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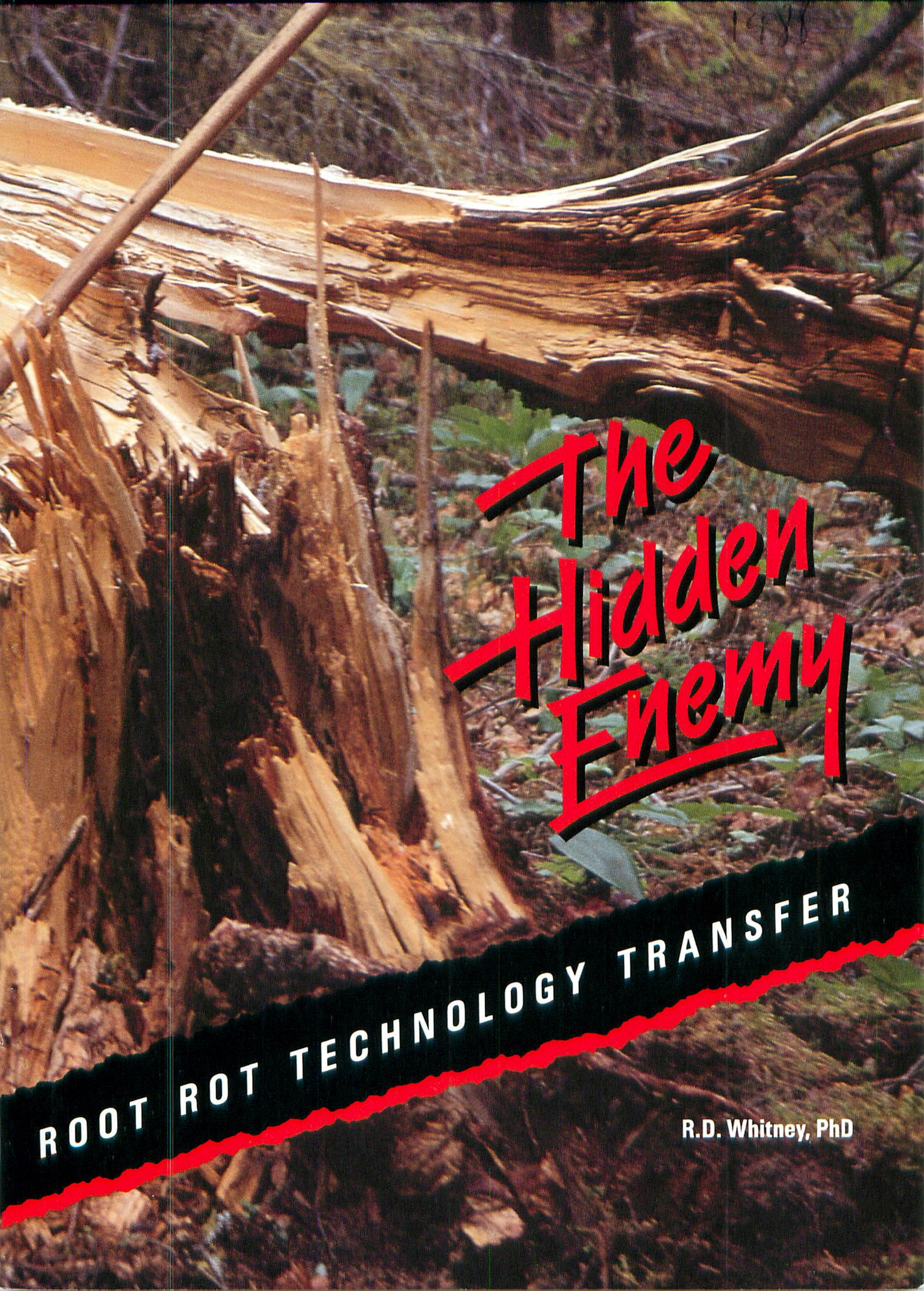

The Hidden Enemy

ROOT ROT TECHNOLOGY TRANSFER

R.D. Whitney, PhD

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For Practical Use in the Field: A Forester's Guide to Identification and Reduction of Major Root Rots in Ontario

R.D. Whitney, PhD

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Foreword

Considerable information, mostly of a highly technical nature, has been published on root rots affecting trees in Ontario. Journals and the proceedings of professional symposia continue to chronicle the pathology of root-rotting tree diseases.

Discussions with provincial forest managers indicated a need for a less technical field guide to the principal root rots of Ontario trees. *The Hidden Enemy* is intended to serve as a practicable tool for management planning. It should assist in identification of the diseases and offer prescriptions for minimizing the resulting losses in commercially important stands.

This guide provides information in simplified form, compiled from a variety of sources, on symptoms, damage, hosts and geographic range of root diseases, as well as suggested methods of controlling them.

The guide concentrates on root rots caused by fungi. Stem rots and root disorders caused by other factors such as nematodes, viruses, insects, mycoplasmas, bacteria or environmental extremes are not discussed in detail.

CHAPTER 1

Root Rot– An Overview

The evolving philosophy of forest management

In the primeval forest, living wood was consumed by fire or succumbed to the inevitable process of decay. Nature returned nutrients to the site and completed a cycle of the forest ecosystem.

As settlement began, the forest was declared the adversary. The good fight was for agricultural progress, and the battleline was drawn along the field edge. Settlers enlisted fire and decay as allies in the struggle to turn forests into fields. Articles appeared in agricultural journals of the day with advice on land-clearing techniques. One such publication proclaimed: "One man, with the proper use of fire, can clear a hundred acres a day."

An industry evolved that was based on what was still perceived to be an endless resource. As the lumbermen took the first commercial bite out of the forests of Ontario they declared: "There is enough timber here to last 700 years." That estimate was far too optimistic.

By 1930, parts of the province showed the effects of overcutting. Extensive erosion and the disappearance of wildlife species, such as the Ontario wild turkey and Great Lakes Atlantic salmon, were mute testimony to forest exploitation that was based on the myth of endless woodlands.

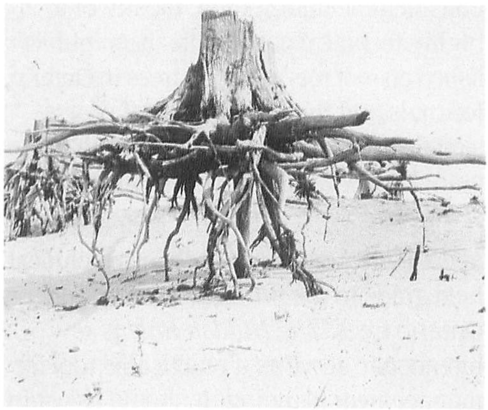

Fig. 1-1.
An extreme example of erosion due to overcutting in southern Ontario.

Today, a philosophy of intensive forest management is evolving in recognition of the fact that forest resources are a most important natural asset to Ontario. With the increasing social and economic value of each tree, we can no longer afford to plant and walk away. The latest developments in science and technology are evident in every aspect of modern forest management. The continuing objectives in the laboratory and in the field are to increase the sophistication of silvicultural practices such as growing trees, protecting them from fire and disease, controlling populations of destructive insects, and harvesting mature stands.

Loss to Decay in Ontario Forests

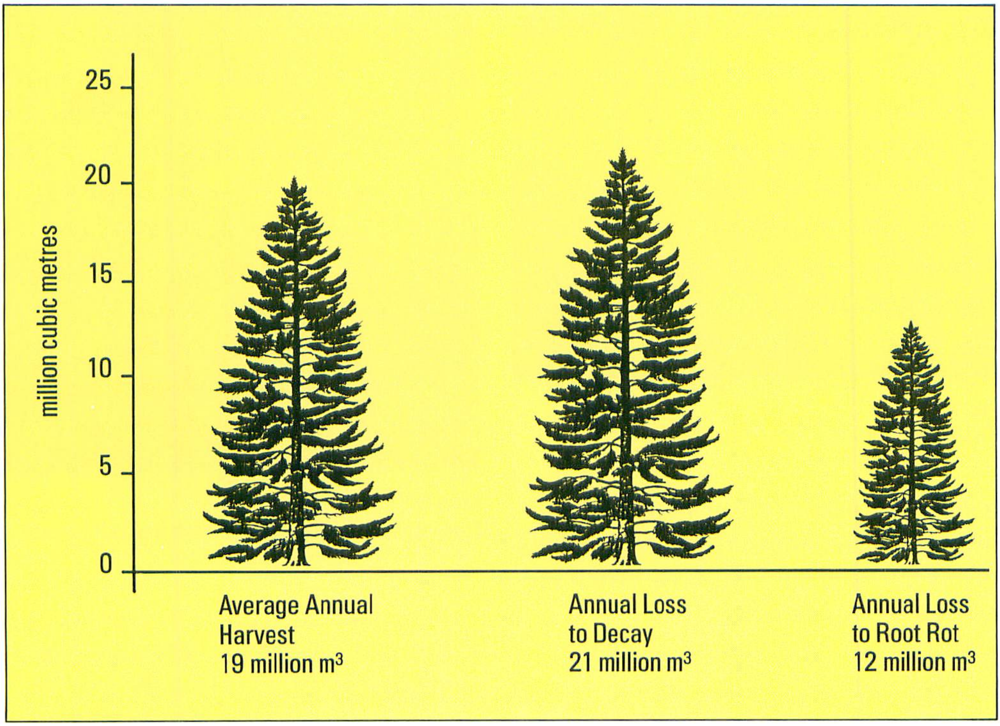

Fig. 1-2.
Ninety percent of merchantable trees sampled in Ontario forests showed evidence of root decay.

Rots in Perspective

The average annual harvest from Ontario forests is over 19 million cubic metres. The annual loss to decay is estimated to be over 20 million cubic metres of living wood. Of this annual loss, more than 11 million cubic metres can be attributed directly to tree kill and lost increment resulting from root rots. Ninety percent of merchantable trees sampled in Ontario forests showed some evidence of root rot.

Root rot and decay statistics are used by provincial foresters to ensure the accuracy of inventory. They aid in establishing wood measurement regulations, stumpage rates and estimates of available wood volumes. As long as additional stands are available for harvesting, this competition for sound wood between root rot and the forest manager matters little. However, new stands are becoming scarce. As the forest inventory is depleted, anything done to decrease losses of sound wood to natural causes, such as root-rotting diseases, is highly significant.

Of course, not all fungi in the forest environment are in competition with the woodlands manager. A group of fungi known as mycorrhizal fungi actually form

Fig. 1-3.
The fruiting body of a mycorrhizal fungus.

a symbiotic relationship with the host tree. Mycorrhizal roots absorb greater amounts of moisture and nutrients because the surface area of the rootlets has increased. In return, the fungus uses carbohydrates supplied by the tree.

Fig. 1-4.
A mycorrhizal tree root.

Other fungi, such as *Fomitopsis pinicola*, the red belt fungus, and *Gleophyllum sepiarium*, known as the slash conk, attack and break down dead wood. Considered slash destroyers, these fungi are essential to the ecosystem of the forest.

Fig. 1-5.
Fruiting bodies of *Fomitopsis pinicola* (red belt fungus).

Numerous fungi affect the roots of various trees in Ontario. The three most significant fungi that affect the roots of commercially important conifer species, *Armillaria obscura, Inonotus tomentosus* and *Heterobasidion annosum*, are the focus of this field guide.

Fig. 1-6.
Fruiting bodies of *Gleophyllum sepiarium* (slash conk).

CHAPTER 2

Root Rot and the Forest

The Individual Tree

Root-rotting fungi cause decay in the roots, butt and stem of living trees. Decay is a chemical action by enzymes on the various substances that make up the complex structure of the wood. These enzymes are produced by fungal hyphae.

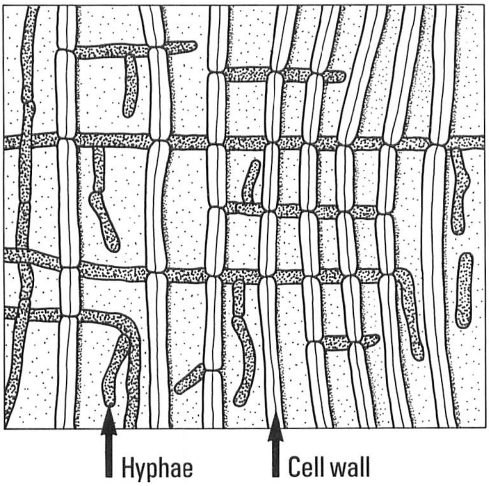

Fig. 2-1.
Hyphae are sharply constricted as they pass through cell walls.

Hyphae are the vegetative structures of fungi, similar to the cells of the human body. Many hyphae grouped together form mycelium, much the way human cells form tissues such as muscle or skin.

Different root rots decompose different components of wood (cellulose, lignin, etc.) at varying rates. However, the effects are always the same. The chemical action of enzymes allows the hyphae of the fungus to punch through the walls of cells and spread through the wood. As the damage progresses through the roots, into the butt and eventually into the stem, the tree slowly dies (Fig. 2-5).

Infection takes place at or below ground level, usually through an interruption in the bark or by direct contact with infected material. In the early stages of the disease, lateral roots 5 millimetres to 20 millimetres in diameter are usually the first to die. The dead roots are often resinous and have accumulations of resin-soaked humus or soil clinging to them. Forty percent of the root system may be killed even though there are no apparent above-ground symptoms (Fig. 2-3).

The next stage of the disease involves main lateral roots, and kills up to 80 percent of the total root system. Dead branches appear in the lower crown. Other visible symptoms include reduced increment and abnormal curling of the ends of branches. At this point decay is probably present in the butt and stem of the tree (Fig. 2-4).

In the final stages, fewer than 20 percent of the roots are still alive. By this time, trees have only a few living branches at the top, or else the entire tree is dead. Decay can extend for more than one metre into the stem. In very young trees all foliage may die simultaneously.

Progression of Root Rot

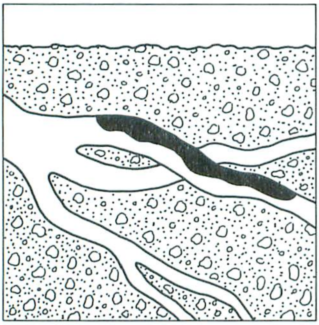

Fig. 2.2. Early stage.

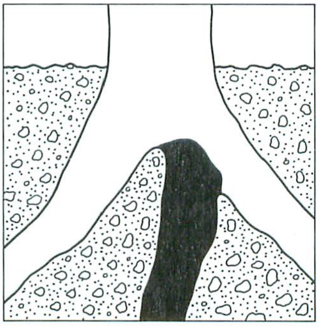

Fig. 2-3. Middle stage.

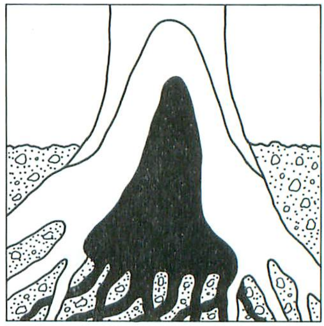

Fig. 2-4. Advanced stage.

Natural Stands

Root-rotting tree diseases affect all commercially important trees. Natural stands of white spruce, black spruce and balsam fir have been intensively studied in Ontario. Losses of sound wood to root rot occur in four significant ways:

- through mortality
- through reduced increment
- through windfall
- through butt cull.

Advanced Root Rot Healthy

Fig. 2-5.
Tops from a 60-year-old white spruce stand.

One of the physiological effects of root rot on the living material of the tree (bark, cambium and sapwood) is lost increment in the disease stage when more than 40 percent of the roots have been killed. This physiological effect is the eventual cause of tree death in the late stages of the disease, when more than 80 percent of the roots are dead.

Slow Growth Healthy Tree

Fig. 2-6.
Discs from 60-year-old white spruce showing slow growth resulting from root rot.

Windfall results from the attack of root-rotting fungi on structural elements of the tree (cellulose, lignin, etc.). As the disease progresses, the root systems of the trees are weakened severely. Blowdowns are often the result.

Fig. 2-7.
Mortality—a 50-year-old red pine killed by root rot.

Single, windthrown trees may be scattered through the stand or groups of trees may be affected. One blowdown often starts a chain reaction. For this reason, an important root rot caused by *Inonotus tomentosus* is commonly referred to as "stand opening disease."

Fig. 2-9.
Patchy opening caused by root rot in a black spruce stand.

Fig. 2-8.
Windfall caused by advanced root rot.

High winds tend to knock down large areas of standing timber and leave trees lying in the same general direction. Trees weakened by root rot and subsequently windthrown are scattered through the stand. Groups of trees lie in crisscross patterns. These patchy openings are not an automatic thinning and, except in massive blowdowns, the dead standing and windfallen trees cannot be harvested economically.

Butt cull is the result of the advanced stages of decay progressing from the roots some distance into the butt of the tree. Failure of the woodlands manager to recognize this effect of root rot may result in inaccurate forest inventory and unsound wood may be transported to the mill.

Fig. 2-10.
Butt cull caused by root rot.

• Some planting, site preparation and tending practices increase the incidence of root rot.

Root rots tend to affect older trees. The provincial average of 2 percent mortality per year in young plantations less than 15 years of age is of little consequence unless dead trees are closely grouped. However, some plantations exhibit mortality as high as 11 percent. A mortality rate of over 10 percent in such young plantations may influence restocking, tending and harvesting plans.

Plantations

In Ontario, root rot attacks both spruce and pine in plantations of all ages. Sound wood is lost in the same ways as it is in natural stands, i.e., by mortality, windthrow, reduced increment and butt cull. Fewer details are known about the specific effects of root-rotting tree diseases in plantations because of the relatively brief history of large-scale planting practices in the province.

Problems caused by root-rotting tree diseases are often magnified in plantations for the following reasons:

• These woodlands usually represent a greater management investment than natural stands.

• Large areas of single species and even-aged stands provide a medium susceptible to the spread of root-rotting diseases.

Fig. 2-11.
A sapling killed by root rot.

CHAPTER 3

Decay Types in Roots

Stains

In the incipient stage, root rot appears as stain in otherwise sound wood. It is most often reddish brown, but it can be found as a faint water stain in the very early stages and pinkish, violet or dark cinnamon brown stains are common. The color depends on the specific fungi involved. It may also vary from host to host even when these are infected with the same fungus on similar sites. This stain on the surface of a freshly cut stump is often the first clue to the fact that roots are seriously decayed.

Fig. 3-1.
Brown stain—the early stage of root rot.

Not all stains in the roots, butt and stem of living trees are caused by root-rotting fungi. Mineral stains and those caused by non-rotting fungi are also common. A pink stain is often present in the wood of Ontario spruce. It is associated with a non-rotting fungus, *Ascocoryne sarcoides*. A yellow stain common in balsam fir is not consistently associated with any organism. These pink and yellow stains have characteristics that may actually protect trees from invasion by root-rotting fungi.

Fig. 3-2.
Pink stain—associated with non-decaying fungi.

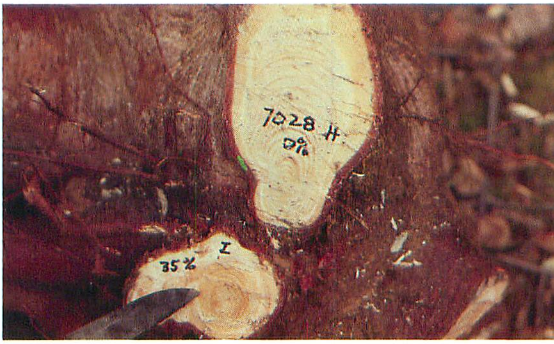

Fig. 3-3.
Yellow stain—not consistently associated with any organism.

Cultures

Staining in wood is certainly a clue to the presence of a root-rotting disease in the incipient stage. However, similar stains caused by other factors have been discussed. Even when decay is present in the advanced stages, positive identification of the specific disease is most often impossible in the field. For positive identification of individual causal fungi it is necessary to culture the fungus in a laboratory environment.

Culturing fungi is an involved process. Once the forest manager suspects the presence of rot in a stand, culturing is best undertaken by a forest pathologist or specially trained technician with access to appropriate facilities. An infected area of the tree, most often root material, is exposed and removed. In the laboratory an aseptic surface is created by scraping away the outer layer containing any foreign material. A tiny cube of wood, approximately 2 millimetres per side, is then cut from this prepared area. The cube is cultured in a sterile test tube to which malt agar has been added as a medium for growth. Malt provides nutrients, the agar solidifies into a carrier medium and distilled water is the necessary source of moisture. After 4 to 6 weeks it may be possible to identify the fungus by observing the macroscopic characteristics of resultant mycelium. In other cases, it may be necessary to continue the culturing process on a petri dish by using the same type of malt agar medium. In 4 to 6 weeks, definite identification can be made by observing macroscopic characteristics and by utilizing a compound microscope. Macroscopic observations are made to examine characteristics such as color, the appearance of the advancing zone and the texture of the fungus or mat. Microscopic observations are made to determine particular characteristics of the hyphae and other cellular structures.

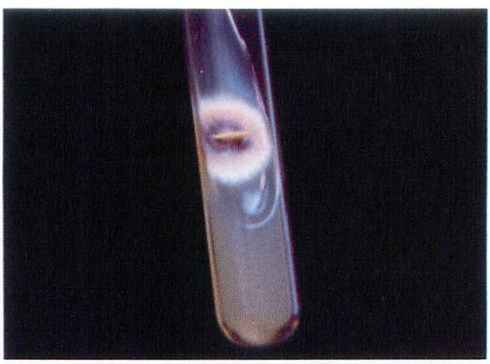

Fig. 3-4.
Causal fungus isolated on malt agar.

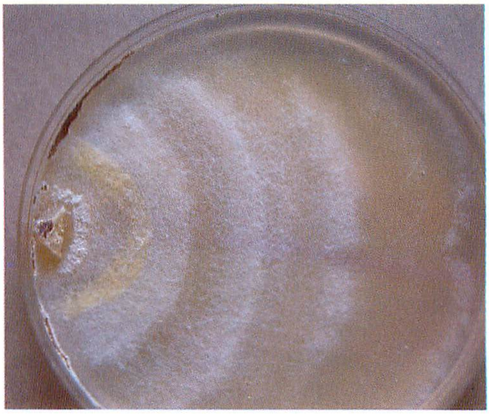

Fig. 3-5.
Culturing causal fungus for identification.

Advanced Decay

Decay caused by various root-rotting fungi can be divided into three major types named after the appearance of the advanced stages:

- yellow stringy rots
- white pocket rots
- brown cubical rots.

White pocket and yellow stringy rots decompose mostly lignin. Brown rots decompose mostly cellulose and associated pentosans. Sometimes two types may be found in the same tree, a white or yellow rot attacking the heartwood first and then a brown rot destroying the remaining sound components.

Fig. 3-6.
Yellow stringy rot.

Yellow stringy rot has a spongy texture. Infected areas vary in color from a vivid yellow to almost white. In the most advanced stages the wood breaks apart in stringy masses. Both heartwood and sapwood are attacked and infected areas are often marked by numerous black zone lines.

In the advanced stage, wood affected by white pocket rot shows small white

Fig. 3-7.
Close-up, white pocket rot.

elongated pockets separated by areas of firm brownish wood. Sometimes these pockets have black spots in the center. Eventually the pockets run together, forming a spongy mass flecked with black.

Brown rots reduce wood to a carbonous mass, colored with various shades of brown. The decayed wood is easily reduced to powder between one's fingers, a feature that has led to the common name "dry rot", although wood cannot rot without a source of moisture.

Fig. 3-8.
Brown cubical rot.

CHAPTER 4

Important Root Rots in Ontario

The bulk of damage in Ontario forests is caused by three major root-rotting tree diseases: Armillaria, annosus and tomentosus root rots. All of Ontario's commercially important conifer species are affected in plantations and natural stands.

Armillaria Root Rot

Causal Organism: *Armillaria obscura*

Common names: shoestring fungus, honey mushroom

Range of Armillaria Root Rot in Ontario

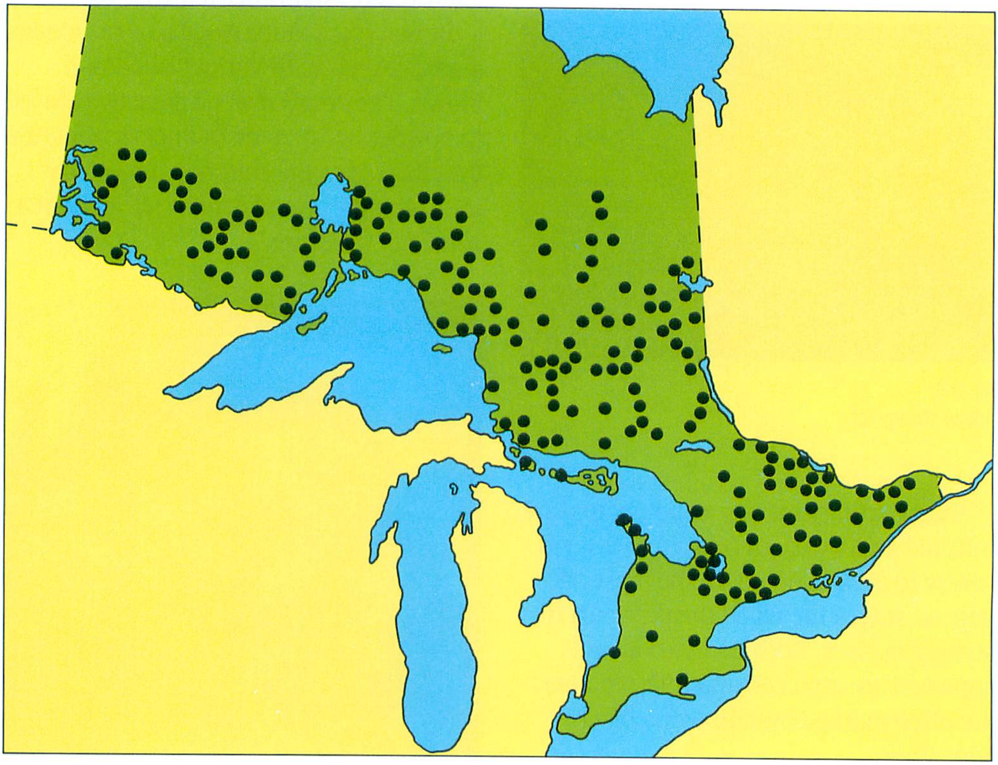

Fig. 4-1.
Dots represent locations in which Armillaria root rot has been found.

Range

Armillaria is the most common root rot in the world. It is caused by a complex of species of which there are eight biological types in North America. Of these, *A. obscura* is responsible for the most damage throughout Ontario.

Identification and Symptoms

A general decline in vigor, dwarfed or discolored foliage and thinning of the crown from below are usually the first symptoms to be noticed by the casual observer. Especially in pines, there may be an abnormal flow of resin from the root collar, sometimes to the extent that the surrounding soil is a crusted, compact mass. Further inspection of the base of the tree will

Fig. 4-2.
Abnormal resin flow—a symptom of Armillaria root rot.

probably reveal areas of decayed bark and wood. If white mycelial fans and dark shoestring-like rhizomorphs are revealed when the bark is removed, diagnosis in the field is certain.

Fig. 4-3.
White mycelial fans of *Armillaria obscura* under the bark of a coniferous stump.

A faint water stain usually appears in the incipient stage of decay caused by *Armillaria obscura*. It then turns light brown and in the advanced stages the result is a yellow, stringy decay or rot.

Fig. 4-4.
Sub-cortical rhizomorphs of *Armillaria* species.

Fig. 4-5.
Armillaria obscura sporophores.

Fall fruiting is often found in association with advanced stages of the disease. The mushrooms develop in clusters on the butts of living trees and on the ground above infected roots. The fruiting bodies have a yellow or brown, solid central stock from 8 centimetres to 25 centimetres long. The broad cap is yellow and dotted with dark brown scales on the upper surface. The lower surface is composed of whitish gills that are attached to the stock as well as the cap. There may be a raised ring or annulus on the stock a short distance below the gills.

Spread

Armillaria root rot spreads in two ways: by basidiospores from the gills of the fruiting bodies and by subterranean rhizomorphs.

The basidiospores are windborne. They infect stumps and dead trees but rarely a living host, except possibly through open wounds at the base or on exposed roots.

The main method of infection in living trees is by subterranean rhizomorphs. These structures are similar to the dark-colored subcortical rhizomorphs found in conjunction with white mycelial fans under the bark of infected trees. Rhizomorphs consist of a dark outer layer of compacted fungus tissue enclosing a central core of hyaline hyphae arranged in longitudinal rows. These cordlike strands are 1 millimetre to 3 millimetres in diameter. They grow through the soil, usually close to the surface. When the tip of the rhizomorph contacts a living root, it penetrates the bark by a combination of mechanical and chemical means. Hyphae from the rhizomorph then penetrate the inner bark and wood of the new host.

Fig. 4-6.
String-like subterranean rhizomorphs—the major means of *Armillaria* species infection.

Disease Cycle – Armillaria Root Rot

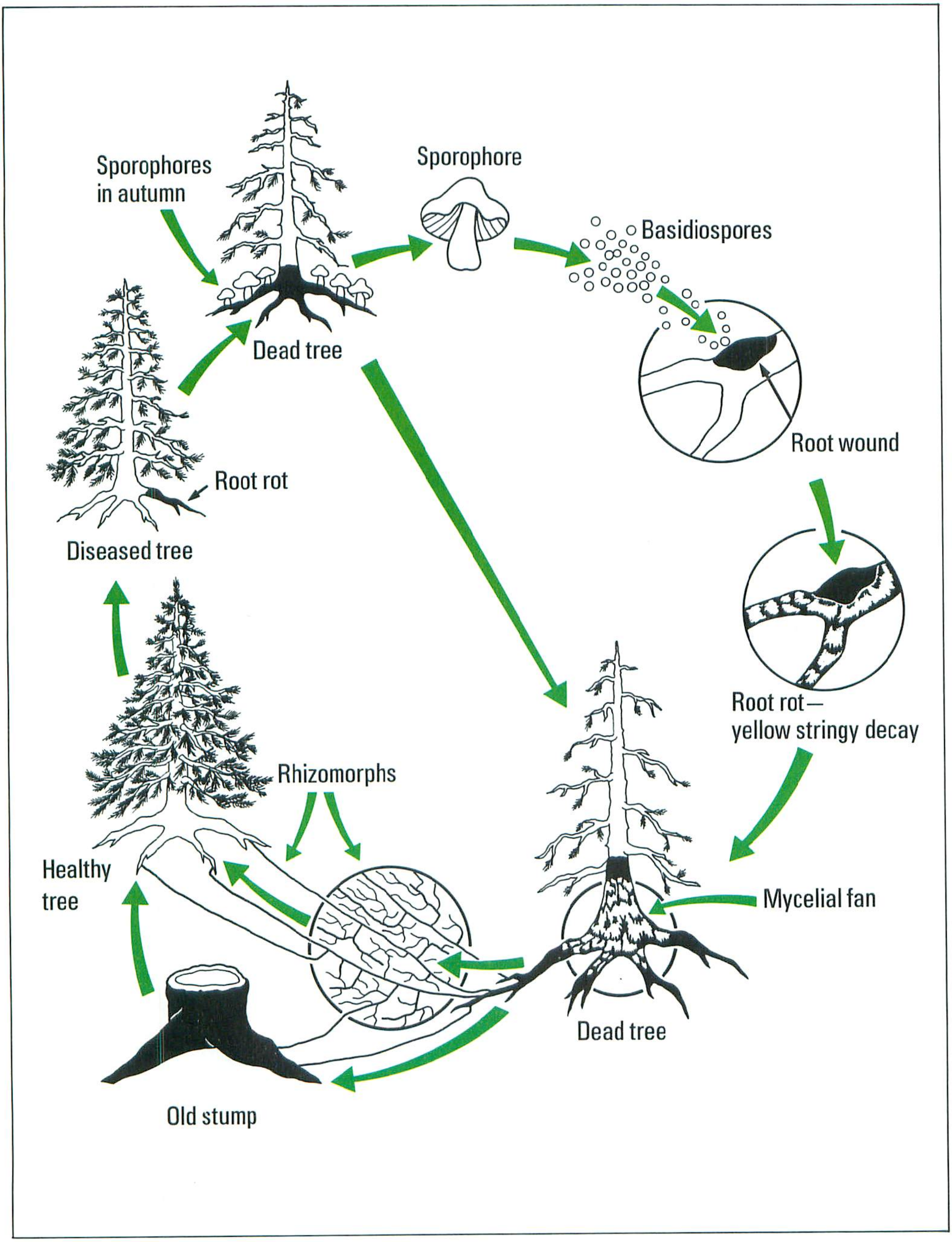

Fig. 4-7.

Damage

All species of trees in Ontario are susceptible to infection by *Armillaria obscura* or other *Armillaria* species. Trees of all ages are affected in both plantations and natural stands. Trees may be killed singly, in small groups, or here and there throughout the stand.

General Disease Cycle – Tomentosus and Annosus Root Rots

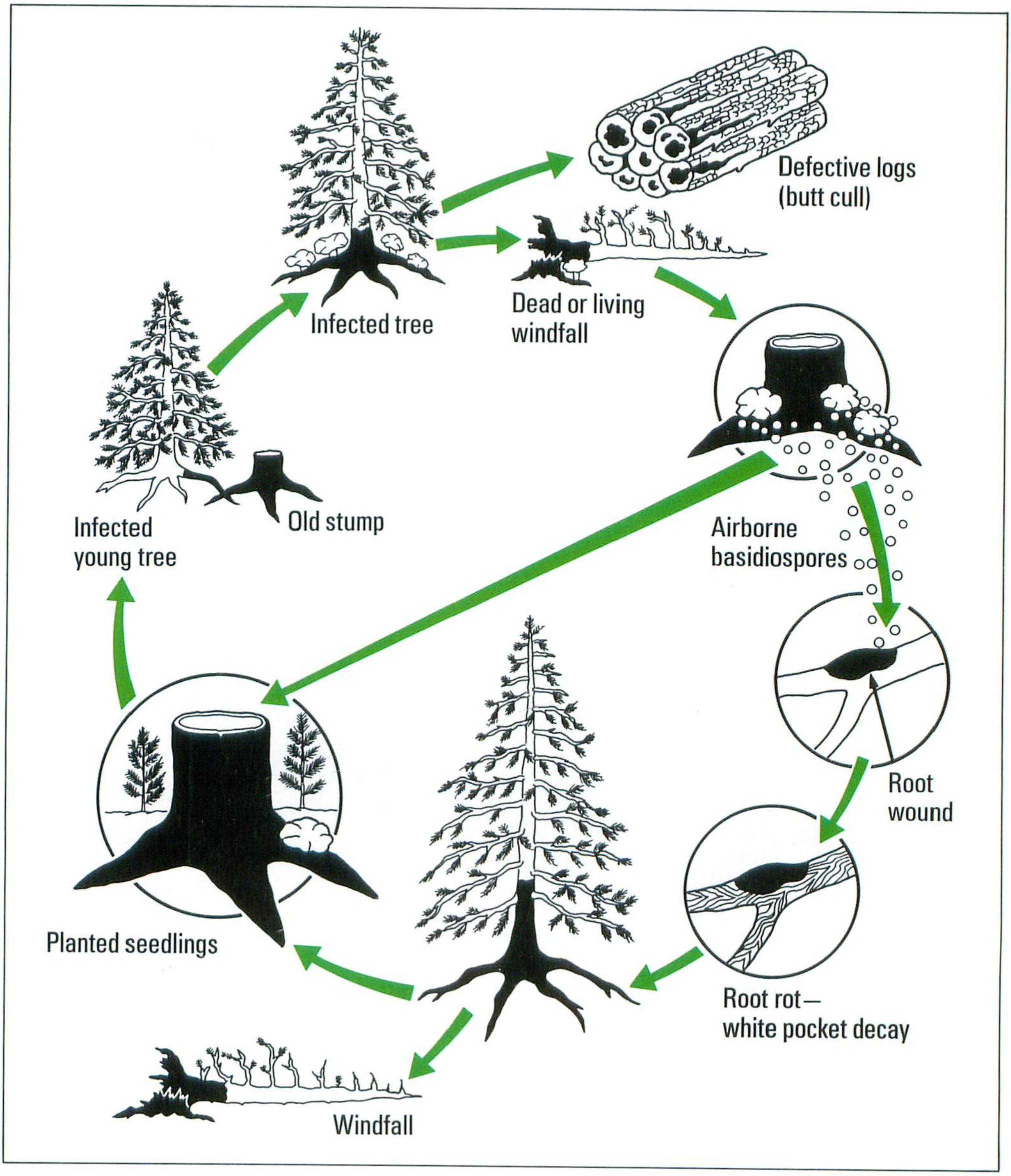

Fig. 4-8.

Tomentosus Root Rot

Causal Organism: *Inonotus tomentosus*

Common Names: stand opening disease, red root rot, white pocket root rot

Range

Tomentosus root rot can be found throughout Ontario. Damage appears to be worse in the northern part of the province because of the susceptibility of mature spruce stands, which are more plentiful in the north.

Range of Tomentosus Root Rot in Ontario

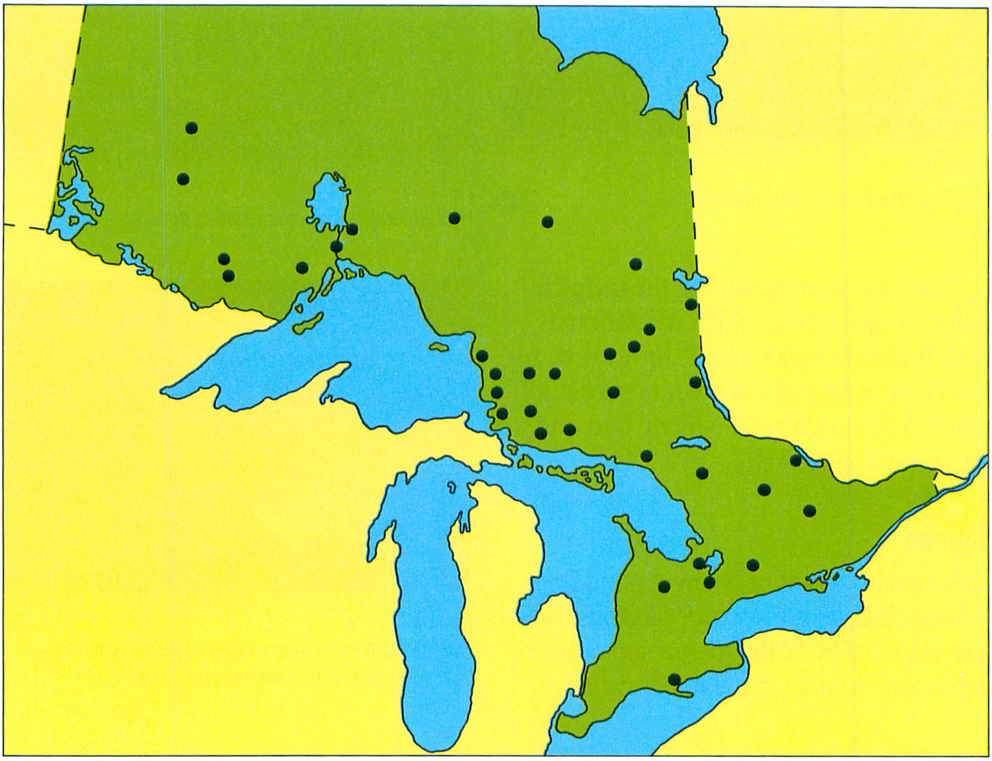

Fig. 4-9.
Dots represent locations in which tomentosus root rot has been found.

Identification and Symptoms

Foliage is often dwarfed and chlorotic in the advanced stages. The crown dies from below until only a few stunted branches are left in severely affected trees. Basal cankers often occur and resinous exudations are common from badly infected areas, especially the roots. Two types of fruiting occur from midsummer to the end of autumn, except in very dry years. Sporophores can be funnel-shaped on the ground above infected roots (Fig. 4-11) or bracket-shaped and attached to the trunk (Fig. 4-10). The upper surface is tan to brown with a velvety or chamois texture. The undersurface is usually the same color or lighter.

Fig. 4-10.
Inonotus tomentosus sporophore.

The stain accompanying the incipient stage ranges from pinkish through reddish brown to violet in still-firm wood. As the disease progresses a white pocket rot develops throughout the roots, butt and lower stem (Fig. 4-15).

Spread

Infection occurs at or below ground level. Although large numbers of basidiospores are produced by both types of sporophores, direct root contact is the major cause of infection. Mycelium grows directly from a diseased root into a healthy one. There is evidence that root wounds increase the chance of infection from root contacts and basidiospores.

Fig. 4-11.
Experimental collection of *Inonotus tomentosus* spores.

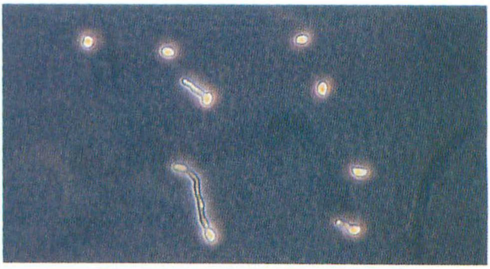

Fig. 4-12.
Hyphae arising from germinating spores.

Fig. 4-13.
Inonotus tomentosus spreading by direct root contact. Dark roots are dead, light wood is living.

Damage

Tomentosus root rot is most common in black spruce and white spruce. In both plantations and natural stands, trees become susceptible after 25 years of age. Plantations tend to have a higher incidence of infection. Because the rot spreads by direct root contacts, groups of diseased trees radiate from a central point. The fact that windthrow and mortality create openings in a stand accounts for the common name "stand opening disease."

Fig. 4-14.
Stand opening caused by *Inonotus tomentosus.*

Fig. 4-15.
White pocket rot—the advanced stage of tomentosus root rot.

Annosus Root Rot

Causal Organism: *Heterobasidion annosum*
Common Names: spongy sap rot, brown root, Fomes root rot

Range

Annosus root rot is currently found in Ontario south of a line from Owen Sound to Ottawa.

Range of Annosus Root Rot in Ontario

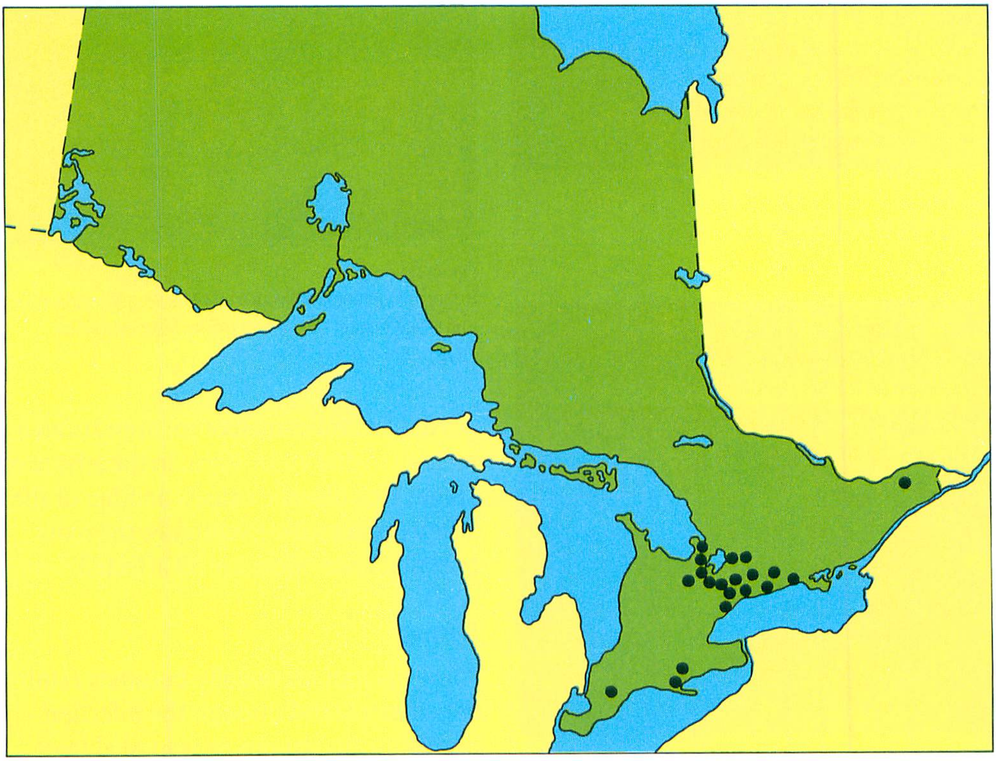

Fig. 4-16.
Dots represent locations in which annosus root rot has been found.

Identification and Symptoms

In the advanced stages infected trees exhibit the typical lack of vigor common to root rots. Growth is often reduced and foliage retention may be affected.

Fig. 4-17.
Trees killed by annosus root rot.

Fig. 4-18.
Typical fruiting of *Heterobasidion annosum* at the base of an infected red pine.

October and November are peak fruiting months for *H. annosum*. Sporophores can be found at the base of stumps and at the base of dead or living trees. It is often necessary to clear the forest litter to find the fruiting bodies. The sporophores, called conks, are typically bracket-shaped, but frequently irregular, especially when growing from the underside of roots. Sheltered places, such as windthrown trees and rodent holes, are favored locations for fruiting. The upper surface of the sporophore is usually reddish-brown to dark brown with a white to creamy margin. The underside is also white to creamy. Fresh conks have a rubbery texture.

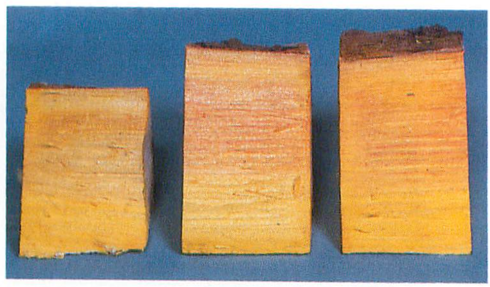

Fig. 4-19.
Prepared sections of large roots showing the pink stain and white pocket decay caused by *Heterobasidion annosum.*

At first, annosus root rot appears as a pinkish to dull violet stain. In the advanced stages this disease causes another of the white pocket rots. Eventually, the roots, butt and lower stem are all affected.

Spread

Annosus root rot usually becomes established in a stand through the infection of freshly cut stumps or wounded trees by windborne basidiospores. Mycelium then grows down the stump and spreads

Fig. 4-20.
Freshly cut stump and roots showing the presence of annosus root rot.

to nearby trees by contacting roots. Therefore, thinned stands are most often attacked.

Damage

Annosus root rot attacks and kills pines mainly over 25 years of age because in Ontario the first thinning usually takes place a few years before this. Annosus is most damaging to southern Ontario pine plantations, especially those on old field sites that have been thinned.

Fig. 4-21.
Red pine seedlings killed by annosus root rot. The fungus was transmitted by the diseased roots of a stump. Note the small sporophore on the base of the tree.

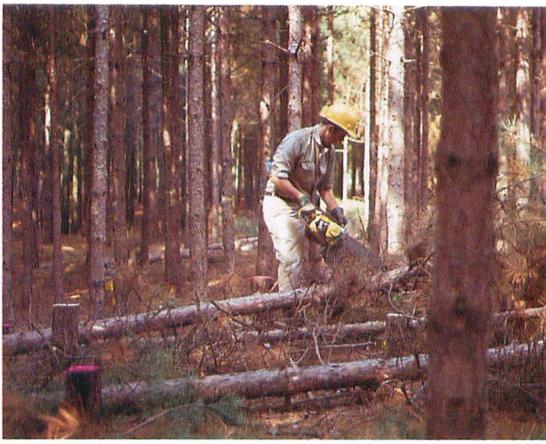

Fig. 4-22.
Intermediate cutting in a pine plantation.

Other Root Rots

From the perspective of forest management, annosus, Armillaria and tomentosus root rots are of most concern. On a province-wide basis, these three diseases are responsible for the bulk of damage attributable to root rot on productive forest land. However, many other root rots have been found in Ontario trees. In specific parts of the province and on individual species these diseases may be significant. Many of them have not been studied in detail.

Coniophora puteana is a common cause of brown cubical root and butt rot of many coniferous species. It favors balsam fir but has also been isolated from black spruce, jack pine, white pine and white spruce in Ontario (Fig. 4-23).

Fig. 4-23.
Coniophora puteana (brown cubical decay) in the base of a living white spruce.

Scytinostroma galactinum is a common cause of yellow stringy root and butt rot in several Ontario conifers and some hardwoods. Included are balsam fir, white spruce, black spruce, jack pine, red pine, white pine, yellow birch and sugar maple. It is also known to kill apple trees.

Fig. 4-24.
Butt cull resulting from *Scytinostroma galactinum.*

Tyromyces balsameus causes a brown cubical root and butt rot, most often in balsam fir. Occasionally, other conifers are attacked. In Ontario it has been isolated from balsam fir, white pine and black spruce.

Fig. 4-25.
Advanced decay in the butt of a living white spruce, caused by *Tyromyces balsameus.*

Fig. 4-26.
Rot in the stump of a balsam fir, caused by *Haematostereum sanguinolentum.*

Haematostereum sanguinolentum is a special case in that it causes a decay that could be classified as intermediate between brown cubical and yellow stringy. It is a major cause of stem decay in balsam fir and to a lesser extent in black spruce, white spruce and, rarely, jack pine. The disease usually enters the roots through existing stem infections, although it can also enter through root wounds. *H. sanguinolentum* is known to cause a lethal root rot elsewhere, but it has not been linked with mortality in Ontario.

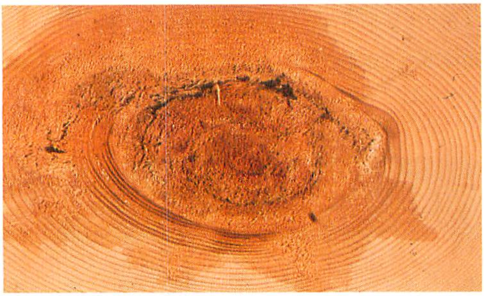

Fig. 4-27.
Stain and stringy rot caused by *Resinicium bicolor.*

Resinicium bicolor is a cause of white stringy root and butt rot in several coniferous species. In Ontario it has been isolated from balsam fir, black spruce and white spruce.

Phaeolus schweinitzii is known to cause brown cubical root and butt rot in many conifers. It has been found to affect black spruce, white spruce, jack pine, red pine, white pine and balsam fir in Ontario.

Poria subacida causes a yellow stringy or white feathery root and butt rot, flecked with black spots. White spruce, black spruce, several pines and especially balsam fir are affected in Ontario.

Dichomitus squalens causes a white pocket trunk rot that affects several western North American conifers. It has been found in roots of jack pine, balsam fir and white spruce in Ontario.

Fig. 4-28.
Advanced decay caused by *Poria subacida.*

Fomitopsis pinicola causes a brown cubical decay, chiefly in stems. It is widespread as a fungus that destroys coniferous slash. In Ontario it has been found in roots of living black spruce and white spruce.

Root Rots of Lesser Importance

Sistotrema brinkmannii—white sap rot

Polyporus adustus—white mottled or cubical sap rot

Phlebiopsis gigantea—white stringy rot

Phellinus pini—white pocket rot

Ganoderma tsugae—soft, spongy, white rot

Polyporus borealis—white pocket rot

Polyporus sericeomollis—brown cubical rot

Trametes americana—brown cubical rot

Cerrena unicolor—white pocket rot

Poria tsugina—white pocket rot

Hymenochaete corrugata—white pocket rot

Asterodon ferruginosus—yellow stringy rot

Peniophora pseudopini—yellow stringy rot

CHAPTER 5

Entrance Courts

Fig. 5-1.
Damage caused by carpenter ants.

Damage by carpenter ants and various snout beetles of the *Hylobius* complex create ideal entrance courts for root-rotting fungi.

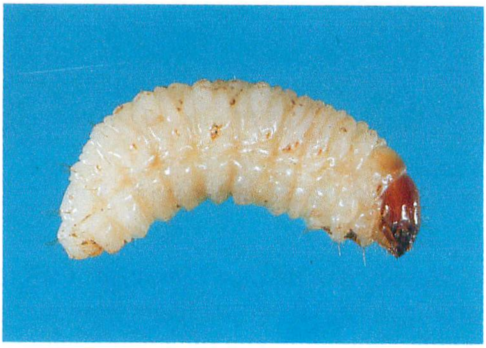

Fig. 5-3.
Larva of a *Hylobius* beetle.

Root-rotting fungi can more easily infect healthy trees through damaged areas near or below ground level. These injuries may result from conditions as natural as a very wet season or the force and friction of trees swaying in high winds; both kill root ends.

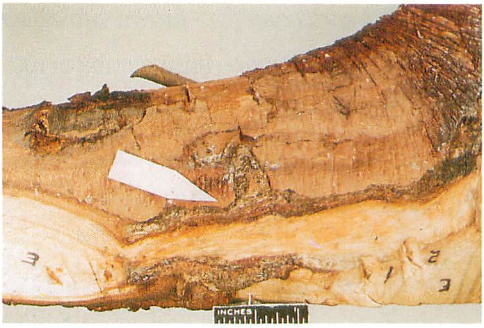

Fig. 5-2.
Damage caused by the larvae of *Hylobius* beetles.

Fig. 5-4.
A stone contacting a living root. Note the resulting yellow stringy decay.

Compression wounds caused by growing roots contacting stones or other roots allow fungi to enter through broken bark.

Roots grafting to one another, usually between trees of the same species, provide an interruption in the bark and an invitation to root-rotting tree diseases.

Fig. 5-5.
A root of one tree grafted to the stump of another.

Fig. 5-6.
Roots damaged by human traffic in a campground.

Fig. 5-7.
A fire-scarred white pine.

Trampling by cattle or moose and deer can damage exposed roots and give root rot an opportunity to infect otherwise healthy trees.

Wildfires and prescribed burns often damage the bark of surviving trees. Root-rotting fungi may enter through these wounds.

CHAPTER 6

Intensive Forest Management and Root Rot

Harvesting

Since the 1950s and the development of the wheeled skidder, the science and technology of harvesting mature timber have progressed dramatically. The use of multi-operation harvesting machines and advanced partial cutting systems is now common. Unfortunately, one of the side effects of this advanced science and technology can be increased incidence of root rots. The possibility of root rot damage is greatest where large multi-operation machinery is used in partial cutting. Operator error, carelessness or ignorance may result in damage to trees near ground level. These wounds provide entrance courts for root-rotting fungi. Harvesting techniques should also be modified when residual trees are left to provide a start for the next crop.

Fig. 6.2.
Modern harvesting.

Fig. 6.1.
Harvesting in the past.

In the case of intermediate or partial cutting, a skidder trail system should be laid out before logging begins. The trail should be spaced so that all trees can be removed without leaving the main track. Bumper trees can be left at critical points to absorb damage, then felled when harvesting operations are complete. Felling should take place from the back of the stand towards the landing. Directional felling and dropping of trees into natural openings can further reduce wounding.

Site Preparation and Tending

Intensive site preparation and tending, especially in plantations, can shorten rotations and improve growth rates. However, these same practices may increase the incidence of root-killing diseases.

Wherever root rot occurs, infected dead material, especially buried roots, can be identified as a source of inoculum. Exposing this material during site preparation allows it to dry and greatly reduces potential inoculum. *Inonotus tomentosus* has been known to survive in buried roots for 16 years.

Sanitizing a site during preparation and intermediate cuttings reduces the potential for new infections. Removing as much dead material as possible is an effective means of reducing Armillaria root rot in all conifers, tomentosus in boreal spruce, and annosus in the pine plantations of the St. Lawrence lowlands.

Stumps left during intermediate cuttings are ideal entry courts for both Armillaria and annosus root rots. The highest risk is that of infection by annosus root rot in pine plantations on old field sites in the St. Lawrence lowlands. Treating freshly cut stumps in these plantations with borax

Fig. 6.3.
Conventional site preparation—a possible source of inoculum.

Fig. 6-4.
A pine stump treated with borax mixed with pink dye.

reduces the disease. Powdered borax can be applied to the stumps with homemade shakers (jars with holes punched in the top) or painted on as a solution. Sodium nitrite is also effective in this procedure; however, it is seldom used because of its corrosive and toxic nature. This chemical has also been found to inhibit natural decomposition of treated stumps.

The roots of low-value hardwoods such as poplar, killed to eliminate competition in conifer stands, have proven to be an important source of Armillaria root rot in plantations. When using chemical or mechanical methods to control vegetation, one should plan to leave as much living root material as possible. Often a forester must balance losses in plantations from competition with losses from root rots, and plan his tending procedures accordingly.

Fig. 6-5.
A weed tree killed by herbicide and then infected by *Armillaria obscura*. Note the rhizomorphs, which spread the fungus to planted conifers.

CHAPTER 7

Controls

When intensive forest management is applied, four principles concerning root-killing diseases should be kept in mind:

- Root rot in living trees increases with age.
- Some species are more prone to root rot than others.
- There is a direct relationship between site characteristics and the incidence of root rot.
- Vigorous trees are less susceptible to diseases than non-vigorous trees.

Incidence of Root Rot Related to Tree Species and Age

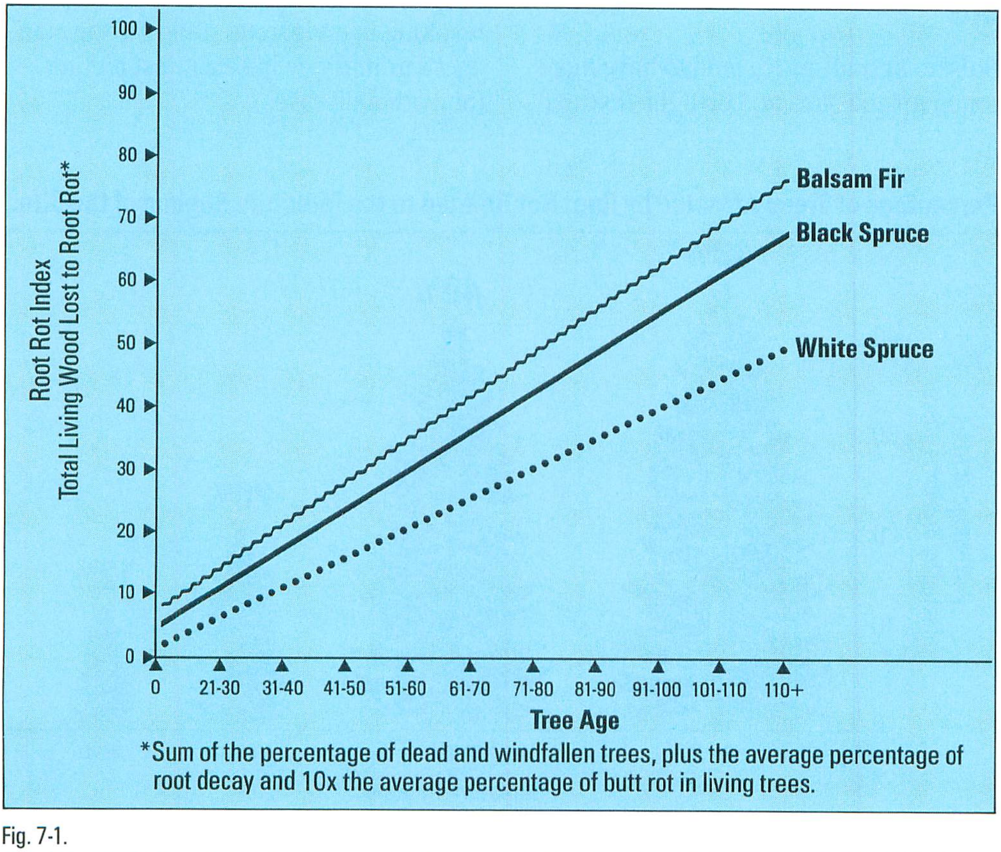

Fig. 7-1.
The above graph shows that root rot increases with tree age. In Ontario, balsam fir is most susceptible and white spruce shows the greatest resistance of the three species.

Age

Every forester knows that a 60-year-old tree will probably not have decayed to the same extent as a tree 120 years of age (Fig. 7-1). Cutting younger trees before root rot becomes serious is a primary method of control.

Species

The forester also knows that in Ontario a balsam fir or poplar is much more likely to decay than a spruce. Spruce sites infected with tomentosus root rot can be harvested and planted to less susceptible pines.

Site

Balsam fir and spruce tend to have more rot on upland sites and on light-textured soils with low moisture regimes. Black spruce on lowland sites generally has very little root rot. Harvesting high, dry sites first and retaining trees on lowland sites for later harvesting can improve yields and prevent negative growth rates. Annosus root rot in southern Ontario pine plantations is most severe on old-field sandy sites. In such a situation early harvest and conversion to other species can be considered.

Vigor

Root-rotting fungi are unlikely to affect the growth of otherwise healthy trees. Intensive forest management techniques resulting in a vigorous stand are the manager's primary defense against root rot (and other diseases).

Percentage of Trees Affected by Root Rot Related to the Moisture Regime of the Site.

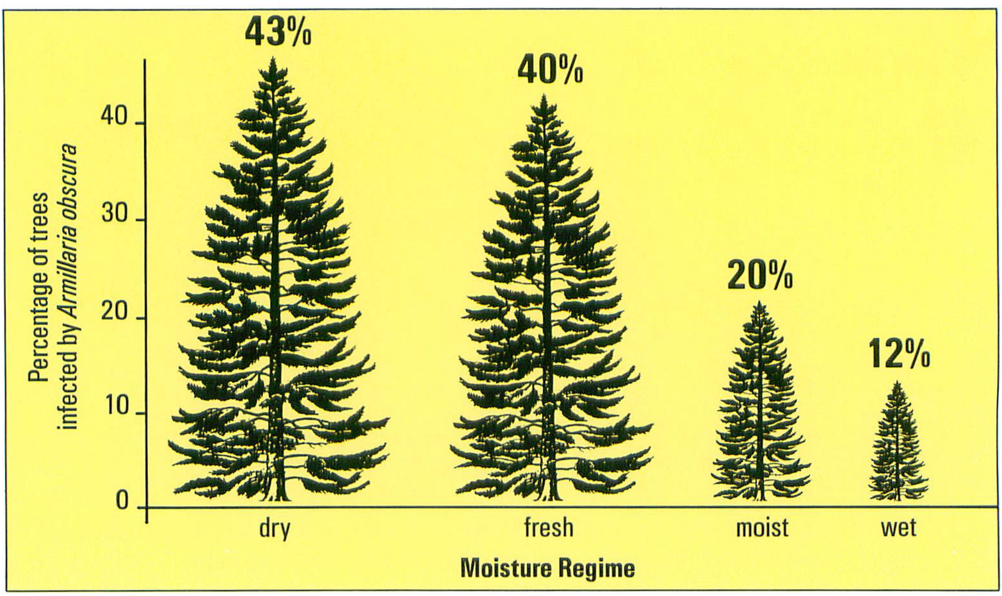

Fig. 7-2.
The relationship between the percentage of black spruce affected by a major root rot and the moisture regime of specific sites in northwestern Ontario.

CHAPTER 8

New Horizons for Root Rot Control

There are no chemical treatments for root-killing diseases. As root rot occurs primarily underground, treatment would have to be systemic and most likely would be prohibitively expensive. Damage to beneficial fungi such as mycorrhizae is also possible. However, forest pathologists are ever seeking new methods of controlling "the hidden enemy."

Fig. 8-2.
A living root inoculated with the fungus for experimental purposes.

Biological Control

Biological control of root rot involves the use of non-decaying fungi with properties antagonistic to root decay fungi. The antibiotic properties of these harmless fungi are revealed either through direct lysis of the pathogen's infective organs or by the release of products of metabolism toxic to the pathogen. These antagonistic fungi can be successfully cultured in the laboratory; however, few methods of biological control are yet practicable in the field.

Fig. 8-1.
A cultured root-rotting fungus.

Growth of root-rotting fungus prevented by the introduction of an antagonist.

The most successful biological control program in forest pathology involves the inoculation of freshly cut stumps with *Phlebiopsis gigantea* to prevent infection by annosus root rot. The infection court is the stump in this instance, and the control measure is easily applied. However, with the two most important root rots of the boreal mixedwood forest, Armillaria and tomentosus, infection occurs mainly through the roots. Therefore, any potential biological control agent must be capable not only of inhibiting these organisms but also of establishing itself in a new niche.

It has been demonstrated that healthy wood contains a variety of microorganisms that inhibit decay fungi. Future work with biological controls may involve manipulation of these naturally occurring organisms. Introducing them and/or modifying the environment within the tree may encourage them to survive and spread. Subsequently, the incidence of root rot could be substantially lowered.

Genetic Selection

Work in forest genetics has resulted in the identification of seed provenances with improved resistance to frost, insects and specific diseases. In the future, these studies may lead to the development of provenances of various species with high resistance to root rots.

Work planned for Ontario by researchers at the Great Lakes Forestry Centre includes the study of plots containing various provenances of mature white spruce and Norway spruce. Trees will be inoculated with *Inonotus tomentosus* and the rate and severity of the resulting infections will be studied.

Species Identification

If root rot is to be controlled it is essential that specific fungi causing damage be isolated and identified. Only after identification of the specific disease can work begin on control.

Armillaria root rot has long been attributed to the fungus *Armillaria mellea*. Recently, it was discovered that *A. mellea* is a complex of species, and the specific fungus *A. obscura* has been singled out as causing most of the damage to Ontario conifers. Further work with specialized culturing techniques is being done to identify species of *Armillaria*.

Stump Removal for Root Rot Control

We know that annosus root rot often enters through cut stumps and then spreads by direct root contact. Control of annosus spread by stump removal on severely diseased sites has been demonstrated recently in British experiments.

Other methods of control have been attempted in Ontario on an experimental basis. Trenching in the Larose forest achieved control of secondary spread of annosus root rot, but the isolated infection remained and the area involved was no longer available for pine production. Application of silvicides to kill healthy trees surrounding infected areas, in order to stop the disease from spreading beyond the centre of infection, has proven ineffectual in several areas of southern Ontario.

The Ontario Ministry of Natural Resources is testing stump removal as a means of controlling the spread of annosus in southern Ontario red pine plantations. This long-term study is designed for the purpose of gathering information on the cost-effectiveness of removing stumps in and around areas affected by annosus root rot. Through this study the Ministry hopes to determine if stump removal will prevent the spread of annosus root rot to surrounding healthy trees, and to the next crop on the same site.

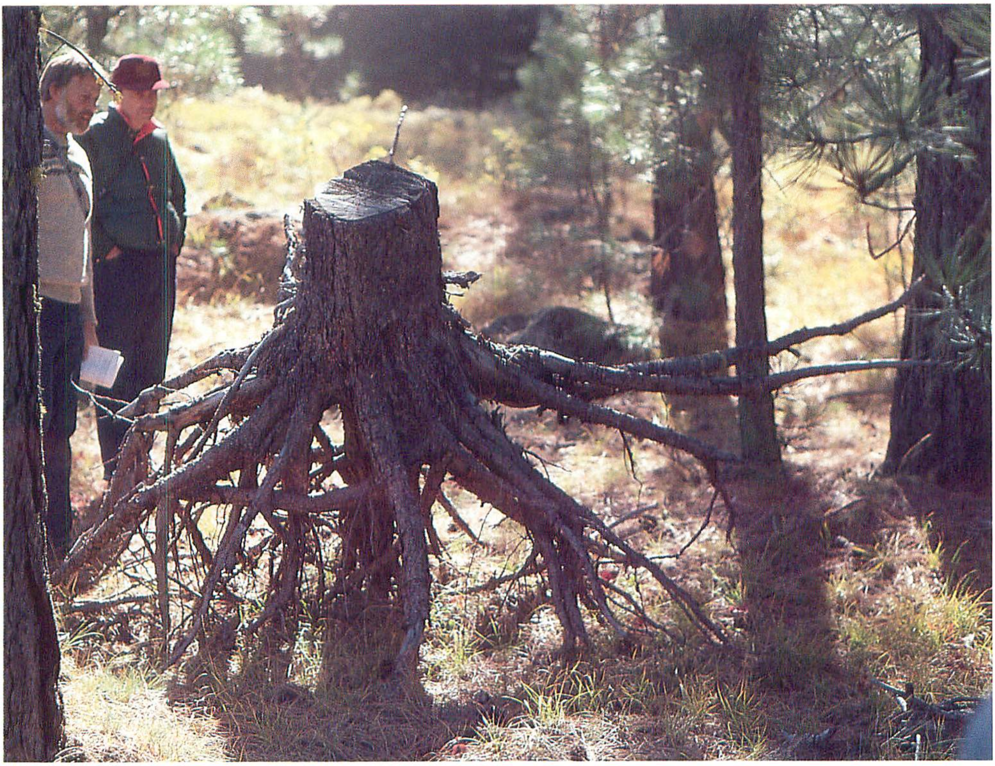

Fig. 8-3.
A stump has been mechanically removed from the site to reduce infection by root rot.

CHAPTER 9

Conclusions

Root rot, "the hidden enemy," is a natural end to living wood. It is a part of nature that cannot and should not be eliminated from the ecosystem. Decay-causing fungi play an essential role in breaking down forest residues. However, large volumes of wood that could be delivered to the mill are lost each year to root rot through:

- mortality
- butt cull
- windthrow
- lost increment.

Of the large number of organisms causing decay in the roots of Ontario trees, *Armillaria obscura, Inonotus tomentosus* and *Heterobasidion annosum* cause the bulk of damage and, therefore, are of most concern to the forester.

At present, a vigorous stand and an understanding of the following three basic principles are the most effective means of control:

- Root rot in living trees increases with age.
- Some species are more prone to root rot than others.
- There is a direct relationship between site characteristics and the incidence of root rot.

Forest pathologists continue to develop new methods of controlling root rot. The goal of research is to develop a better understanding of root-rotting tree diseases and their interaction with hosts and the environment. The future objective is tighter control of "the hidden enemy."

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The Publication

Text

Conceived by and based largely on the work of: R.D. Whitney PhD

Writer/Researcher: Mark Hopson

Design and illustration: Susan Mark

Chief Scientific Advisor: R.D. Whitney PhD

Technical Advisors:
Mr. D. Jovic,
Ontario Ministry of Natural Resources,
Geraldton, Ontario

Mr. J. Lambe,
Ontario Ministry of Natural Resources,
Owen Sound, Ontario

Editor: C.A. Plexman

Translator: Marsha Beaulieu

Photographs

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Chapter 1—figure 1, chapter 6—figures 3 and 4.

Dr. D.T. Myren
Chapter 4—figures 17, 18, 19, 20, 21, 22, chapter 5—figure 3.

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Chapter 4—figure 5.

Stuart Beecroft
Chapter 1—figure 4, chapter 2—figure 6, chapter 3—figures 4 and 5, chapter 8—figure 1.

Peter Llewellin
Chapter 1—figures 3 and 5.

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Executive Producer: Peter Llewellin

Producers: Stuart Beecroft, Mark Hopson

Directors: Stuart Beecroft, Mark Hopson

Writer/Researcher: Mark Hopson

Chief Scientific Advisor: R.D. Whitney PhD

The Hidden Enemy


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