were established where trees were showing symptoms of root rot, and a decayed or stained root from each of five trees of each species (when present) was submitted to the laboratory for culturing and identification of the causal fungi. The sample from each plot was too small to permit an accurate causal relationship between the fungi isolated and the dead trees. Of the basidiomycetes cultured, *Polyporus tomentosus* Fr. was isolated most frequently from white and black spruce. *Armillaria mellea* (Vahl ex Fr.) Kummer was identified most commonly from balsam fir. *Coniophora puteana* (Schum. ex Fr.) Karst. and *Stereum sanguinolentum* (Alb. and Schw. ex Fr.) Fr. were two other fungi isolated regularly from balsam fir. *Armillaria mellea, C. puteana,* and *S. sanguinolentum* occurred in all four tree species. Many other fungi were isolated less frequently, several of them for the first time in Ontario. Since it is probable that nonbasidiomycetes also have an important role in the root-rotting process, their occurrence and frequency were summarized.

# RÉSUMÉ

En 1971 et 1972, le personnel d'un groupe appartenant à l'Inventaire des insectes et maladies des arbres, membre du Service canadien des forêts, Sault Ste. Marie, Ontario, inventoria le pourridié des racines chez plusieurs espèces de résineux. On échantillonna au total 215 Sapins baumiers (*Abies balsamea* [L.] Mill.), 144 Epinettes noires (*Picea mariana* [Mill.] B.S.P.), 150 Épinettes blanches (*Picea glauca* [Moench] Voss) et 104 Pins gris (*Pinus banksiana* Lamb.). On établit des parcelles là où les arbres montraient des symptômes de pourridié des racines et on envoya au laboratoire une racine pourrie ou colorée de chacun de cinq spécimens de chaque espèce (lorsque présents) pour fins de culture et d'identification des Champignons pathogènes. Les échantillons de chaque parcelle étaient trop peu pour permettre une relation précise de cause à effet les Champignons isolés et les arbres morts. Parmi les Basidiomycètes, *Polyporus tomentosus* Fr. fut isolé le plus souvent des Épinettes blanches et noires. *Armillaria mellea* (Vahl ex Fr.) Kummer se trouva le plus souvent dans le Sapin baumier. *Coniophora puteana* (Schum. ex Fr.) Karst. et *Stereum sanguinolentum* (Alb. & Schw. ex Fr.) Fr. furent aussi trouvés régulièrement dans le Sapin baumier. *Armillaria mellea, C. puteana* et *S. sanguinolentum* existèrent dans les quatre espèces. On isola différents autres Champignons, souvent pour la première fois en Ontario. Vu que des non Basidiomycètes peuvent probablement aussi faire pourrir les racines, les auteurs signalent leur presence et leur frequence.

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Cover Photo: Root rot damage in 90-100-year-old black spruce, Spruce River Road, north of Thunder Bay, Ontario.

# INTRODUCTION

Root rot, caused chiefly by members of the basidiomycetes, is known to occur in most conifers in North America. Faull (1922) first reported root rots in Ontario white pine (*Pinus strobus* L.), eastern hemlock (*Tsuga canadensis* [L.] Carr.), and spruces (*Picea* spp.), identifying *Polyporus tomentosus* Fr. as the main causal fungus. During studies on stem decay of trees in Ontario, McCallum (1928), Basham, Mook and Davidson (1953), White (1953), Basham and Morawski (1964), Basham (1966), and Basham (1973a), described butt rots and causal fungi, most of which enter through the roots. Huntley et al. (1961), Jorgensen (1956), and Punter (1968) conducted studies on pine root rots in plantations attributed chiefly to *Fomes annosus* (Fr.) Karst. and *Armillaria mellea* (Vahl ex Fr.) Kummer. Gross (1970) has recently consolidated existing information on several of the main root-rotting fungi in Ontario.

The extent of damage that could be attributed to root rot in Ontario is unknown. *Armillaria mellea*, with a worldwide distribution and an extremely broad host range, kills trees, especially those weakened by other factors (Patton and Bravo 1967). *Polyporus tomentosus* Fr. causes mortality and growth slowdown in spruces (Whitney 1962), and spruce mortality has recently been reported in natural stands in Ontario (Whitney 1972) as well as in plantations (Sippell et al. 1968, 1971). Other root-rotting fungi such as *Polyporus schweinitzii* Fr., *P. balsameus* Peck, *Poria subacida* (Peck) Sacc., *Scytinostroma galactinum* (Fr.) Donk, *Coniophora puteana* (Schum. ex Fr.) Karst., *Odontia bicolor* (Alb. and Schw. ex Fr.) Bres., and several others are known to occur in butts of living conifers in natural stands in Ontario (Basham and Morawski 1964). Again, however, their distribution and relative importance are unknown. *Fomes annosus* root rot has so far been reported only from plantations in southern Ontario, although spores of this parasite have been collected more widely in natural stands (Punter 1970).

To increase our knowledge of the fungi causing root rot in Ontario and the relative importance of each fungus species in white spruce (*Picea glauca* [Moench] Voss), black spruce (*Picea mariana* [Mill.] B.S.P.), and balsam fir (*Abies balsamea* [L.] Mill.), a study was begun in 1971 to identify the fungi causing root rot in these species in widespread forested areas of Ontario. In 1972 the study was extended to include jack pine (*Pinus banksiana* Lamb.). In addition, information was sought on the pathogenic nature of the fungi by selecting the sample trees adjacent to dead trees or windfalls wherever possible, and by assessing tree vigor in the areas sampled. Field sampling was conducted during the summers of 1971 and 1972 by personnel of the Forest Insect and Disease Survey of the Canadian Forestry Service, Sault Ste. Marie, Ontario.

## MATERIALS AND METHODS

Black spruce, white spruce, balsam fir and jack pine stands throughout Ontario were examined for stand openings containing dead or windfallen trees or for individual or small groups of dead trees showing evidence of root rot. Root rot can be suspected when stunted or chlorotic crowns develop on dominant or codominant trees or when premature windfall or dead standing trees cannot be obviously attributed to other factors. Six stands of each species (jack pine in 1972 only) in each survey region (Fig. 1)--if suitable stands could be found--were selected for sampling in each of 1971 and 1972. All large roots were exposed on each of five living trees (adjacent to dead trees) in each selected stand, and a disc about 4 in. (10.16 cm) long containing advanced and incipient decay was cut from one living root on each tree. If there was no obvious rot or stain in any large root on the tree, no sample was obtained in 1971. In 1972 an evidently clear root specimen was submitted from such trees. The root specimens were sent to the laboratory in Sault Ste. Marie for culturing and identification of the decay-causing fungi.

When the roots were excavated, an evaluation of the damage in the area was made. From a starting point 2 chains (40.22 m) within the stand being examined, the nearest dominant or codominant host tree in each of four equal quadrants was selected and rated as diseased, healthy, or dead. Trees were rated as diseased when there was evidence of reduced leader growth, loss of foliage, dead branches, chlorosis, or resinosis. If a host tree was not present within 100 ft (30.48 m), the quadrant was void. This procedure was repeated at intervals of not less than 2 chains (40.22 m) but not more than 5 chains (100.55 m) from the first subplot until 10 subplots had been evaluated for a maximum of 40 trees at each location. Proportions of dead or unhealthy trees were converted to percentages of the total trees evaluated.

In the laboratory the bark was removed and the exposed ends of the roots cut off with a band saw to maintain sterile conditions. The remaining portion of the root was examined for evidence of stain or decay and longitudinal or horizontal cuts were made through these areas. From each root disc a minimum of five sites were chosen from which to attempt isolation of the causal organisms. These sites were generally near the incipient decay and usually one was within the area of advanced decay. Specimens with no stain or decay were cultured at random across the freshly split root surface. With a sterilized scalpel or wood chisel a thin layer was removed from the surface of the root wood and a small triangular piece of wood about 3 mm (.76 in.) on a side was removed from the exposed surface and placed on sterile malt agar slants (Nobles 1948).

The cultures were incubated at room temperature, $20^{\circ}C \pm 2^{\circ}$ for at least three weeks. At the end of this time, any slants which did not show evidence of growth from the wood chip(s) were discarded and recorded as sterile. As soon as the remaining cultures had suitable

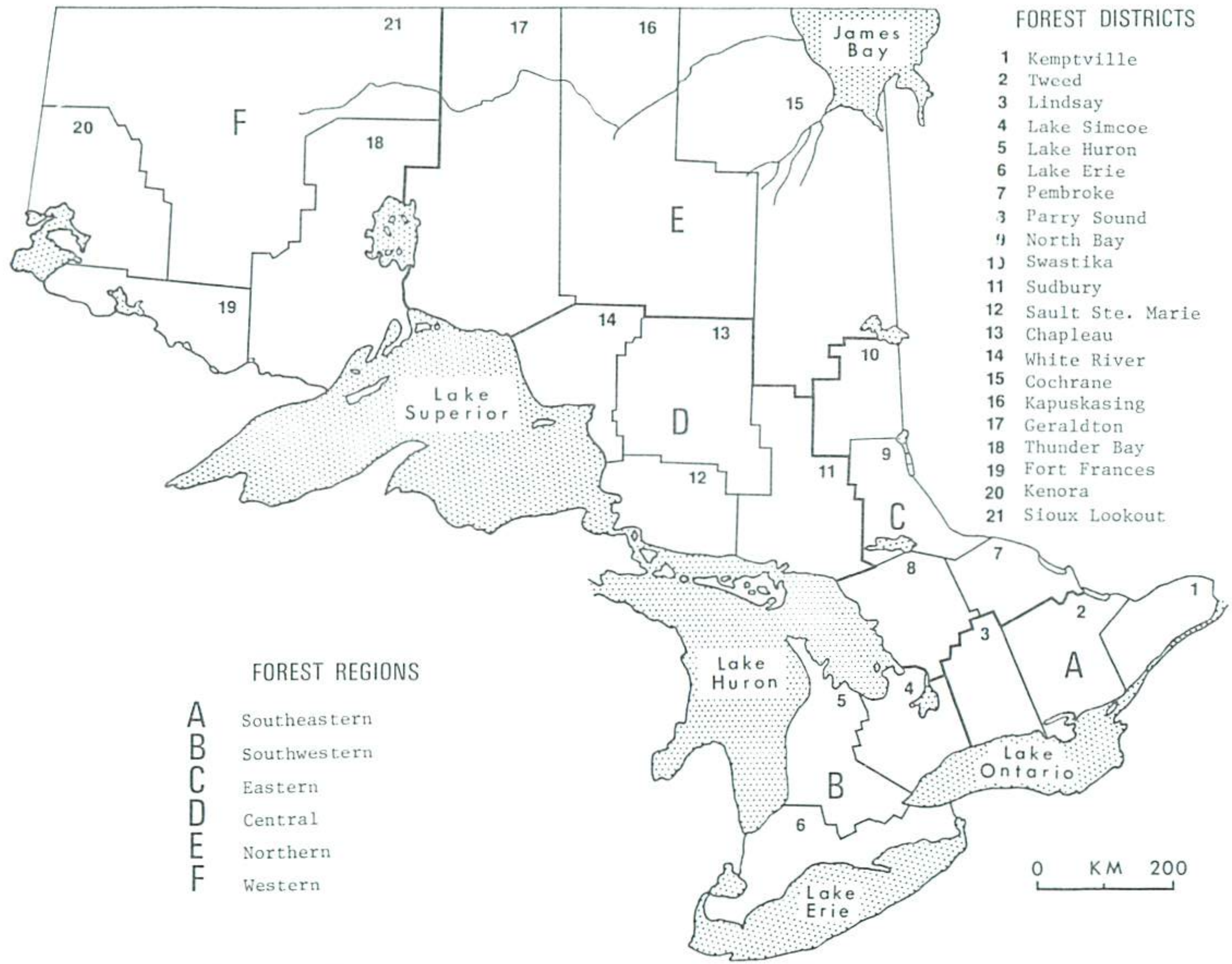


Figure 1. Forest regions and districts referred to in this report.

growth, those suspected of being basidiomycetes were transferred to 1.25% malt agar plates and gallic and tannic acid agar plates for the oxidase reaction test (Nobles 1948). From the acid reactions, the growth rates, the color of the mycelial mat and hyphal characteristics described in keys (Nobles 1948, 1965), identification of the basidiomycetes was made. Those which remained unidentified were taken to the Plant Research Institute in Ottawa for identification. Some are still unidentified and are so recorded in the results. Imperfect fungi, phycomycetes and ascomycetes were plated out on either a 2% V-8 juice medium to induce formation of conidia or on 2% malt agar.

## RESULTS

### Fungi causing root rot

All fungi isolated are listed by tree species and survey region in Table 1. Although the nonbasidiomycetes probably play a role in infection and subsequent growth of basidiomycetes in the tree (Shigo 1967), this role is ill-defined. Members of the basidiomycetes are known causes of stain and decay in living trees and the species of this group are considered of paramount importance in the deterioration found in this study.

Of the 613 trees sampled from 155 locations, 206 trees (34%) from 111 locations (72%) had wood-rotting basidiomycetes isolated from their roots (Table 2). Among these were 29 identified species, 14 of which occurred in more than one tree species. Nineteen species were associated with the root rot in black spruce, 15 in balsam fir, 12 in white spruce, and 6 in jack pine. *Armillaria mellea*, *Coniophora puteana*, and *Stereum sanguinolentum* (Alb. and Schw. ex Fr.) Fr. occurred in all four tree species. *Polyporus tomentosus*, *P. schweinitzii*, and *P. anceps* Pk. occurred in three tree species; *P. tomentosus* was by far the most common root-rotting fungus in white and black spruce. Eleven basidiomycetes occurred at three locations or more, but *P. tomentosus*, *Armillaria mellea*, and *Coniophora puteana* were the three dominant root-rotting species and together caused the bulk of the root rot in this survey (Fig. 2, p. 12).

Forty-five locations (29%) yielded more than one basidiomycete from the sampled trees; ten locations yielded more than two basidiomycetes, and three yielded four different basidiomycetes. Three balsam fir trees, three black spruce and two white spruce yielded more than one decay-causing basidiomycete.

### *Polyporus tomentosus*

This fungus causes extensive white pocket root and butt rot in spruces and pines throughout the temperate zone (Jørstad and Juul 1939,

Table 1 Frequency by tree species of basidiomycetes and nonbasidiomycetes isolated from root sections submitted during 1971 and 1972 by Ontario Forest Insect and Disease Survey personnel

| | White spruce | | | | | | Black Spruce | | | | | | Balsam fir | | | | | | Jack pine | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey region[a] | SE | SW | E | C | N | W | SE | SW[b] | E | C | N | W | SE | SW | E | C | N | W | SE[b] | SW | E | C | N | W |
| BASIDIOMYCETES | | | | | | | | | Number of Locations | | | | | | | | | | | | | | | |
| *Armillaria mellea* | | | | | 1 | | | | 1 | 2 | 1 | 1 | 1 | 2 | 3 | 1 | 4 | 5 | | 3 | | | | 2 |
| *Asterodon ferruginosus* | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| *Coniophora puteana* | | | | 2 | | | | | | 1 | 1 | 1 | 1 | 1 | 2 | 3 | | 2 | | | | 2 | | |
| *Daedalea unicolor* | | | | | | | | | 1 | | | | | | 1 | | | | | | | | | |
| *Fomes annosus* | | | | | | | | | | | | | | | | | | | | 3 | | | | |
| *Fomes pini* | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| *Fomes pinicola* | 1 | | | | | | | | | 1 | | | | | | | | | | | | | | |
| *Ganoderma tsugae* | | | | | | | | | | | 1 | | | | | | | | | | | | | |
| *Hymenochaete corrugata* | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| *Merulius lacrimans* | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| *Odontia bicolor* | | 1 | | | | | | | | | | | | 1 | 1 | 2 | | | | | | | | |
| *Peniophora gigantea* | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| *Peniophora pithya* | | | | 1 | | | | | | | | | | | | | | | | | | | | |
| *Peniophora pseudopini* | | | | | | | | | | | 1 | | | | | | | | | | | | | |
| *Polyporus adustus* | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| *Polyporus anceps* | | 1 | | | 1 | | | | | | | | | | | | | 1 | | | | | | 1 |
| *Polyporus balsameus* | | | | | | | | | 2 | | | | | 1 | | 1 | | | | | | | | |
| *Polyporus berkeleyi* | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| *Polyporus borealis* | | | | 1 | | | | | | 1 | | | | | | | | | | | | | | |
| *Polyporus hirsutus* | | | | 1 | | | | | | | | | | | | | | | | | | | | |
| *Polyporus tomentosus* | 1 | 1 | 3 | 4 | 4 | 2 | 1 | | 4 | 3 | 4 | 4 | | | | 2 | | 2 | | | | | | |
| *Polyporus schweinitzii* | | | | | | | | | 1 | | | 1 | | 1 | 1 | | | | | | | | | |
| *Polyporus semipileatus* | | | | | | | | | | | | | | | 1 | | 1 | | | | | | | |
| *Polyporus sericeomollis* | | | 1 | | | | | | | | 1 | | | | | | | | | | | | | |
| *Poria tsugina* | | | | | | | | | 1 | | | 1 | | | | | | | | | | | | |
| *Scytinostroma galactinum* | | | | | | | | | | | | | | | | | 1 | 1 | | 1 | | | | 1 |

(continued)

Table 1 Frequency by tree species of basidiomycetes and nonbasidiomycetes isolated from root sections submitted during 1971 and 1972 by Ontario Forest Insect and Disease Survey personnel (continued)

| | White spruce | | | | | | Black Spruce | | | | | | Balsam fir | | | | | | Jack pine | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey region[a] | SE | SW | E | C | N | W | SE | SW[b] | E | C | N | W | SE | SW | E | C | N | W | SE[b] | SW | E | C | N | W |
| | Number of Locations | | | | | | | | | | | | | | | | | | | | | | | |
| BASIDIOMYCETES (continued) | | | | | | | | | | | | | | | | | | | | | | | | |
| *Stereum sanguinolentum* | | | | | | 1 | | | | | | 1 | | | | | | 3 | | | | 2 | | |
| *Trametes americana* | | | | | | | | | | | 1 | | 1 | | | 1 | | | | | | | | |
| *Trechispora brinkmannii* | | | | | | | | | | | 1 | | | | | | | | | | | | | |
| Unknown C | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| Unknown | | 2 | | 4 | 2 | 3 | | | 2 | 2 | 1 | 2 | | | 2 | 6 | 2 | 3 | | | | 2 | | 1 |
| NONBASIDIOMYCETES | | | | | | | | | | | | | | | | | | | | | | | | |
| *Absidia* sp. | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| *Acrophialophora* sp. | | | | | | | | | | | | | 1 | | | | | | | | | | | |
| *Actinomycete* | | | | 1 | | | 1 | | | | | 1 | | | | 2 | 1 | 1 | | 1 | | | | |
| *Alternaria* sp. | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| *Ascocoryne sarcoides* | | | | 5 | 4 | 2 | | | 5 | 5 | 5 | 6 | | | | | | 1 | | 1 | 1 | | 1 | 2 |
| *Aspergillus* sp. | | | | 1 | | | | | | | | | | | | | | | | | | | 1 | |
| Bacteria | | 1 | | 2 | 3 | 4 | | | 2 | 2 | 1 | 4 | 2 | 2 | 2 | 10 | 3 | 8 | | 4 | 1 | 3 | 1 | 4 |
| *Beauvaria bassiana* | | | | | | | | | | | | | | | | | | 1 | | | | | | |
| *Bisporomyces* sp. | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| *Botrytis* sp. | | | | 1 | | | | | | | | | | | | | | | | | | | | |
| *Catenularia* sp. | | | 1 | 1 | | | | | | | 2 | | | | | | | | | | | | | |
| *Cephalosporium* sp. | | | | | | | | | 3 | 2 | | 1 | 1 | | | | 2 | 2 | | | | | 1 | |
| *Cladosporium* sp. | | | | | 1 | | | | | 1 | | 1 | 1 | | 1 | 1 | | 1 | | 1 | | 1 | | 3 |
| *Chloridium* sp. | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| *Chlorosplenium* sp. | | | | 2 | 1 | | | | | 1 | | | | | 1 | 3 | 1 | 1 | | | | 2 | | |
| *Coniothyrium* sp. | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| *Cylindrocephalum* sp. | | | | | | | | | | | | | | | | | | | | | | 1 | | 1 |
| *Endosporostilbe* sp. | | | | | | | | | | | | | | | | | | 1 | | | | | | |
| *Fusarium* sp. | | | | | | | | | | | | | | 1 | | | | | | | | | | 1 |

(continued)

Table 1 Frequency by tree species of basidiomycetes and nonbasidiomycetes isolated from root sections submitted during 1971 and 1972 by Ontario Forest Insect and Disease Survey personnel (concluded)

| | White spruce | | | | | | Black spruce | | | | | | Balsam fir | | | | | | Jack pine | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey region[a] | SE | SW | E | C | N | W | SE | SW[b] | E | C | N | W | SE | SW | E | C | N | W | SE[b] | SW | E | C | N | W |
| NONBASIDIOMYCETES (continued) | | | | | | | | | | | | | | | | | | | | | | | | |
| *Gliocladium roseum* | | | | 4 | 4 | 2 | | | 2 | 2 | 3 | 3 | | | | | | 1 | | | | | 1 | 1 |
| *Leptographium* sp. | | | 1 | 1 | | | | | | | | | | | | 1 | | 1 | | 2 | | | | |
| *Menispora* sp. | 1 | | | | | | | | | | | | | | | | 1 | | | | 1 | | | |
| *Monocillium* sp. | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| *Mucor* sp. | | | 1 | 3 | | 3 | | | | | | | | 1 | | | | 1 | | | 1 | | 1 | 1 |
| *Mucorales* | | | | | | | | | | | | | | 1 | | | | 1 | | 1 | | | | |
| *Papulospora* sp. | | | | 1 | | | | | | | | 1 | | | | | | | | | | | | |
| *Penicillium* sp. | 1 | 1 | 3 | 9 | 5 | 5 | 1 | | 3 | 7 | 2 | 5 | 2 | 4 | 4 | 5 | 4 | 8 | | 6 | 1 | 3 | 2 | 2 |
| *Penicillium lapidosum* | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| *Penicillium lilacinum* | | | | | | | | | | | 1 | | | | | | | | | | | | | |
| *Penicillium thomi* | | | | 3 | | | | | | | | 2 | | 1 | | | 1 | 2 | | | | | | 3 |
| *Phialophora* sp. | | 1 | | 1 | 2 | | | | 1 | 3 | 1 | 1 | 2 | 3 | 6 | 8 | 5 | 9 | | 2 | | 1 | | |
| *Phoma* sp. | | | | 1 | | 1 | | | | | | | | | | | | 1 | | | 1 | | | |
| *Phycomycete* | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| *Rhinocladiella* sp. | | | | 1 | | | | | | | | | | | | | | 1 | | | | | | |
| *Rhizopus* sp. | | | | | | 1 | | | 1 | | | 1 | | | | | | | | | | | | |
| *Rhodotorula* sp. | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| *Scopulariopsis* sp. | | | | | | 1 | | | | | | 1 | | | | | | 2 | | | | | | |
| *Stachylidium* sp. | | | | 1 | | | | | | | | | | | | | | | | | | | | |
| *Tilachlidiopsis* sp. | | | | | | | | | | | | | | | | 1 | 1 | | | | | | | |
| *Torula* sp. | 1 | 1 | | 1 | | | | | | | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 3 | | 1 | | | | |
| *Trichoderma* sp. | | 1 | 1 | 2 | 1 | 3 | | | | 2 | 1 | 1 | | 1 | 1 | 3 | 2 | 5 | | 4 | | 3 | | 2 |
| *Trichoderma album* | | | 1 | | | | | | | | | 1 | | | | | | | | | | | | |
| *Trichoderma viride* | | | | 2 | | | | | | | | | | | | | | | | | | | | |
| *Verticladium* sp. | | | | | | | | | 1 | 4 | | | | 1 | | 1 | | | | | | | | |
| *Verticillium* sp. | | | | | 1 | | | | | | 1 | 1 | | | 2 | | | 3 | | | | | 1 | 1 |
| Yeast | | | | | 1 | 3 | | | 1 | 3 | 1 | 1 | 2 | 2 | 4 | 3 | 1 | 2 | | | | | | |
| Unknown | 1 | | 1 | 2 | 1 | 1 | | | 1 | 1 | 1 | 1 | | 1 | | | | | | 1 | | 1 | | |

[a] SE = southeastern, SW = southwestern, E = eastern, C = central, N = northern, and W = western.

[b] No plots for this species in this Region owing to insufficient numbers of trees.

Table 2 Frequency of basidiomycetes isolated from four tree species during root rot survey in 1971 and 1972 in Ontario by the Forest Insect and Disease Survey

| Fungus | White Spruce | | | Black Spruce | | | Balsam Fir | | | Jack Pine | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates |
| *Polyporus tomentosus* Fr. | 15 | 31 | 74 | 16 | 32 | 77 | 4 | 4 | 6 | | | | 35 | 67 | 157 |
| *Armillaria mellea* (Vahl ex Fr.) Kummer | 1 | 2 | 5 | 5 | 7 | 15 | 16 | 22 | 31 | 5 | 6 | 14 | 27 | 37 | 65 |
| *Coniophora puteana* (Schum. ex Fr.) Karst. | 2 | 2 | 3 | 3 | 3 | 3 | 9 | 10 | 24 | 2 | 2 | 3 | 16 | 17 | 34 |
| *Fomes annosus* (Fr.) Karst. | | | | | | | | | | 3 | 6 | 22 | 3 | 6 | 22 |
| *Stereum sanguinolentum* (Alb. & Schw. ex Fr.) Fr. | 1 | 1 | 3 | 1 | 1 | 1 | 3 | 3 | 7 | 1 | 1 | 2 | 6 | 6 | 13 |
| *Polyporus balsameus* Pk. | | | | 2 | 2 | 7 | 2 | 2 | 4 | | | | 4 | 4 | 11 |
| *Odontia bicolor* (Alb. & Schw. ex Fr.) Bres. | 1 | 1 | 1 | | | | 4 | 6 | 8 | | | | 5 | 7 | 9 |
| *Scytinostroma galactinum* (Fr.) Donk | | | | | | | 2 | 2 | 4 | 2 | 3 | 3 | 4 | 5 | 7 |

(continued)

Table 2 Frequency of basidiomycetes isolated from four tree species during root rot survey in 1971 and 1972 in Ontario by the Forest Insect and Disease Survey (continued)

| Fungus | White Spruce | | | Black Spruce | | | Balsam Fir | | | Jack Pine | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates |
| *Polyporus anceps* Pk. | 2 | 2 | 3 | | | | 1 | 1 | 1 | 1 | 1 | 2 | 4 | 4 | 6 |
| *Polyporus schweinitzii* Fr. | | | | 2 | 2 | 4 | 2 | 2 | 2 | | | | 4 | 4 | 6 |
| *Trametes americana* Overh. | | | | 1 | 1 | 1 | 2 | 2 | 4 | | | | 3 | 3 | 5 |
| *Daedalea unicolor* (Bull. ex Fr.) Fr. | | | | 1 | 1 | 2 | 1 | 1 | 1 | | | | 2 | 2 | 3 |
| *Polyporus sericeomollis* (Rom.) Baxtel | 1 | 1 | 2 | 1 | 1 | 1 | | | | | | | 2 | 2 | 3 |
| *Fomes pinicola* (Sw. ex Fr.) Cke. | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | 2 | 2 | 2 |
| *Polyporus borealis* Fr. | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | 2 | 2 | 2 |
| *Polyporus semipileatus* Pk. | | | | | | | 2 | 2 | 2 | | | | 2 | 2 | 2 |
| *Poria tsugina* (Murr.) Sacc. & Trott | | | | 2 | 2 | 2 | | | | | | | 2 | 2 | 2 |

(continued)

Table 2 Frequency of basidiomycetes isolated from four tree species during root rot survey in 1971 and 1972 in Ontario by the Forest Insect and Disease Survey (continued)

| Fungus | White Spruce | | | Black Spruce | | | Balsam Fir | | | Jack Pine | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates |
| *Fomes pini* (Thore ex Fr.) Karst. | | | | | | | 1 | 2 | 2 | | | | 1 | 2 | 2 |
| *Asterodon ferruginosus* Pat. | | | | 1 | 1 | 1 | | | | | | | 1 | 1 | 1 |
| *Ganoderma tsugae* Murr. | | | | 1 | 1 | 1 | | | | | | | 1 | 1 | 1 |
| *Hymenochaete corrugata* (Fr.) Lev. | | | | 1 | 1 | 1 | | | | | | | 1 | 1 | 1 |
| *Merulius lacrymans* Jacq. ex Fr. | | | | 1 | 1 | 1 | | | | | | | 1 | 1 | 1 |
| *Polyporus adustus* Willd. ex Fr. | 1 | 1 | 1 | | | | | | | | | | 1 | 1 | 1 |
| *Polyporus berkeleyi* Fr. | | | | | | | 1 | 1 | 1 | | | | 1 | 1 | 1 |
| *Peniophora gigantea* (Fr.) Mass. | | | | | | | 1 | 1 | 1 | | | | 1 | 1 | 1 |

(continued)

Table 2 Frequency of basidiomycetes isolated from four tree species during root rot survey in 1971 and 1972 in Ontario by the Forest Insect and Disease Survey (concluded)

| Fungus | White Spruce | | | Black Spruce | | | Balsam Fir | | | Jack Pine | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates | No. of locations | No. of trees | No. of isolates |
| *Polyporus hirsutus* Wulf. ex Fr. | 1 | 1 | 1 | | | | | | | | | | 1 | 1 | 1 |
| *Peniophora pithya* (Pers.) Erikss. | 1 | 1 | 1 | | | | | | | | | | 1 | 1 | 1 |
| *Peniophora pseudopini* Weresub and Gibson | | | | 1 | 1 | 1 | | | | | | | 1 | 1 | 1 |
| *Trechispora brinkmannii* (Bres.) Rogers & Jacks | | | | 1 | 1 | 1 | | | | | | | 1 | 1 | 1 |
| Unknown C | | | | 1 | 1 | 1 | | | | | | | 1 | 1 | 1 |
| Unknown basidiomycetes | 11 | 12 | 18 | 7 | 7 | 11 | 13 | 14 | 14 | 3 | 3 | 4 | 34 | 36 | 47 |
| No basidiomycetes | 9 | 97 | | 9 | 83 | | 15 | 143 | | 11 | 84 | | 44 | 407 | |
| All basidiomycetes | 30 | 53 | 114 | 28 | 61 | 124 | 39 | 72 | 112 | 14 | 20 | 50 | 111 | 206 | 410 |
| Total in sample | 39 | 150 | | 37 | 144 | | 54 | 215 | | 25 | 104 | | 155 | 613 | |

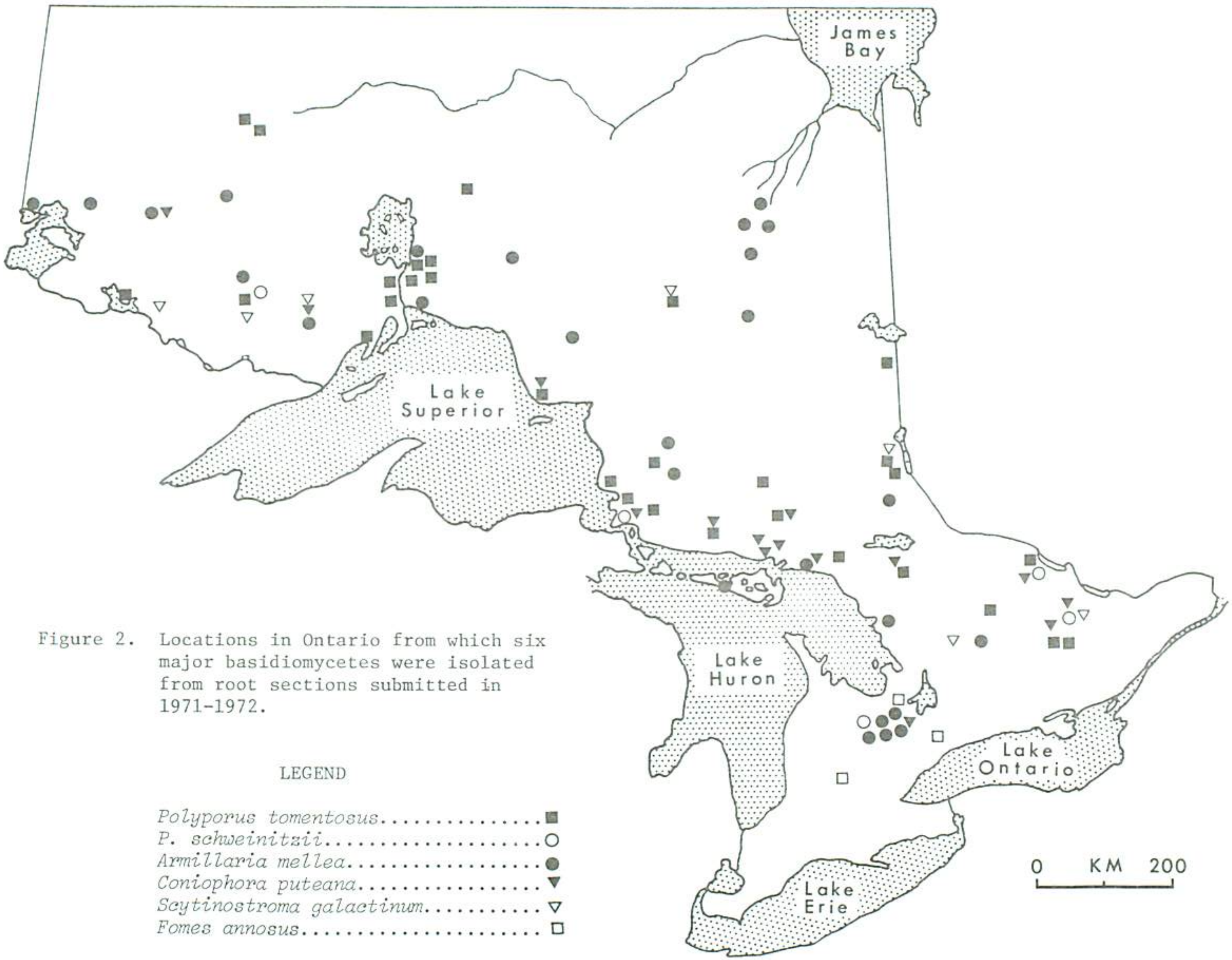


Figure 2. Locations in Ontario from which six major basidiomycetes were isolated from root sections submitted in 1971-1972.

Domanski and Dzieciolowski 1955, Basham and Morawski 1964, Whitney 1962). It is responsible for premature mortality of white spruce in Saskatchewan (Whitney 1962), of white and black spruce in Ontario (Whitney 1972), and of plantation white spruce in Wisconsin (Patton and Myren 1970) and Quebec (Ouelette 1972).

White spruce

One hundred and fifty white spruce trees were sampled in 39 locations. *Polyporus tomentosus* was isolated 74 times from 31 trees (21%) in 15 locations (38%) (Table 2, Fig. 2). The fungus was isolated consistently[1] from at least three of the five roots submitted from Tarentorus Twp, Sault Ste. Marie District; Venacher, Tweed District; and near Rye, Parry Sound District, indicating heavy root rot that was probably associated with tree mortality in these four areas. *Polyporus tomentosus* was also isolated regularly from the single samples sent from Midhurst Nursery, Lake Simcoe District, and Ompha, Tweed District. Samples from the other 10 locations yielded from one to six cultures of *P. tomentosus* from the five trees, suggesting light damage by this fungus.

Black spruce

One hundred and forty-four black spruce trees were sampled from 37 locations (Table 2). *Polyporus tomentosus* was isolated 77 times from 32 trees (22%) in 16 locations (43%). It was isolated consistently from three to five of the five trees sampled in Lount Twp, Parry Sound District; Cameron Falls, Thunder Bay District; Lineus Lake, Chapleau District; Nickle Lake Road, Fort Frances District; and Beardmore, Geraldton District, indicating heavy root rot in these areas. This fungus was isolated from one or two of the five trees sampled from an additional 10 areas, suggesting moderate-to-light root rot.

Balsam fir

Two hundred and fifteen balsam fir trees were sampled in 54 locations (Table 2). *Polyporus tomentosus* cultures were obtained from individual balsam fir trees at Flack Lake, Sault Ste. Marie District; Kimmewin Lake, Sioux Lookout District; Goulais River, Sault Ste. Marie District; and McTavish Twp, Thunder Bay District. As this represented only 7% of the areas from which balsam fir was sampled, *P. tomentosus* was considered to be causing little damage in this species.

These observations show that *P. tomentosus* is widespread in black and white spruce in Ontario. It is abundant in roots of living trees adjacent to dead dominant and codominant trees which it had probably killed.

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1 When at least three of the five isolation sites yielded a single fungus, this fungus was considered to be isolated consistently or regularly.

*Armillaria mellea*

The yellow stringy decay caused by *Armillaria mellea* is the most widespread root rot of trees throughout the world, including plantations (Boyce 1961, Patton and Bravo 1967). *Armillaria mellea* lives saprophytically in old stumps and logs and spreads to living trees via rhizomorphs, and the ensuing attack is reputed to be most successful on trees under physiological stress. It was present in most Ontario tree species investigated for decay (Basham and Morawski 1964), and is suspected of causing much more damage than was apparent from infections observed at stump level (Basham 1973a).

Balsam fir

*Armillaria mellea* was isolated 31 times from 22 trees (10%) in 16 locations (30%) (Table 2). It was obtained consistently from one of the five trees at each of Smooth Rock Falls, Kapuskasing District and Silverwater, Sudbury District. Three of the five trees from the Dog River area, Thunder Bay District, yielded isolates of this fungus. A moderate attack by this fungus is indicated in these areas. In the other 11 locations yielding *A. mellea*, the fungus was isolated only once or twice, usually from only one of the five trees, suggesting a light attack.

Black spruce

*Armillaria mellea* was isolated 15 times from seven trees (5%) in five locations (13%). At Horton Lake in the Chapleau District it was isolated consistently from three of the five trees, indicating a heavy attack. In the other four locations only one or two isolates were obtained from one of the five trees per location, suggesting a light attack.

Jack pine

One hundred and four jack pine trees were sampled in 25 locations (Table 2). *Armillaria mellea* was isolated 14 times from six trees (6%) in five locations (20%). It was isolated consistently from one of the two infected trees from Vespra Twp, Lake Simcoe District. All other locations yielded only one or two isolates from one of the five trees sampled.

White spruce

*Armillaria mellea* was isolated from two white spruce trees (1%), both in the Caramat area, Geraldton District.

Results of this survey indicate that the occurrence of *A. mellea* is frequent on balsam fir in the province, moderate on black spruce and jack pine, and occasional on white spruce. This fungus is known to be parasitic on otherwise unhealthy trees and it is probably much more widespread in Ontario than cultural data from this survey indicate.

Other fungi

*Coniophora puteana* was isolated 24 times from 10 balsam fir trees (5%) in nine locations (17%). It was isolated consistently from three of the five trees from mile 33 on the Dog River Road, Thunder Bay District, indicating heavy damage on balsam fir in this area. It was isolated from one tree each of white spruce and jack pine at each of two locations, and from black spruce at three locations. *Coniophora puteana* is a common cause of brown cubical root and butt rot of many coniferous species (Basham and Morawski 1964). There is evidence that this fungus invades trees already attacked by other decay fungi (Whitney and Denyer 1970).

*Scytinostroma galactinum* is a common cause of yellow stringy root and butt rot in several Ontario conifers (Basham and Morawski 1964) and is known to parasitize and kill apple trees (Lentz and Burdsall 1973). In the present study it was isolated from balsam fir and jack pine in two locations each.

*Polyporus balsameus* which causes a brown cubical root and butt rot in balsam fir and occasionally in other conifers, including white and black spruces (Denyer and Riley 1953, Basham and Morawski 1964), was isolated from balsam fir and black spruce at two locations each.

*Stereum sanguinolentum* is a well-known common cause of red stain and yellow stringy stem decay in balsam fir and to a lesser extent in black and white spruce. It is rarely isolated from jack pine stems (Basham and Morawski 1964). In the current study it was isolated from roots of all four tree species including jack pine. *Stereum sanguinolentum* usually enters the roots from existing stem infections although it can enter through root wounds (Jørstad and Juul 1939). It causes death of pines in South Africa (Luckhoff 1955) and is apparently a lethal root rot in the western United States (Hubert 1935); to date it has not been linked with mortality in Ontario.

*Odontia bicolor*, the cause of white stringy root and butt rot in several conifers (Smerlis 1961, Whitney 1961, Basham and Morawski 1964), was isolated from balsam fir in four locations and from white spruce at one location.

*Polyporus schweinitzii*, the cause of brown cubical root and butt rot in many conifers (Basham and Morawski 1964, Hepting 1971), was isolated from black spruce and balsam fir in two locations each.

*Polyporus semipileatus* Pk., isolated from balsam fir in two locations (Cochrane and Parry Sound), causes a white to straw-colored sap rot (Overholts 1953), chiefly in hardwoods. It has been reported from *Picea* spp. and *Pinus* spp. in Ontario (Overholts 1953) but the above (i.e., at Cochrane and Parry Sound) are the first reports of its occurrence in roots of balsam fir.

*Fomes annosus* (Fr.) Karst., which is causing increased mortality in southern Ontario pine plantations (Punter 1968, Myren 1973), was isolated only from jack pine in three locations, all of them in planted pine in the Southwestern Region.

*Polyporus anceps*, isolated from white spruce, balsam fir and jack pine, causes a white pocket trunk rot of several western North American conifers (Boyce 1961). It has been isolated from several pines and black spruce in Ontario (Basham 1958a, Pilley and Trieselmann 1969), although the only previous report from living trees in Ontario is from balsam fir (Basham and Morawski 1964).

Root-rotting fungi isolated from only one or two locations

*Fomes pinicola* (Sw. ex Fr.) Cke., isolated from black and white spruce, causes a brown cubical decay, chiefly in stems. It is widespread as a coniferous slash destroyer and has been reported from living trees as well, including the butt section of living white spruce (Denyer and Riley, unpublished; Parker and Johnson 1960). This is the first report of the occurrence of *F. pinicola* on living black spruce roots.

*Trechispora brinkmanni* (Bres.) Rog. and Jacks, isolated from black spruce, is a cause of white sap rot in dead pine trunks (Basham 1958a) and in poplar (Basham 1958b) in Ontario. It has been isolated infrequently from living stems of black spruce and balsam fir (Basham and Morawski 1964) and was isolated from a brown rot in living white spruce in Saskatchewan (Denyer and Riley, unpublished).

*Polyporus adustus* Willd. ex Fr., isolated from white spruce roots apparently for the first time (Geraldton District), is a widespread cause of white mottled or cubical sap rot of dead hardwoods (Boyce 1961). It has been reported in balsam fir in Ontario (Basham and Morawski 1964).

*Peniophora gigantea* (Fr.) Mass., isolated from balsam fir roots, is widespread as a white stringy sap rot of coniferous and hardwood slash. It is also associated with infrequent white root rot of white spruce (Whitney 1961, 1962) and with balsam fir and black spruce stem rot (Basham and Morawski 1964).

*Fomes pini* (Thore ex Fr.) Karst., isolated from balsam fir roots apparently for the first time (Kapuskasing District), is the cause of the widespread white pocket heart rot of living black spruce, white spruce, jack pine and other conifers (Boyce 1961, Basham and Morawski 1964). *Fomes pini,* though successfully inoculated into balsam fir stems (Whitney and Denyer 1970), occurs only rarely in this tree in nature (Hepting 1971). This fungus, like *Stereum sanguinolentum,* causes root rot chiefly by extensions of trunk infections into the roots.

*Ganoderma tsugae* Murr., isolated from black spruce roots apparently for the first time (Geraldton District), causes a soft, spongy, white rot of dead conifers and occasionally of living hemlock (Boyce 1961).

*Polyporus borealis* Fr., isolated from black spruce and apparently for the first time from white spruce roots (Sudbury District), causes a white mottled rot of living conifers (Boyce 1961). It has been associated with rot in living black spruce in Ontario (Basham and Morawski 1964), and reportedly causes root rot in this species (Hepting 1971). It causes a white cuboidal decay of basal heartwood of Norway spruce (*Picea abies* [L.] Karst.) in Europe (Jørstad and Juul 1939).

*Polyporus sericeomollis* (Rom.) Baxter ≡ *Poria asiatica* (Pilat) Overh., isolated from white spruce and black spruce, causes a brown cubical butt and trunk rot of many conifers, but chiefly of living western red cedar (*Thuja plicata* Donn). It has been isolated from black spruce in Ontario (Basham and Morawski 1964), and from white spruce stems (Denyer and Riley, unpublished) and roots (Whitney 1961) in Saskatchewan.

*Trametes americana* Overh., isolated from black spruce and apparently for the first time from balsam fir roots (Tweed District), causes a widespread brown cubical decay of living, but chiefly dead trees; it also decays structural timbers (Nobles 1948, Overholts 1953).

*Daedalea unicolor* (Bull. ex Fr.) Fr., isolated apparently for the first time from black spruce (Pembroke District) and balsam fir (Parry Sound District), is widespread as a white heart rot of hardwoods (Boyce 1961). It occasionally causes cankers on living trees (Campbell 1939), but is rare on conifers (Weir 1917).

*Poria tsugina* (Murr.) Sacc. and Trott, isolated from black spruce in two locations, causes a white heart rot of conifers (Nobles 1948). It has been isolated from white rot in black spruce roots in Saskatchewan (Denyer and Riley, unpublished), and from western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) in British Columbia (Foster and Foster 1951). *Poria tsugina* has been found on balsam fir and eastern hemlock (*Tsuga canadensis* [L.] Carr.) in Ontario (Pilley and Trieselmann 1969). The latter authors consider it a synonym for *Poria punctata* (Fr.) Karst.

*Polyporus hirsutus* Wulf. ex Fr., isolated from white spruce, causes a widespread white spongy sap rot of hardwoods and rarely of conifers. It has been isolated from eastern hemlock in Ontario (Basham and Morawski 1964) and has been found on white spruce in British Columbia (Pilley and Trieselmann 1969). This fungus is difficult to distinguish in culture from at least three other *Polyporus* species (Nobles 1948, Basham and Morawski 1964).

*Hymenochaete corrugata* (Fr.) Lev., isolated from black spruce, causes a canker and white rot of hardwoods and rarely of conifers (Hepting 1971). It has been recorded on balsam fir in Ontario (Pilley and Trieselmann 1969) and on eastern hemlock in an unidentified location (Hepting 1971).

*Asterodon ferruginosus* Pat., isolated from black spruce, has been isolated previously from a white feathery rot in balsam fir in Nova Scotia (Nobles, unpublished; Magasi 1971) and from western hemlock in British Columbia (Pilley and Trieselmann 1969).

*Merulius lacrymans* Jacq. ex Fr., isolated from black spruce, is known chiefly as a dry rot fungus causing a brown cubical decay of building timbers in Europe (Boyce 1961), but rarely in North America. It has been reported on spruces in Ontario (Pilley and Trieselmann 1969) and on western red cedar in British Columbia (Hepting 1971).

*Peniophora pithya* (Pers.) Erikss., isolated from white spruce, decomposes slash of both conifers and hardwoods (Slysh 1960). Apparently it has not been previously reported from living trees.

*Peniophora pseudopini* Weresub and Gibson, isolated from black spruce (Geraldton District), is a common heart-staining fungus of lodgepole pine (*Pinus contorta* Dougl.) in Alberta (Loman and Paul 1963) and of jack pine in Ontario (Basham and Morawski 1964). Evidently it has not been previously reported on living black spruce.

*Polyporus berkeleyi* Fr., isolated from balsam fir, causes a white butt rot, chiefly of hardwoods but also of conifers, near the Pacific coast of North America (Boyce 1961). It has not been previously isolated from conifers in Ontario.

An unknown fungus, referred to by Denyer and Riley (unpublished) as Unknown C, isolated from black spruce, is the cause of a white butt rot in black and white spruces in the prairie provinces (Denyer and Riley, unpublished. Apparently it has not been previously isolated in Ontario.

Nonbasidiomycetes associated with root rot

The ascomycete, *Ascocoryne sarcoides* (Jacq. ex Gray) Groves and Wilson, two species of hyphomycetes (*Gliocladium roseum* [Link] Thom and

*Phialophora* sp.), two groups of hyphomycete species (*Penicillium* spp. and *Trichoderma* spp.), and species of bacteria, were frequently isolated from sampled trees (Table 1, Fig. 3).

*Ascocoryne sarcoides* was isolated frequently from reddish-brown stains and from yellow stringy or pocket decays in white spruce, black spruce, and jack pine. It was isolated once from balsam fir. On the basis of previous studies (Whitney 1962, Etheridge 1970, Basham 1973b), one would expect *A. sarcoides* to be isolated from the spruces and jack pine, but this seems to be the first report of its occurrence in balsam fir. This fungus is suspected of inhibiting decay in black spruce (Basham 1973b), and possibly in other conifers (Etheridge 1970) as well.

*Gliocladium roseum* was isolated from pink or reddish-brown stains, and to a lesser extent from yellow stringy decay, of white and black spruces. It was very seldom isolated from balsam fir or jack pine. It is interesting that *G. roseum* was isolated much more abundantly in 1972 than in 1971, the first year of the survey. A possible reason for this difference is that in 1972 a root sample from every tree was sent to the laboratory for culturing, while in 1971 only those with obvious decay were submitted.

*Phialophora* sp. was isolated chiefly from yellow or brown stains and from yellow stringy decay of balsam fir. It was seldom isolated from black spruce, white spruce, or jack pine.

*Penicillium* spp. were isolated frequently from pink, yellow, or brown stains and from yellow stringy or yellow pocket decay of all tree species.

*Trichoderma* spp. were isolated frequently from brown or yellow stains and yellow stringy or brown cubical decay in balsam fir. They were also isolated frequently from reddish-brown and pink stains in white spruce and jack pine, and infrequently from these stains in black spruce.

*Bacteria* spp. were frequently isolated from various stains (pink, brown, yellow and reddish-brown) in balsam fir and jack pine. They were isolated less frequently from brown or pink stains and from brown cubical or yellow stringy decays in white and black spruces.

Damage resulting from root rot

Dead and unhealthy trees of all three species were more prevalent in some districts than in others. However, differences in root-rotting fungi isolated from the trees in districts of varying mortality were not evident. The small number of roots sampled and the technique of

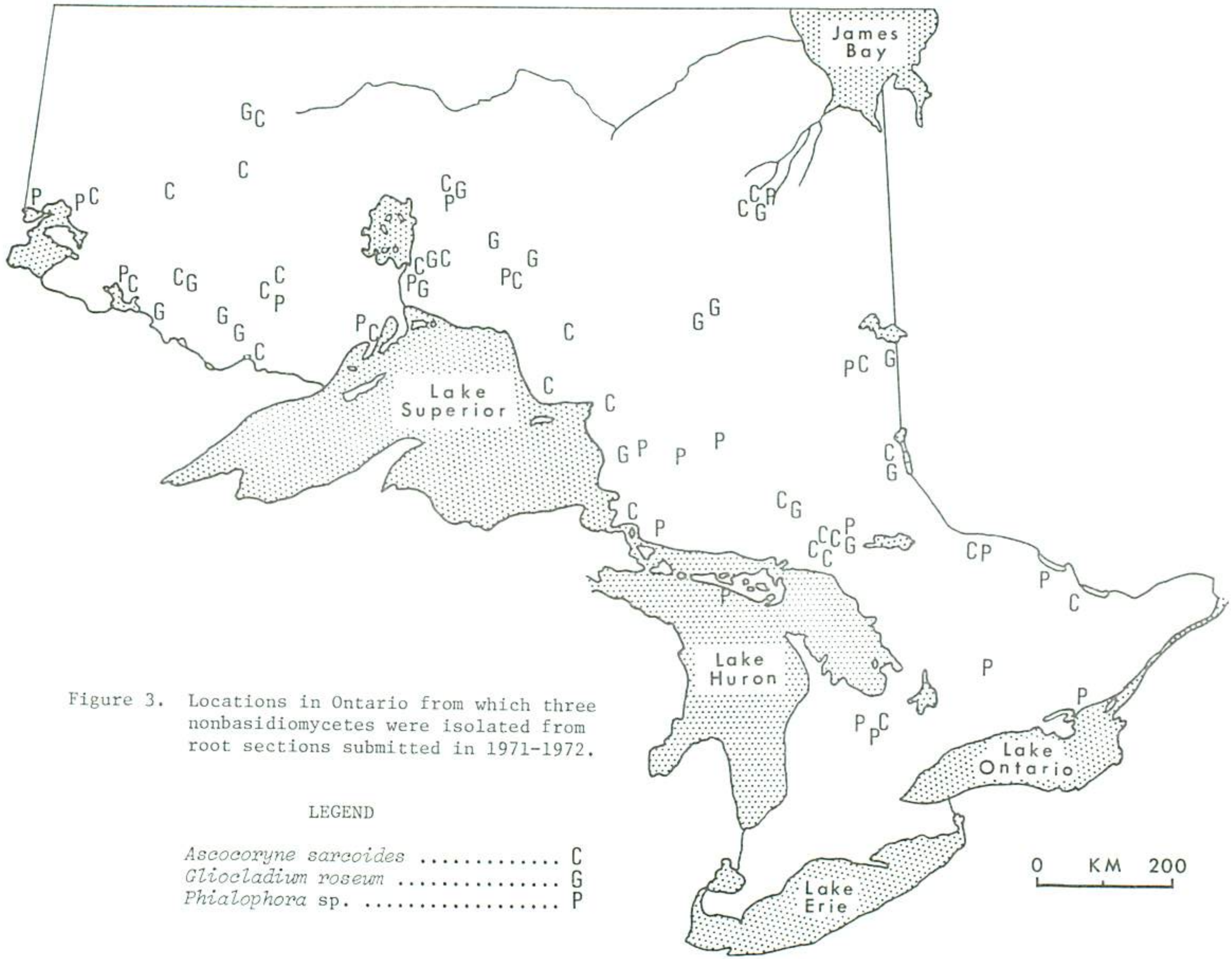


Figure 3. Locations in Ontario from which three nonbasidiomycetes were isolated from root sections submitted in 1971-1972.

LEGEND

*Ascocoryne sarcoides* ............. C
*Gliocladium roseum* .............. G
*Phialophora* sp. .................. P

evaluating stand mortality at some distance from sampled trees precluded the possibility that the fungi isolated were responsible for the death of all the trees.

The two most frequently isolated root-rotting fungi, *Armillaria mellea* and *Polyporus tomentosus*, were well distributed throughout the districts, including those districts with both high and low levels of damage as indicated by dead or unhealthy trees.

There were no definite associative effects among species or groups of species of nonbasidiomycetes and decay-causing basidiomycetes.

## DISCUSSION AND CONCLUSIONS

*Armillaria mellea* attacked all four tree species and is probably the most abundant root-rotting fungus in these species in Ontario. This fungus is known to attack and kill otherwise weakened and unhealthy trees (Patton and Bravo 1967), but in this study the fact that dominant and codominant trees were attacked and adjacent trees were dead suggests primary killing by this fungus.

*Polyporus tomentosus* was the chief cause of root rot in white spruce and black spruce. It was of minor consequence in balsam fir and was not isolated from jack pine, although it is known to be widespread on this species in Ontario (Basham and Morawski 1964). This fungus is known to attack and kill white spruce trees as young as 20-25 years old (Whitney 1972a), and is capable of causing stand openings extending over several acres in older stands (Whitney 1972b). Killing by this fungus in spruce plantations can probably become important, especially in areas where the previous stand was heavily attacked.

*Coniophora puteana* occurred in living trees of all four species and is ranked third in importance in the present survey. Its main role is apparently in attacking trees that have been wounded around the base or have already been infected and partly decayed by other root-rotting fungi (Whitney and Denyer 1970). *Coniophora puteana* is not known to kill trees but causes its greatest damage by structural weakening of the tree at or near ground level.

The above three fungi caused about 75% of all infections found in the present survey and are most likely the fungi of greatest importance in causing root rot in natural pulpwood stands in Ontario.

*Odontia bicolor* and *Scytinostroma galactinum* are the causes of butt rot in Ontario conifers, particularly in black spruce and balsam fir (Basham and Morawski 1964), and these two fungi could probably be ranked as next in importance to the above four fungi in causing root rot in these species in Ontario. Neither fungus is known to kill conifers.

Many of the other fungi isolated in this study appear to be localized and are sporadic in their occurrence in Ontario in the four conifers studied. However, the results are based on only 613 trees over a vast area and little is known of the potential of these fungi for causing damage in the province. In a recent Ontario study (Basham 1973a, 1973b) in which more than 6,000 living black spruce were analyzed, 25 basidiomycetes were associated with stain or decay, mostly in the butt section of the tree. In the present survey the fungus species isolated were basically the same as in the black spruce study, but the latter included four frequently occurring fungi (*Peniophora septentrionalis* Laurila, Unknown F, *Poria subacida* (Peck) Sacc., and *Xeramphalina campanella* (Batsch ex Fr.) Kuhn and Maire) that were not isolated in the present survey. This comparison serves to emphasize the restraint that must be exercised when interpreting results based on a very small sample. Absence of these four fungi in the current survey may be due to site differences between the two studies or to chance. Similarly, *Armillaria mellea* was much more prominent in the present study than in Basham's (1973a and b) study, probably owing to the site of isolation, which in his case was generally a stump 1 ft high (30.48 cm) or higher, while all isolations in the present study were from roots.

With the exception of damage by *Fomes annosus* in plantations of red pine (*Pinus resinosa* Ait.) and jack pine (Myren 1973), a quantitative estimate of damage caused by root rot in Ontario pulpwood stands has not been made. The technique for evaluating damage in this survey did not supply sufficient root rot data to establish a causal relationship between the dead or unhealthy trees and the root-rotting fungi isolated. Thus, while the sample of 40 trees per stand may have revealed real differences in tree mortality among dominant and codominant trees between locations, the five living trees sampled for root rot were insufficient to establish the cause of death of these trees. For a valid causal relationship, at least 10 trees should be sampled at each location, and they should be distributed among the dominant and codominant trees tallied in the tree-vigor evaluation. In addition, cultures should be obtained from at least two roots on each sampled tree. In order to establish relationships between root rot and unhealthy trees, one must evaluate root rot quantitatively in living trees of various vigor classes, but such an evaluation was beyond the scope of the present study.

The comparatively high proportion of trees in this survey that seemed to have no root rot (i.e., 407, or 67%, had no basidiomycete isolated from them) is probably deceptively low because of the few samples taken. Cultures from additional roots on each tree would undoubtedly have produced decay-causing fungi from a much higher proportion of the trees. In a separate, more detailed study currently under way on the major pulpwood species of Ontario, in which all major roots of each tree are being examined, at least 95 percent of the trees thus far examined have been found to contain root rot.

Figure 4. *Armillaria mellea* sporophores around the base of a living diseased white spruce (x 0.2).

Figure 5. *Polyporus tomentosus* sporophores on moss near diseased trees (x 0.3).

In recommending control or management modifications necessitated by the presence of root rot in various stands, it is essential to identify the causal fungi, as their growth rates, life cycles, and effects on the hosts are markedly different. Identification of the causal fungi can be made from sporophores or from cultures of the fungi present in the wood. The presence of two of the main root-rotting fungi in this survey, *Armillaria mellea* and *Polyporus tomentosus*, can be confirmed by the presence of annual sporophores that appear around the base of infected trees in the autumn under conditions of abundant soil moisture (Fig. 4,5). *Fomes annosus* can also be detected from sporophores (Myren and Sippell 1972). However, fruiting of *Coniophora puteana* and all the other root-rotting fungi identified, except *Polyporus schweinitzii*, is rare or difficult to detect. If fruiting is absent, the only definite means of determining the presence of root rot in living trees is by exposing the roots, locating decay within root tissues, and making agar cultures which may be identified using standard keys (Nobles 1948). The labor-intensive aspects of root sampling no doubt account for the paucity of information on root-rot damage in Ontario tree species. Direct control of root rot is usually not feasible in natural Ontario conifer stands. Where the trees are merchantable, root rot losses can be kept minimal by cutting affected stands as soon as possible, before more trees die or succumb to windfall. For example, in planted pine stands in southern Ontario where *Fomes annosus* is suspected, affected trees should be removed and stumps treated as prescribed by Myren and Punter (1972).

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