ROOT DISEASES OF FOREST TREES IN ONTARIO

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Frontispiece. Stand opening in white and black spruce stand (80 to 100 years old) resulting from root rot caused by Polyporus tomentosus.

ABSTRACT

Root diseases are discussed with regard to symptomatology, signs, diagnosis, and control. Included also are detailed descriptions of five root diseases: Armillaria root rot, *Armillaria mellea* (Vahl. ex Fr.) Kummer; Annosus root rot, *Fomes annosus* (Fr.) Karst.; velvet top, *Polyporus schweinitzii* Fr., stand-opening disease, *Polyporus tomentosus* Fr.; and Rhizina root rot, *Rhizina undulata* Fr.

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INTRODUCTION

The purpose of this report is to consolidate information on five important root rots: Armillaria root rot, *Armillaria mellea* (Vahl. ex Fr.) Kummer; Annosus root rot, *Fomes annosus* (Fr.) Karst.; velvet top, *Polyporus schweinitzii* Fr.; stand-opening disease, *Polyporus tomentosus* Fr.; and Rhizina root rot, *Rhizina undulata* Fr. *Scytinostroma galactinum* (Fr.) Donk [*Corticium galactinum* (Fr.) Burt] is reported to cause a root rot of many coniferous and broad-leaved trees. This organism causes a considerable amount of butt rot of conifers in Ontario, and it probably also affects roots. However, the root disease aspects of damage caused by this organism remain to be elucidated. Root diseases of nursery crops are not included.

The actual impact of a root disease is difficult to assess, because other influences such as insects, climate, and site conditions often contribute to the overall problem. In certain situations, root diseases are recognized as the primary cause of tree mortality and growth loss, and these pathogens frequently invade root systems of trees when vigor is reduced by other causes. Regeneration, either natural or planted, is very susceptible to infection by root disease. To date, most of the damage observed has been in plantations because these areas are more intensively managed and diseases generally spread faster and are more damaging in pure stands. Considerable damage is also occurring in natural stands.

ROOT FUNCTIONS

Roots contribute to many of the vital life processes of trees. Food, water, and minerals circulate continuously in trees with most of the food transported through the inner bark and most of the water through the xylem. Roots are a vital link in this system, being the major means by which water and minerals are absorbed. Considerable food is stored in the roots, and they anchor and support the aboveground tree parts. Thus, roots serve a multitude of purposes, all important to the health of the tree.

SYMPTOMS

Surveys to determine the degree to which trees are affected by root disease, or to delineate areas of diseased trees, must rely on symptoms expressed by the aboveground tree parts. Aboveground symptoms should be confirmed by exhuming enough root systems to give a reliable classification of the degree of infection present.

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Trees affected by root rots usually appear to be starving, because the supply of water and nutrients taken from the soil is reduced. Symptoms that reflect the starved condition of the tree are reduced terminal and diameter growth, dwarfed and/or discolored foliage, and dieback of terminal crown portions. Root rots often render trees susceptible to windthrow, and patches of dead and windthrown trees are present at many centers of infection. Root systems frequently become infected through contact with adjacent diseased root systems. This often results in a radial spread pattern from the original focus of infection, and common names such as "stand-opening disease" have been used for many of the diseases. The diseased roots exhibit symptoms that are characteristic of the presence of the pathogen concerned as outlined in Table 1 (see page 14).

SIGNS

Pathologists consider any vegetative or fruiting structure of the organism to be a sign, rather than a symptom, of disease. Signs are frequently used to identify the organism responsible for the diseased condition. When fruiting structures of the pathogen are present, these are reliable indicators of the cause of the disease; however, fruiting is inconsistent and signs are often absent throughout most of the year. Root diseases often advance along the root most rapidly in the cambial region by means of mycelial fans. These aggregations of fungal tissue are considered by some workers to be distinctive for certain root diseases. Also, several fungi which cause root diseases have the ability to form strands of fungal tissue, called rhizomorphs, which are capable of growing through the soil or other debris in the soil and can be helpful in diagnosing root diseases. By means of rhizomorphs, the pathogen can use previously colonized materials as an energy source to infect other root systems.

DIAGNOSIS

The symptoms and signs presented in this report will usually provide enough information for foresters to identify the disease. In cases of uncertainty, foresters may request assistance from the Insect and Disease Survey Unit of this Laboratory. Requests should be accompanied by a sample of the rotted roots.

A good sample will include incipient rot, advanced rot, and a healthy portion of the root (Table 1). Shipment should be by the most expedient means. Samples of diseased roots are frequently contaminated by other soil fungi and accurate diagnosis is not possible in many cases. Samples should not be packaged in airtight containers such as plastic bags, because high humidity and warmer temperatures favor the growth of molds and other contaminants.

Fig. 1 (1/5X) Mushrooms of Armillaria mellea growing on an oak tree.

SPECIFIC ROOT DISEASES

1. *Armillaria Root Rot*

COMMON NAMES: Armillaria root rot, shoestring root rot, mushroom root rot, etc. (The disease has been well known for many years and has acquired numerous names.)

CAUSAL ORGANISM: *Armillaria mellea* (Vahl. ex Fr.) Kummer

HOSTS: All tree species growing in Ontario should be considered susceptible.

SYMPTOMS AND SIGNS: The disease causes the stand openings characteristic of many root diseases. Infected trees may also be present as isolated individuals or they may be scattered throughout the stand.

Reduced terminal and diameter growth are usually apparent and dieback symptoms indicate a general decline in vigor. Foliage is frequently chlorotic and/or dwarfed, and crowns often appear thin.

Trees that produce resin or gum in response to wounding usually exude large quantities of these materials from cankers and rotted roots. Cankers that are extensions of diseased roots frequently occur at the ground line. (See Table 1 for a description of the rot caused by this disease.)

Fruiting bodies of the fungus are typical mushrooms (Fig. 1) with a central stalk, cap, and ring but no cup at the base of the stalk. Color varies from pale yellow to light brown with darker scales often apparent on the cap. Cap size is usually from 2 to 5 inches in diameter. These mushrooms usually occur at the base of dead or dying trees in the fall, but fruiting is erratic and may not occur each year.

Mycelial fans often develop between the bark and the wood of diseased tissues. Fans developed by *A. mellea* are considered to be distinct because they have a veined appearance and are thicker than those developed by most fungi. However, mycelial fans can be caused by a variety of fungi; therefore, these signs are not a reliable indication that *A. mellea* is causing the diseased condition. Investigators should check for other symptoms, especially rotted roots.

Rhizomorphs developed by *A. mellea* are covered by a brown to black rind. The inner core and rhizomorph tips are white and succulent. These structures are root-like when growing in the soil. A network of rhizomorphs often develops under the bark of dead trees and in this situation rhizomorphs are more flattened than usual and are frequently connected in a maze of strands. Rhizomorphs rapidly invade dying and recently dead roots.

DAMAGE: Root disease caused by armillaria root rot is hard to assess. The fungus is capable of colonizing dying and recently dead root systems and has been considered a secondary organism requiring the presence of other damaging agents. However, the disease can be observed in situations where the influence of other damaging agents is not apparent; therefore, the amount of weakening necessary before *A. mellea* can cause extensive root decay may be very little. Root investigators often encounter an occasional root rotted by *A. mellea* when exhuming roots for other purposes and presence of the disease does not mean the tree is seriously affected. The pathogen is capable of surviving for long periods on dead trees and stumps. Thus, inoculum is usually available to infect trees which may be weakened for only a short period.

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2. *Annosus Root Rot*

COMMON NAMES: Annosus root rot, Fomes root rot.

CAUSAL ORGANISM: *Fomes annosus* (Fr.) Karst.

HOSTS: Red pine (*Pinus resinosa* Ait.), jack pine (*Pinus banksiana* Lamb.), Scots pine (*Pinus sylvestris* L.), and white pine (*Pinus strobus* L.) have been observed dying from this disease in Ontario. The fungus has been recognized fruiting on the stumps of a variety of coniferous species. Reports from other countries of species affected indicate that most coniferous species should be considered susceptible. The disease is considered not to affect hardwoods but rare occurrences indicate that some hardwood species can be affected, especially any growing near diseased conifers or large concentrations of dead material on which the fungus is well established.

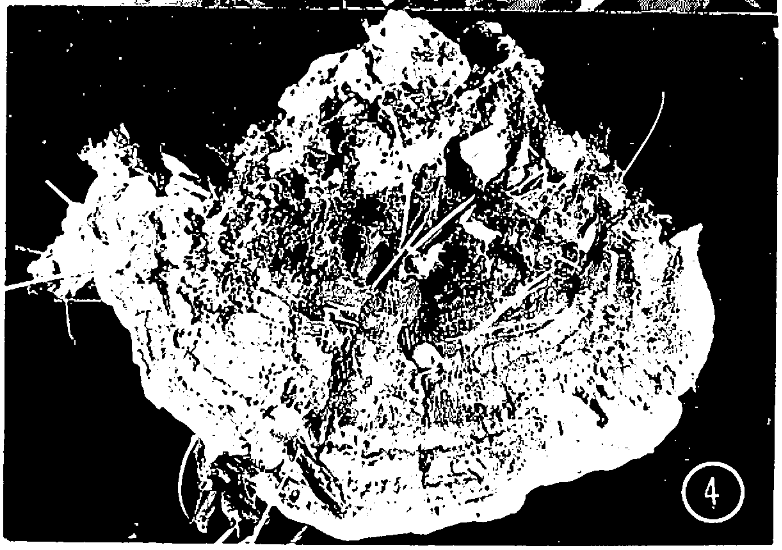

Fig. 2 (1/10X) A red pine tree infected with annosus root rot with the forest litter removed to show fruiting bodies.

Fig. 3 (IX) Fomes annosus fruiting body pore surface.

Fig. 4 (IX) Fomes annosus fruiting body upper surface.

SYMPTOMS AND SIGNS: Stand openings develop because of mortality caused by *F. annosus*. Occasional healthy trees may be present in these openings; also several infection centers may merge. Thus, the stand openings may not be easily recognized.

Infected trees can sometimes be recognized by a lack of vigor. Foliage is chlorotic and may be dwarfed; terminal and diameter growth is reduced, and needle retention may be affected. However, these symptoms are not always apparent and trees with badly rotted root systems may show no aboveground symptoms. (See Table 1 for a description of rotten roots.)

Fruiting bodies of *F. annosus* sometimes form at the base of infected trees or stumps (Fig. 2). It is usually necessary to clear the forest litter from the base of the tree or stump to find the fruiting bodies. Sheltered locations on the root systems of windthrown trees and rodent holes are also favored sites for fruiting. Conks are typically bracket shaped (Fig. 3), but are often very irregular, especially when growing on the undersurfaces of roots. The upper surface (Fig. 3) is reddish brown to dark brown with the color usually brightening toward the margin which is white to creamy. The pore surface (Fig. 4) is white to creamy. Fresh specimens have a rubbery texture. Species of the genus *Fomes* are perennial polypores, yet, conks of *F. annosus* are frequently annual, and are usually not present throughout most of the year. With experience, an investigator can learn to recognize rotted dead conks, the remains of which can last for more than a year.

DAMAGE AND CONTROL: Annosus root rot usually becomes established in a stand through the infection of freshly cut stump surfaces or wounds and spreads to adjacent root systems through root grafts and contacts. Thus, cutting operations, especially thinnings, increase the susceptibility of a stand. Spores capable of infecting freshly cut stump surfaces and other wounds have been sampled from air for most parts of Ontario. To date, however, the disease has been recognized only in southern Ontario. Fortunately, stump treatment to prevent the establishment of annosus root rot is effective, and a bulletin (Anonymous, 1969) which describes procedures and materials is available from the Director, Forest Research Laboratory, Department of Fisheries and Forestry, Box 490, Sault Ste. Marie, Ontario. Forest managers are urged to apply this treatment during all thinning and harvesting operations when conifers will be present in the future stand. If stump treatment is not applied, this disease could have the same serious impact on the forests of Ontario as it has had in Europe and parts of the United States. Natural stands are more adapted to the site, but the possibility of infection by *F. annosus* after partial cuts in natural stands cannot be neglected.

In older trees the root rot frequently develops to a heart rot, which can cause extensive losses.

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3. *Velvet Top*

COMMON NAME: Velvet top.

CAUSAL ORGANISM: *Polyporus schweinitzii* Fr.

HOSTS: Reports of root rot caused by this disease have been recorded for red and white pine in Ontario. The disease is better known as a brown-cubical butt rot, and as such, affects a wide variety of coniferous species. Therefore, it probably also affects many conifers as a root rot.

SYMPTOMS AND SIGNS: Baxter (1967) gives a good description of a stand of white pine affected by this disease. Infected trees showed a characteristic loss of vigor. Needles produced were undersized and bronze green. Butt rot caused by *P. schweinitzii* is distinct (Table 1). Affected trees often have swollen butts and the rot usually extends into the roots.

The fruiting bodies of this fungus are usually funnel shaped, flattened on top (Fig. 5) and up to 1 ft or more in diameter. When attached to the trunks of trees, fruiting bodies are bracket shaped. Color of the upper surface is usually a rich chocolate to rust brown, with the margin tan to yellow. The undersurface is the same color as the margin, though sometimes it is somewhat greyish. The texture of the upper surface is velvety. In many respects fruiting bodies are similar to those of *P. tomentosus*, but in most cases those of *P. schweinitzii* are much larger and darker.

DAMAGE: The root rot aspects of this disease are not well defined. Baxter (1966) leaves little doubt that extensive damage can be caused in certain situations. Root-disease investigations that identify characteristic cubical brown rot or fruiting bodies of this fungus should be reported so that more knowledge of this pathogen can be obtained for Ontario. Butt rot caused by *P. schweinitzii* has been observed for white pine, red pine, and white spruce [*Picea glauca* (Moench) Voss].

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Peace, T. R. 1962. Pathology of trees and shrubs. Oxford Univ. Press. London. 753 p.

4. *Stand-opening Disease*

COMMON NAMES: Stand-opening disease, red root rot.

CAUSAL ORGANISM: *Polyporus tomentosus* Fr. [Also reported in literature as *Polyporus circinatus* Fr. and *Polyporus tomentosus* var. *circinatus* (Fr.) Sartory & Maire.]

HOSTS: Studies by Whitney (1962, 1966) show that white and black spruce [*Picea mariana* (Mill.) BSP.] are susceptible to this root disease. The fungus is known to be associated with a wide variety of conifer species, and other hosts are probably susceptible to the disease.

SYMPTOMS AND SIGNS: Patches of dead and dying trees cause stand openings. Needles are sometimes dwarfed and may also be chlorotic. Terminal growth may be reduced. Crowns die from the lower crown upwards until the crown is reduced to a few stunted branches on severely affected trees. Basal cankers frequently occur and resinous exudations are common from diseased tissues. (See Table 1 for a description of the rotted roots.)

Fruiting bodies of the fungus are up to 1/2 ft or more in diameter, usually funnel shaped but sometimes bracket shaped when attached to tree trunks (Fig. 6 and 7). The upper surface is tan to brown with a velvety or chamois texture. Pore surface and margin is usually the same color or lighter.

Fig. 5 (1/5X) *Polyporus schweinitzii fruiting body growing on the ground near a conifer tree; note the velvety upper surface. When growing on trees fruiting bodies are usually bracket shaped.*

Fig. 6 (1/5X) *Polyporus tomentosus.*

Fig. 7 (1/5X) *Polyporus tomentosus showing root association.*

DAMAGE: This disease is recognized as the cause of extensive damage to stands of spruce in Europe and North America. In Ontario it has been observed causing mortality to trees in hedgerows but the impact on forests is undetermined. Basham and Morawski (1964) determined that *P. tomentosus* was one of the most important heart rots of coniferous species in Ontario; so it is probably present as a root rot in many forest situations.

Whitney (1962) indicates that progress of the disease through root systems is usually slow, and most stand openings have probably had a long history of infection.

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5. *Rhizina Root Rot*

COMMON NAMES: Rhizina root rot, group dying.

CAUSAL ORGANISM: *Rhizina undulata* Fr. also known as *Rhizina inflata* (Schaeff.) Sacc.

HOSTS: At present, all species of conifers should be considered susceptible. The fungus has been found in Ontario near dead spruce roots in recently burned areas.

SYMPTOMS AND SIGNS: Groups of trees are usually affected, and the pathogen usually spreads from infection centers that develop near fire sites. Seedling-sized trees are most susceptible, but the disease affects trees of all size classes. Aboveground symptoms are probably similar to those associated with other root diseases. Murray and Young (1961) report these symptoms: sparse foliage, thin crowns, and resinous exudations are often apparent on the lower trunk. Roots of all sizes can be infected, and diseased tissues appear as resinous cankers. Yellowish white mycelial strands form a conspicuous network over affected roots.

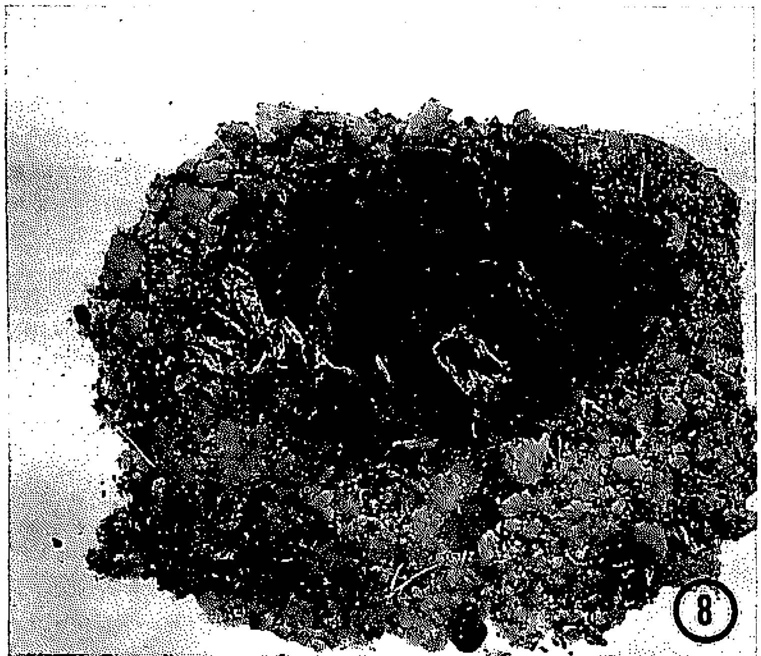

Fig. 8 (1/3X) Rhizina undulata with a portion cut away at (a) to show undersurface.

Fig. 9 (IX) Rhizina undulata undersurface showing cord-like rhizoids.

Fruiting bodies, usually found in sheltered places on the forest soil or duff, are very unique, resembling globules of chocolate spilled on the ground (Fig. 8). They are usually 1 to 2 in. diam., but several may coalesce to form mats 3 to 4 in. or more in dize. Young fruiting bodies have white to creamy margins. The undersurface is also distinctive because of the numerous cordlike strands which form an attachment to mycelium in the soil (Fig. 9).

DAMAGE: Damage is usually recognized in groups of dying seedlings growing near fire sites, and group dying of semimature and mature trees is a serious problem in Europe. Most of the damage occurs in a period of several years following burns. Areas where slash has been piled and burned, wildfire sites, and prescribed burns should be intensively investigated, especially when seedlings are planted in or near these areas. Reports from Europe and recently from British Columbia indicate that this pathogen can be very virulent following fires.

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Ginns Jr., J. H. 1968. Rhizina root rot of Douglas-fir in British Columbia. Can. Dep. Forest. Rural Develop. Forest Pest Leafl. 5 p.

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Table 1. Descriptions of roots rotted by root disease fungi.

Organism	Incipient rot	Advanced rot
1. *Armillaria mellea*	Early stages of rot are characteristically wet, having a faint to well defined water-soaked appearance. Color varies, being usually light brown to pale grey with color becoming more apparent as wood deteriorates.	Wood eventually becomes a soft, wet, spongy mass, which is usually stringy in conifers and amorphous in hardwoods. Rotted wood is usually white to cream colored or sometimes light brown. Black zone lines are often present in the rotted wood.
2. *Fomes annosus*	The early stage of rot is usually indicated by a pink to dull violet color.	Wood eventually is reduced to a white stringy mass. Intermediate stages are characterized as a white pocket rot. Elongated pockets of more advanced rot occur irregularly within areas of firmer wood. Black flecks sometimes occur in the pockets.
3. *Polyporus schweinitzii*	Early stages of rot are indicated by elongate spire-shaped areas which have a light yellow to pale reddish color.	Advanced rot appears as a reddish brown cubical rot. Shrinkage cracks frequently become filled with mycelium which has the appearance of accumulated resin. Usually heartwood is decayed well in advance of sapwood.
4. *Polyporus tomentosus*	Early stages of rot are indicated by a light cinnamon brown to reddish brown color often well ahead of advanced rot.	Advanced rot is very similar to that caused by *Fomes pini*. White to creamy pockets of advanced rot are surrounded by firmer wood which is usually reddish brown in color.
5. *Rhizina undulata*	A description of the wood rot caused by this disease was not apparent in the literature examined. The disease typically affects the bark and inner bark, and secondary infection by *Armillaria mellea* was recognized by Murray and Young (1961). Therefore, the disease may not be capable of causing rot of the woody cylinder.	

CONTROL

After a root disease has become established in a stand, control is difficult, if not impossible. Most spread is underground where conditions that influence the disease or its spread are difficult to control. Orchardists, shade tree pathologists, and managers of nonforest tree crops have developed controls that use soil sterilants to arrest the spread of root disease by providing a zone where live roots are not present. Trees isolated within the treated area are sacrificed to save the remaining healthy trees. Materials used are extremely dangerous and should be handled only by trained personnel. Problems of terrain, irregular spacing, and rocky subsoils which occur in forest situations are usually more formidable. Therefore, this method of control is not recommended in forest situations because it is expensive and additional research is needed to improve techniques for forest applications.

Numerous methods for controlling the spread of root diseases in forest stands have been tested: trenching around the diseased stand to a depth below the rooting depth of the trees; eradicating the diseased root systems from the affected stand; girdling trees previous to felling to make the root systems more susceptible to nonpathogenic organisms; and changing the pH of the soil to make it less favorable for the pathogen. In Europe some of these controls are considered effective, but the above methods have had limited or no success in the control of root diseases in North America.

Delineating diseased portions of a stand for purposes of control is difficult, because early stages of infection are often not reflected in the aboveground parts of a tree. Another problem is that *A. mellea*, *F. annosus*, and *P. tomentosus* can remain viable for long periods in debris and in dead root systems.

The following suggestions to help control root diseases are presented for the consideration of forest managers.

1) Nonhost trees should be spaced between host trees to form natural barriers because mixed stands have fewer root grafts between host trees.

2) Similarly, conversion of diseased stands to nonhost species in future rotations, a form of crop rotation in intensively managed areas, is highly recommended.

3) Infected stands should be considered to be nonproductive forests for a period of years after the final cut, because recropping the host species will probably result in the next crop being infected by the disease.

4) Careful site selection in planting or regeneration programs will promote tree vigor and make the stand more resistant to root diseases.

5) Crowded stand conditions facilitate the spread of root rots because more root contacts are present. Trees should be planted to the widest spacing interval that will give the stocking and tree characteristics desired, so that root contacts will be prevented for a longer period and fewer thinnings will be required.

6) Planting trees to a rigid spacing interval should be discouraged. By recognizing the potential of diseased stumps and contaminated debris, foremen can instruct planting crews to plant trees as far as possible from these sources of infection.