FOREST MANAGEMENT GUIDE FOR

Tomentosus Root Disease

R.D. WHITNEY

Ontario Ministry of Natural Resources

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INTRODUCTION

In Canada and Ontario, intensified forest management has made managers more aware of any factors affecting tree growth, including tree diseases (Stiell 1976). Man-made forests — those planted or seeded — have come under special scrutiny because of the investment and because narrow profit margins can be greatly affected by diseases like Tomentosus (*Inonotus tomentosus (Fr) teng*) root rot (TRR), which are of much less consequence in natural unmanaged stands.

This management guide presents information on identifying, understanding, and managing TRR. It is intended for use by foresters, primarily in Ontario, although much of it applies elsewhere in Canada. Included are descriptions of the disease, related damage, tree species and sites affected, geographic range, as well as disease management strategies. Information was obtained mainly from publications, reports, notes, and field observations of the author during many years of root investigations in Canada, although other information is also referenced. This guide expresses the nature of the disease in the field and silvicultural activities that reduce damage from the disease.

WHAT SPECIES DOES TRR AFFECT?

In Canada, *Inonotus tomentosus,* or the variety *I. t.* var *circinatus, Fr.* causes root rot on 21 conifer species and 2 varieties, including fir (*Abies*), larch (*Larix*), spruce (*Picea*), pine (*Pinus*), and hemlock (*Tsuga*) species, and Douglas-fir (*Pseudotsuga menzesii* (Mirb.) Franco) (Whitney 1978). Cedar (*Thuja*), yew (*Taxus*), and juniper (*Juniperus*) species are rarely attacked and are considered virtually immune. In Ontario, white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) B.S.P.), and red spruce (*Picea rubens* Sarg.) are most susceptible, followed by red pine (*Pinus resinosa* Ait.), white pine (*Pinus strobus* L.), jack pine (*Pinus banksiana* Lamb.), tamarack (*Larix laricina* (DuRoi) K. Koch), eastern hemlock (*Tsuga canadensis* (L.) Carr.) and balsam fir (*Abies balsamea* (L.) Mill.), in order of decreasing susceptibility. The exotic species Norway spruce (*Picea abies* (L.) Karst.) and Scots pine (*Pinus sylvestris* L.) are considerably more resistant. Hardwoods are immune.

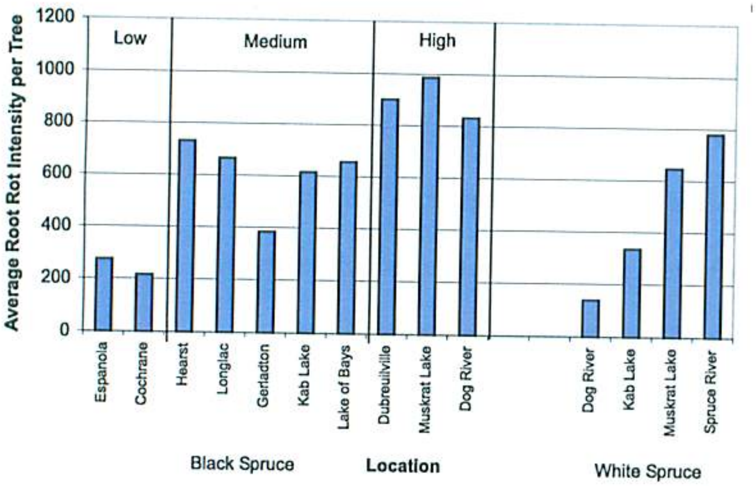


Fig. 1. Average intensity of Tomentosus root rot in living black spruce, 57 to 85 years old at each of 10 locations, and of white spruce, 55 to 70 years old at each of 4 locations, in northern Ontario. Root rot intensity is the average percentage of trees infected in a 10-tree sample on each of 6 to 18 plots per location multiplied by the average percent of advanced root rot per tree.

Fig. 2. A small grouping of dominant white spruce killed by TRR in a 65-year-old plantation. Searchmont, Ontario.

WHERE DOES TRR OCCUR?

Tomentosus root rot occurs throughout the commercial range of native spruces east of the Rocky Mountains in Canada. It has also killed large hybrid spruce trees (*Picea glauca x P. engelmannii*) near Prince George, B.C. (Merler et al. 1988), and is considered an important disease of inland spruce in the B.C. interior (Nevill et al. 1995). Local variation in TRR occurrence and intensity, probably due to differences in site and/or stand history, was found in damage appraisal surveys in northern Ontario (Figure 1). In the southeastern United States, the variety *I. t.* var *circinatus* commonly occurs on loblolly pine (*Pinus taeda* L.) associated with Fusiforme rust (*Cronartium quercuum* (Berk.) Miyabe ex Shiraif. sp. *fusiforme*) cankers (Barnard 1980). In Ontario, the variety *circinatus* is found more often on white and red pine than on spruces. In Europe, this variety occurs on both spruce and pine (Domanski and Dzieciolowski 1955).

ON WHAT SITES DOES TRR OCCUR?

Tomentosus root rot occurs on a wide variety of upland sites but is most prevalent in highly acidic soils that have low moisture-holding capacity and are nutrient poor (Van Groenewoud 1956). Deep duff, which is attractive to root-boring weevils in the genus *Hylobius* that create entrance courts for fungi, also favours TRR (Whitney 1961). On peatlands or very moist sites, *I. tomentosus* grows poorly, and TRR is rare.

HOW CAN TRR BE DETECTED?

Dead Trees and Windfall:

Attention is usually first drawn to the disease by a single or a few dominant or co-dominant dead standing trees or windfalls (Figure 2). TRR kills trees by reducing their effective root area and reducing their ability to absorb moisture and nutrients. In some trees, the root loss causes structural damage, subjecting them to windfall. Affected trees tend to be more concentrated where spruce are planted in pure stands (Patton and Myren 1970, Whitney 1993). The fungus, spreading from root to root, has a continuum of susceptible substrate in such stands. In a natural-seeded forest, species mixtures are common, thus TRR-killed and windthrown trees are more sporadic. In older natural stands, where the disease has been operative for many years, stand openings can become prominent (Figure 3).

Suppressed trees may be the first to die in a stand, probably due to their smaller size rather than increased susceptibility. The roots of dominant and co-dominant trees are attacked as readily as those of suppressed trees (Whitney 1962). The dominant and co-dominant trees, being larger, have more sapwood, cambium, and bark in the roots and lower stem for the fungus to grow through prior to killing the tree. Windfallen trees resulting from this (or any other root rot) are usually criss-crossed (Figure 4) after felling by comparatively light winds at varying times and from different directions. Windfalls resulting from this disease may be either dead or still living (green) when blown over. Quite discrete stand openings may result in pure stands of black, white, or red spruce or spruce mixtures (Figure 5).

Fig. 3. Large opening in a natural 80-year-old black spruce stand, resulting from windthrown and dead trees that had heavy TRR. Near Thunder Bay, Ontario.

Fig. 4. Randomly oriented windfalls resulting in a stand opening in a natural 80-year-old black spruce stand with a high incidence of TRR. Hearst, Ontario.

Fig. 5. Heavy root rot caused by *I. tomentosus* predisposed the trees to windfall in this 80-year-old black spruce stand. Hearst, Ontario.

Fig. 6. Near-dead white spruce with heavy TRR have thinned crowns, shortened internodes, and excessive dead branches, adjacent to symptomless trees. Searchmont, Ontario.

Fig. 7. Recently killed (left) and moribund (right) 65-year-old white spruce, Searchmont, Ontario. Both are heavily diseased with TRR. Note the typical lower branch mortality on the living spruce.

Fig. 8. Basal resinosis on a recently windthrown 65-year-old white spruce extensively colonized by *I. tomentosus*. Petawawa, Ontario.

Reduced Growth, Chlorosis, and Resinosis:

The crowns of infected, living trees adjacent to standing dead or windfallen diseased trees often have thin foliage and reduced shoot growth compared with nearby unaffected trees (Figure 6). In trees with more advanced disease, branch mortality begins at the bottom of the crown (Figure 7), progressing upward. Other symptoms include upward curling of branches, shortened needles and branch growth, and resinosis at the base of the tree (Figure 8). In addition, the foliage may become yellowed (chlorotic) and lusterless, and shedding may occur. Any of these symptoms indicates that the tree has been diseased for more than 10 years, that at least 60% of the root system has been killed, and that an even greater proportion of root wood has been invaded by *I. tomentosus* (Whitney 1962).

Belowground Symptoms:

White pocket decay (Figure 9) develops in the wood of the roots and lower stem and root collar area of diseased trees. This decay can be seen by cutting into the major roots (Figure 10) or near the root collar of dead standing, windfallen, or symptomatic trees. The white pockets are elongate, elliptical areas of cellulose up to 1-cm long (Figure 11) that remain following fungal decomposition of the lignin in the woody xylem tissue. Reddish-brown stained wood may remain between the evenly spaced white pockets, and it may surround the white pocket or advanced decay area of the wood (Figure 12). The reddish-brown "surround" area of incipient decay is usually present several to many centimetres beyond the pocketed or advanced decay area (Figure 13). It can be cultured and identified readily from either of the above decay stages

Fig. 9. White pockets merging into one another in large root of 50-year-old living white spruce. Candle Lake, Saskatchewan.

Fig. 10. Extensive colonization by *I. tomentosus* in the lower stem and roots of 50-year-old naturally seeded white spruce. Thessalon, Ontario. Note the characteristic reddish-brown staining of the wood.

Fig. 11. A close-up of the typical white pockets in white spruce root wood resulting from colonization by *I. tomentosus*.

Fig. 12. Advanced decay and red stain caused by *I. tomentosus* on stump surface of heavily diseased 65-year-old white spruce. Searchmont, Ontario.

by aseptically removing tiny bits of the stained wood to a sterile culture medium (Nobles 1948, Figure 14).

Stump Decay:

Both incipient and advanced decay stages may be present throughout the entire wood volume of the major roots and lower stem of the affected trees (Figure 15). A yellow pocket stage may precede the development of white pockets. In living diseased trees, a central column of pocket decay and stained wood, surrounded by a cylinder of symptom-free white wood (Figure 16), may extend several metres up the stem from diseased roots. Living windfalls usually have at least a few major roots in this condition. In trees with advanced TRR, the reddish-brown stain may extend into the sapwood and cambial area. Since decay and stain in roots and the lower stem are not visible in standing trees, TRR may not be suspected in the absence of dead trees, windfalls, reduced growth, chlorosis, or resinosis.

Fig. 13. Reddish stained wood in base and roots of a 65-year-old white spruce. Searchmont, Ontario.

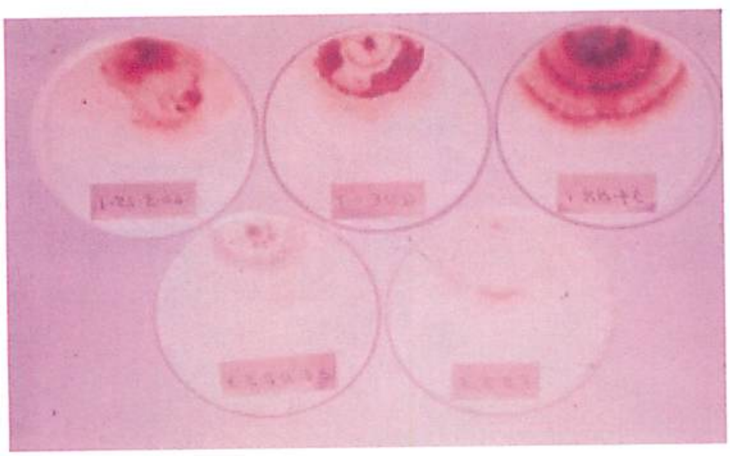


Fig. 14. The mycelium of *I. tomentosus* varies from dark brown to almost white after 10 weeks incubation on artificial nutrient media.

Fig. 15. Vertical section of the stump of a living 65-year-old white spruce showing reddish stain extending up the trunk and down the root following infection by *I. tomentosus*. Searchmont, Ontario.

Sporophores:

The sexual reproductive stage (sporophores, or mushrooms) of this fungus occurs in fall on the forest floor, around diseased trees (Figures 17 and 18), but rarely on the tree base itself (except in pines). These mushrooms are brown, leathery, and velvety above and pored (minute holes) beneath. They have a central stem and grow up through the duff from diseased roots of either living or dead trees (Figure 19). They are abundant in some years (Figure 20) but almost absent in others in the same location. Minute spores (Figure 21), which are released in vast numbers from the undersurface pores, can cause new underground infections, presumably through wounds in roots (Whitney 1963).

WHAT IS THE DISEASE CYCLE OF TRR?

I.tomentosus infects through roots, mainly by healthy roots coming in contact with diseased roots (Lewis et al. 1992, Whitney 1962). The fungus is a facultative saprophyte: It grows chiefly on a living host but can exist in dead material for up to 20 or 30 years (Whitney 1962, Lewis and Hansen 1991, Tkacz and Baker 1991). Spread of the disease from the saprophytic stage is possible, but the fungus is unable to grow more than a few centimetres through soil or organic debris (Whitney 1966). Basidiospores can initiate infections as shown by inoculations (Whitney 1962) and by compatibility and protein studies (Lewis and Hansen 1991). In plantations on old agricultural fields with no stumps or tree roots, the presence of infected trees provides further circumstantial evidence of basidiospore infection from distant sporophores (Whitney 1993).

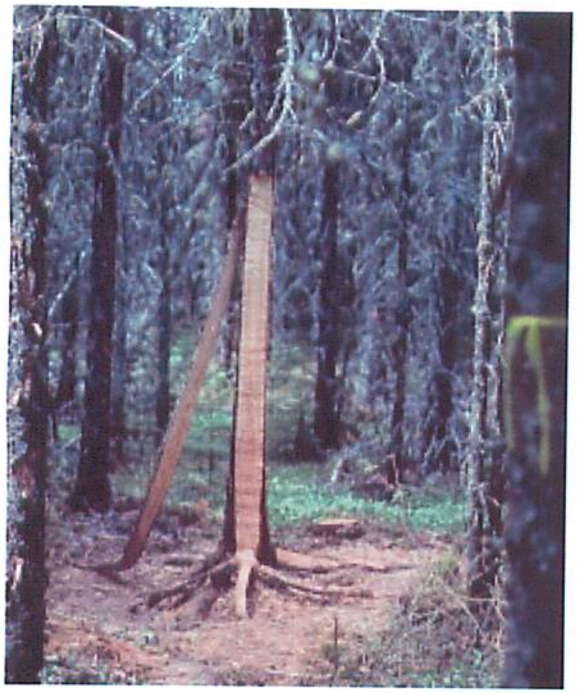


Fig. 16. Reddish-brown stain caused by *I. tomentosus* extending from the roots to about 3.5 m above ground, in a 60-year-old white spruce. Searchmont, Ontario.

While long-distance spread by spores is likely sporadic, the presence of disease in many spots following first observation in a plantation suggests further spread by spores within a plantation. This type of within-plantation spore infection would account for the occurrence of many small infection centres in old field plantations (Patton and Myren 1970), where infections from on-site infected stumps and roots could not occur. Larger stand openings (0.1 to 0.3 ha) in older naturally seeded spruce stands result from spore infections plus the slower root-to-root spread over a longer period of time.

Root excavations, supplemented by inoculations, have shown that following infection, *I. tomentosus* grows slowly through root tissues (Whitney 1966, Lewis et al. 1992). The fungus stains the wood and kills the bark as it advances from the point of infection through the tissues (Figure 22). Stained wood alone is not weakened, but as the decay process

Fig. 17. Group of velvety, light brown (dry weather) *I. tomentosus* sporophores near heavily diseased trees. Petawawa, Ontario.

Fig. 18. Shiny, dark brown (wet weather) *I. tomentosus* sporophores.

Fig. 19. Sporophore growing from a diseased root of a living 45-year-old white spruce. Petawawa, Ontario.

Fig. 20. Brown, disc-shaped sporophores of *I. tomentosus* around the base of a dead white spruce tree. Petawawa, Ontario.

Fig. 21. Germinating *I. tomentosus* basidiospores (highly magnified).

Fig. 22. Brownish stained wood caused by *I. tomentosus* in an early infection of the outer roots (1- to 6-cm diameter) of a 35-year-old white spruce. Searchmont, Ontario.

continues, the lignin decomposes, leaving white or yellow pockets of cellulose. This advanced (pocket) decay weakens the wood severely and reduces the structural strength of buttress roots and the lower stem. Stain and decay can extend 3 metres or more up the trunk. By this time, the bark on most of the main roots and root collar area is dead. Aboveground symptoms — reduced internodes, yellowish needles, and basal resinosis — appear only after 60 to 70% of root bark dies (Whitney 1962, Lewis et al. 1992). Several more years may elapse before the tree dies. With the support system weakened, trees often are windthrown prior to death.

Sporophores of the fungus grow annually from mycelium in infected roots under suitable moisture conditions. The setae of *I. tomentosus* are straight. Occasionally with spruce (Whitney 1977) and often with loblolly pine (Barnard 1980), sessile, bracket-shaped sporophores issue from the base of infected trees. Strongly hooked brown setae are characteristic of the variety *circinatus* (Haddow 1942). Production of the millions of microscopic basidiospores has been shown to be optimal near 20°C under moderate light intensity and high relative humidity (Bohaychuk and Whitney 1973). Major events in the disease cycle are presented in Figure 23.

HOW DOES TRR AFFECT FOREST PRODUCTS?

Losses progress prior to being noticed in the stand. Death of understory trees, mostly attributed to lack of light and overcrowding, can be hastened by the presence of TRR or by other root diseases such as Armillaria (caused by *Armillaria spp.*) (Whitney 1989, Shaw and Kile 1991) or Annosus root rot (caused by *Heterobasidion annosum* (Fr. Fr.) Bref.)) (Punter 1968, Myren 1978). The discussion here is

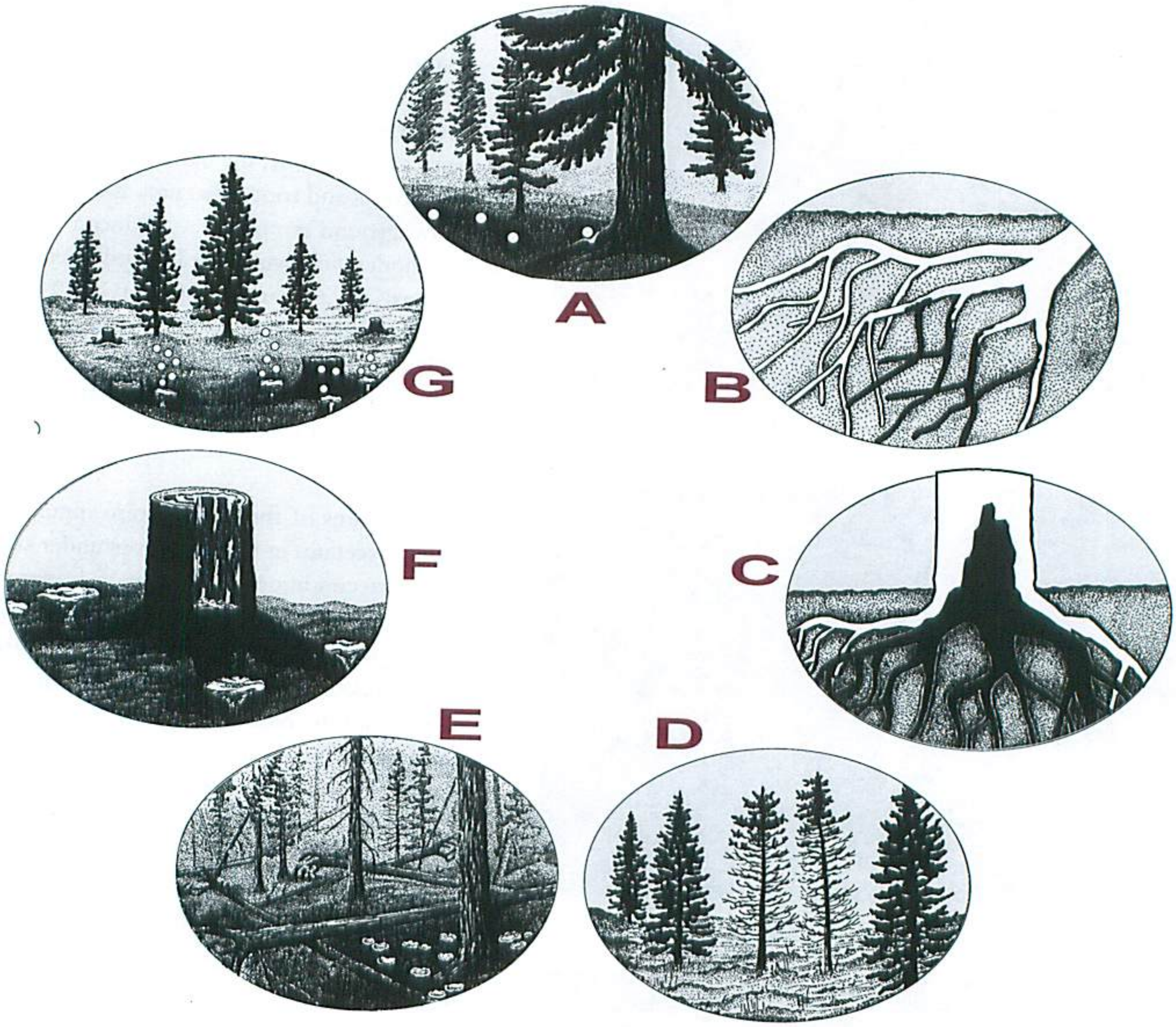


Fig. 23. The disease cycle of Tomentosus root rot.

A. Windborne spores of *I. tomentosus* infect through wounds in roots of trees planted 15 to 30 years earlier.

B. Infected roots can spread the disease to healthy roots (darkened roots are infected). There are no aboveground symptoms at this stage.

C. Root decay and stain caused by *I. tomentosus* spreads to larger roots and into the butt of the tree (30- to 40-year-old trees).

D. Dead branches (from below) and reduced height increment occur in advanced stages of disease (trees 40+ years old).

E. Trees weakened by root rot either die or are blown over in windstorms. Sporophores of *I. tomentosus* are abundant in fall around the base of diseased and/or dead trees.

F. Following logging, white pocket decay may be seen on the stumps. *I. tomentosus* sporophores grow among such diseased stumps.

G. Young trees that were planted on cutovers with diseased stumps may become infected by means of spores or by roots contacting old infected roots from the stumps.

confined to TRR, which causes wood fibre loss in the form of tree mortality, butt cull, and growth loss.

Unusable Trees:

Trees that are killed or windfelled are seldom harvested due to their deterioration, poor physiological condition, and sparse and scattered occurrence, which make them economically unfeasible to remove. Green windfalls may be utilized during coincidental logging. In Canada, TRR is associated with mortality in white, black, red, and white/Engelmann spruce, where it causes the typical stand openings (Whitney 1962, Merler et al. 1988). In natural stands in Ontario averaging 72 and 68 years old, 11% and 6% of black and white spruce, respectively, were identified as dead standing or windfallen (Whitney 1989). Cultural studies indicated 15% and 13% of such affected trees of each species, respectively, were infected with TRR (Whitney 1995). Thus, in naturally seeded stands in Ontario, TRR-caused dead and windfallen dominant and co-dominant (crop) trees account for .15 x 11 = 1.7% of black spruce and .13 x 6 = 0.8% of white spruce volume losses. Higher damage levels are recorded for planted spruce. In Ontario's white spruce plantations, dominant and co-dominant trees 43 to 58 years old averaged 10.3% mortality from TRR (Whitney 1993). At Searchmont, Ontario, 56% of 65-year-old planted white spruce were infected with *I. tomentosus* (Whitney 1993).

Butt Cull and Lost Increment:

The upward extension of root rot into the base and lower stem of the tree results in lost wood volume in the highly valued butt log (Figure 24). Based on the study at Searchmont, Ontario, an average of almost 14% of the scaled gross merchantable volume (GMV) would be culled due to TRR if neither stained nor decayed wood could be utilized. If stained wood could be used in pulping, the cull would be reduced to about 7% of GMV (Whitney 1993).

Lost increment due to root rot is more difficult to ascertain, because so many factors affect tree growth. However, studies have revealed trees can be infected with TRR for many years prior to windfall or death (Whitney 1962, 1993). Heavily diseased dominant trees invariably grow more slowly, even though they still occupy a dominant position in the stand. In white spruce plantations in Quebec, root rot caused primarily by *I. tomentosus* resulted in 27% less gross volume (Lachance

Fig. 24. Advanced decay of TRR extending well up the stem of a 50-year-old white spruce. Thessalon, Ontario.

1978). Nearby healthy or lightly infected trees, however, could grow better due to decreased competition (Courtois 1979), somewhat compensating for reduced growth of heavily infected trees.

Downgrading of Logs:

The most valued products from white spruce trees are veneer logs, which can be harvested only when trees reach 60 years on the best sites and even older ages on medium sites. At Petawawa, Searchmont, and Thessalon, Ontario, white spruce plantations of this age had high proportions of trees infected with *I. tomentosus* (Whitney 1993), thus production of veneer logs and even sawlogs was much reduced. Liquidation of these plantations for smaller, less-valued products, such as pulpwood, was recommended (Whitney 1993). Even though many trees had heavy root rot, a good yield of pulpwood was possible at all 3 locations. Some small sawlogs were also obtainable. In Europe, downgrading of end products due to Annosus root rot resulted in stumpage prices being reduced by up to 23% (Rattsjo and Rennerfelt 1955). At Petawawa, Ontario, where experimental thinning was conducted, residual trees appeared potentially suitable for sawlogs at 70 years of age (Whitney 1993). Many of these trees, however, would have moderate to heavy butt cull due to TRR. Mortality counts showed that non-thinned plots had higher TRR-caused mortality than did plots with light, medium, or heavy thinning.

Other Losses:

When TRR-caused mortality and windfall create stand openings in either naturally seeded or planted forests, problems of forest discontinuity occur. These openings remain treeless, harbour unwanted tree species, or need to be regenerated at additional silvicultural expense, resulting in reduced annual wood volume of the desired species.

Large spruce trees with TRR can pose a threat to nearby structures, including houses and automobiles, as well as to people in campgrounds or other forested areas. Windfalls and standing dead trees can hinder silvicultural operations by creating physical barriers for site preparation, planting, tending, and harvesting.

TRR-caused losses of timber and other forest values are only a portion of losses or changes to the forest. For example, ecological succession can be altered through subtle effects, such as hastening death of understory trees, often attributed to within-stand competition.

HOW SHOULD TRR-AFFECTED FORESTS BE MANAGED?

Background:

TRR is a native disease that lives in harmony with its many native hosts. As a result, direct action on the causal organism is unlikely to prevent or reduce its effects. The fungus, ubiquitous where susceptible hosts are present, is adapted to a broad range of sites and derives nutrition from otherwise healthy susceptible hosts. No chemical control is known. Weak points include its slow rate of growth within the host, its inability to grow more than 2 or 3 cm outside the host, its inability to produce toxic substances that are transported within the host, and its inability to kill trees under 20 years of age in much of Canada (east of the Rocky Mountains). Apparently, TRR can be present in all major roots and have killed 60 to 70% of a root system without reducing the tree's growth rate (Whitney 1962). At this point, however, the disease will have caused butt cull and structurally weakened root systems.

The occurrence of TRR in patches, with areas of healthy trees between the patches, is another characteristic that can be factored into a control plan. Portions of spruce stands can remain disease-free for site-related reasons and thus can be grown to older ages. Stand thinning may reduce TRR-caused mortality by interrupting the continuum of susceptible (living) roots. At Petawawa, Ontario, thinning reduced the proportion of dominant and co-dominant trees that were killed by TRR (Whitney 1993).

As indicated earlier, TRR damage begins to show in spruce at about age 35. Even then, each occurrence usually has only 1 or 2 trees that are dead or windfallen. In a mixed stand, nearby less-susceptible species, such as pines, hemlock, and balsam fir, will be attacked only lightly. As the disease stabilizes, other species will fill the gaps left by dead spruce. In pure spruce stands, or those with 75% spruce, the disease will slowly but relentlessly spread out from diseased trees. When a forester sees the first signs of the disease — 1 or 2 dead or windfallen trees with white pocket root rot or a few locations of *I. tomentosus* sporophores on the ground in fall — he or she knows that within 5 years several more such disease signs will appear. Almost always, however, large portions of the stand remain disease-free for many years, and the timber can be designated for sawlogs or other large-dimension products, such as peeler logs. Portions of the stand having more than 4 or 5 pockets of disease per hectare should be designated for smaller products such as pulpwood on a shorter rotation.

Avoiding the Disease:

Procedures in this section are intended to prevent TRR from developing in crop trees to the extent of causing losses. TRR can be avoided by:

- growing susceptible species, that is spruce, on sites where *I. tomentosus* does not occur, such as on very moist (MR greater than 7.0) or alkaline (pH greater than 7.0) soils.
- using old field sites where no trees have grown for many years (greater than 50), hence no inoculum exists in the soil.
- harvesting the trees before spore infections begin to cause significant damage (e.g., less than 50 years).
- using species other than spruces, especially on cutover sites where TRR was abundant in the previous stand and viable inoculum remains in roots and stumps. On lighter soils plant pines, and on other soils plant species with low susceptibility, such as hemlock, larch, and balsam fir, or immune species, such as cedars and hardwoods.
- planting carefully to avoid root deformities that can lead to *I. tomentosus* infection (Ouellette et al. 1971).

Minimizing the Disease:

The first step is to verify the presence of TRR:

- Refer to symptoms described on pages 7-10.
- Use an axe, saw, increment borer, knife, etc. to examine interior wood of buttress roots or stumps of dead or windfallen trees. If white or yellow pockets are found (Figure 9), TRR is likely present.
- Observe nearby trees, which may be chlorotic with thinned foliage and reduced leader growth.
- Culture samples of decayed or stained wood on a nutrient medium. Examine cultures under a microscope (Nobles 1948). Culturing is essential if only red stain (Figure 15) is found.
- In August, September, and October, look for the pored, brown, and leathery sporophores of *I. tomentosus* on the forest floor. If the sporophores are pored, brown and leathery, and also very thin and funnel-shaped and/or have conspicuous concentric rings or zonations above (top surface), they are likely *I. perennis* L. ex Fr., a harmless fungus that grows in spruce stands.
- If sporophores are present, but dead or windfallen trees are not, examine the nearest trees for basal resinosis, reduction of current internodes, chlorotic or thinned foliage with excessive dead branches in the lower crown, or dead roots with red stain or white or yellow pocket decay directly beneath individual sporophores. Any of these symptoms along with *I. tomentosus* sporophores indicates TRR is present.
- If sporophores are absent, but were present the year before, do not assume the disease has disappeared. Conditions were simply not conducive to fruiting.

If TRR is found:

- Reduce rotations to 50 years or less in heavily diseased portions of the stand. Short rotations allow more frequent (albeit smaller) realization of a return and allow you to take best advantage of mechanized silviculture. At younger ages, the amount of mortality is still low, and while many trees may be infected, damage to individuals is small. Volume losses to mortality and windthrow are also low, and the effects on stand growth are negligible. However, costs per unit of wood may increase due to increased silvicultural activity and more frequent harvesting.
- Survey lightly infected and healthy portions to designate areas for sawlogs and peeler logs. If lightly infected portions of stands become more heavily diseased, designate these areas for smaller products such as pulpwood.
- Use thinning or spacing of diseased stands of pure spruce to reduce the proportion of diseased trees.
- Interplant species of high and low susceptibility to break up the continuum of susceptible root substrate and interfere with the root-to-root spread of the fungus.
- See Figure 25 for silvicultural procedures that can minimize losses from TRR.

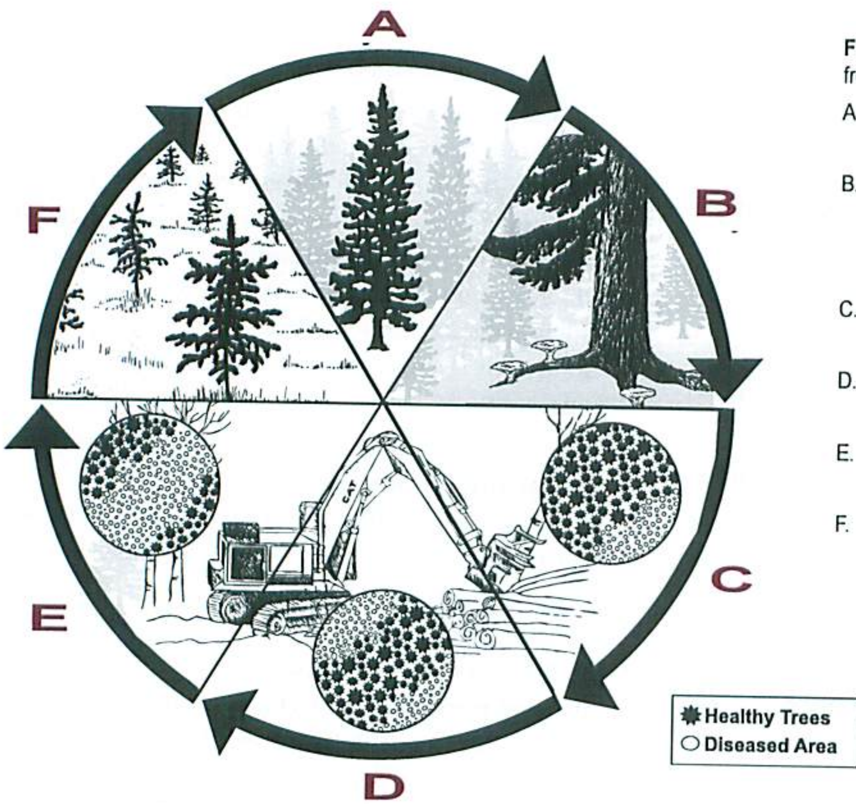


Fig. 25. Silvicultural procedures that can minimize losses from TRR:

A. At 35 years: Trees appear healthy with no aboveground symptoms or sporophores in fall.

B. At 50 years: Where Tomentosus root rot exists in the stand, diseased trees with thinned crowns are present, and dead trees have *I. tomentosus* sporophores at the base.

C. At 60 years: The dead and diseased trees should be salvaged from disease pockets in the stand.

D. At 70 years: Further salvage logging of enlarged diseased areas in the stand.

E. At 80 years: The remaining trees should be clearcut for sawlogs and pulpwood.

F. At 80 years: Following clearcutting, the entire cutover should be regenerated to desired species.

DISEASE FEATURES TO REMEMBER

a. TRR is insidious: It advances without showing itself for many years.

b. One or 2 dead or windfallen trees invariably indicate that several nearby trees are infected but may not show aboveground symptoms.

c. The disease may be patchy with large areas of completely healthy trees between the patches. Soil texture and acidity, topographic features, and stand history may account for the areas of healthy trees. Spruce trees remain healthy longer when growing on fine-textured (clays), high pH (pH 7 or higher) soils with high moisture regimes (MR greater than 6), or old agricultural fields where disease has been absent for 50 years or more.

d. Infected trees cannot be cured, although they may live and even grow well for 1 or more decades.

e. Sporophores are definite signs of the disease, but they are cyclical, being much more numerous in some years than others.

f. Trees infected for several years have an abundance of butt rot. Unlike the decay caused by *Armillaria ostoyae*, this decay may extend several metres up the stem, subjecting the tree to wind breakage and the butt log to severe or total cull.

g. Infected roots and stumps serve as inoculum sources for the next generation of trees.

h. Tree species vary widely in their susceptibility to TRR. Spruce are most susceptible followed by pine, hemlock, and balsam fir. Cedar and all hardwoods are immune.

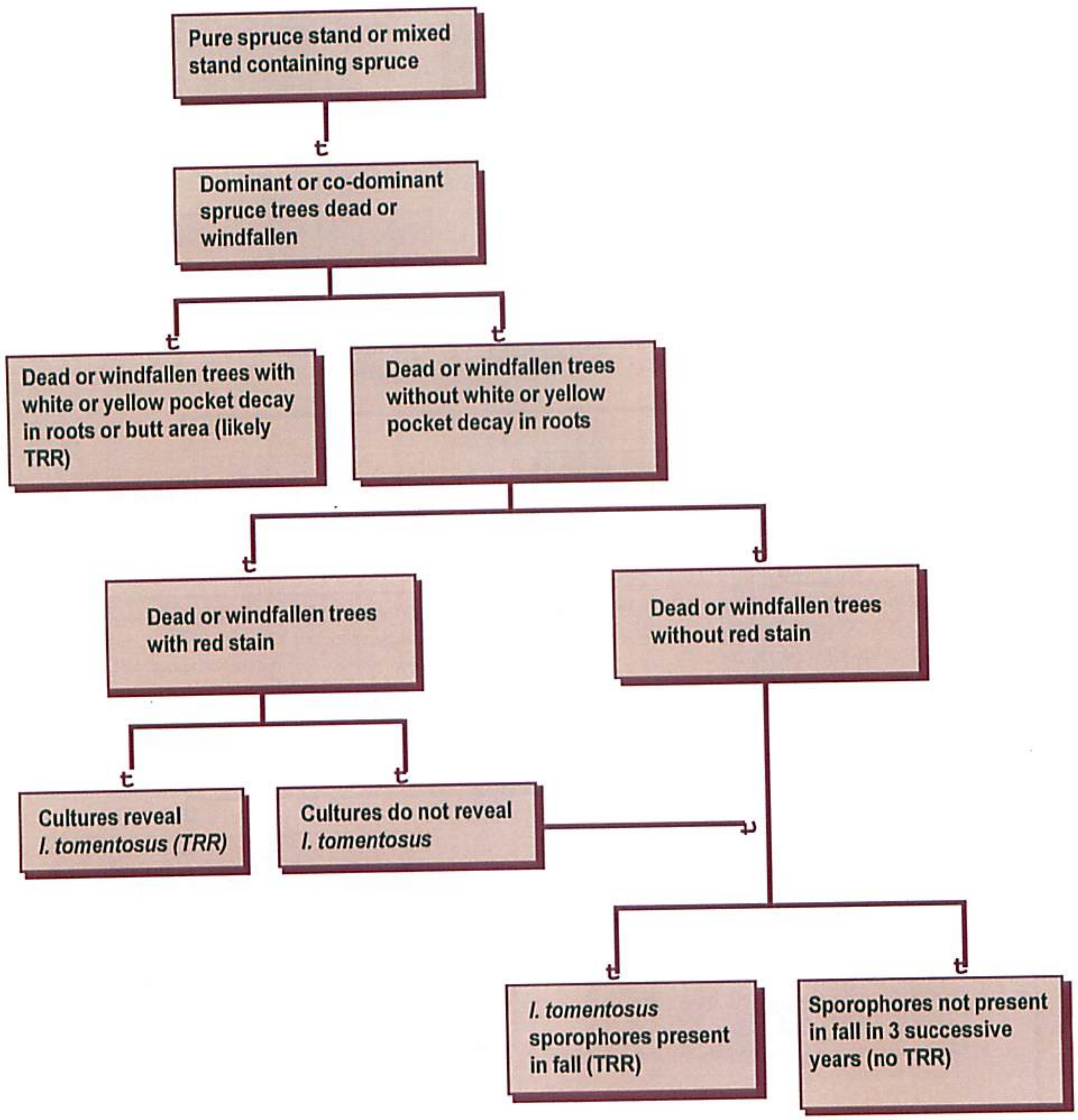
i. The disease is more severe in pure or almost pure white, black, or red spruce stands, because spruce roots provide a nearly continuous favourable substrate for the fungus.

j. Thinning of pure stands at the pole stage reduces the infection rate.

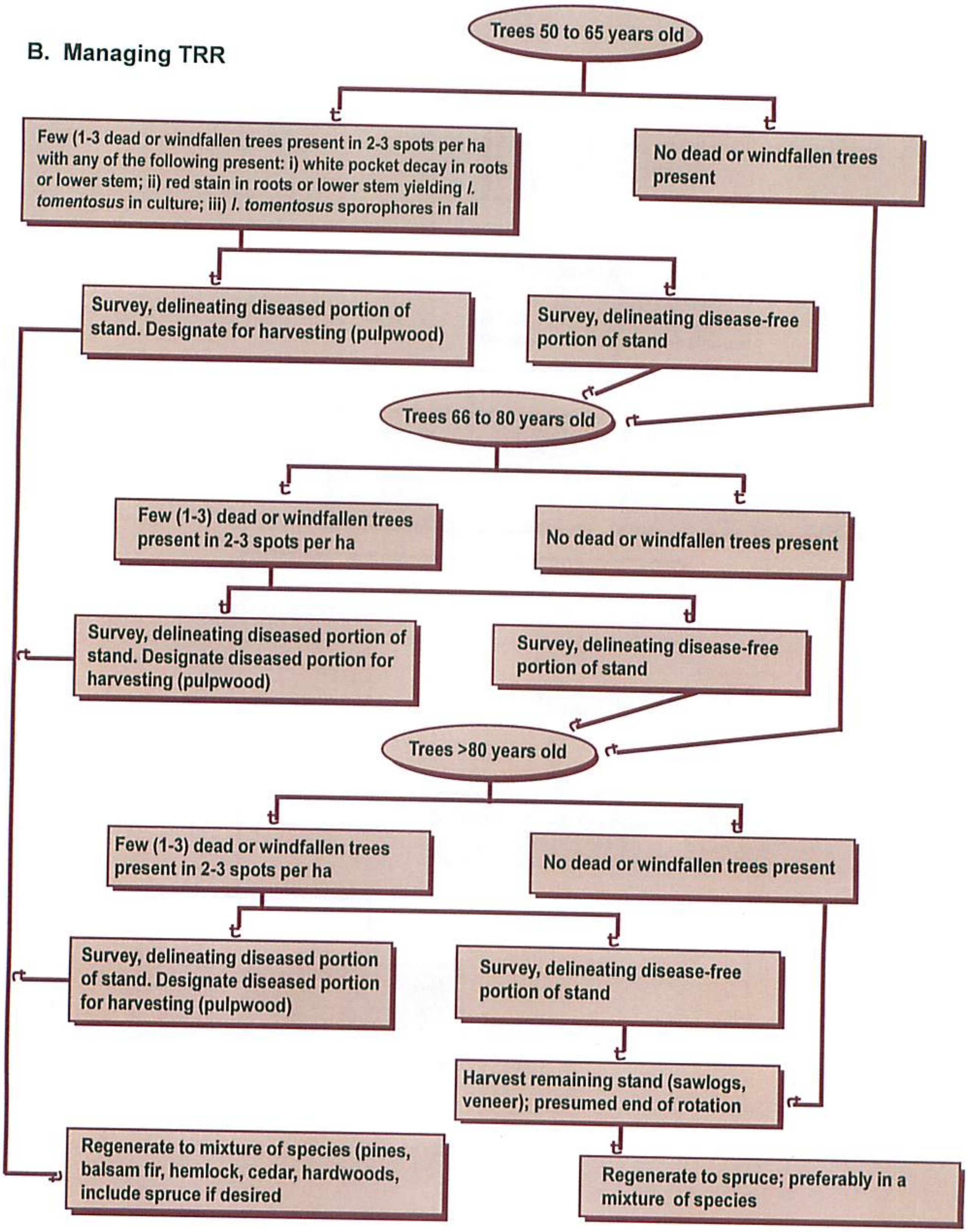
k. The most effective means of monitoring TRR is conducting surveys every 5 to 7 years, noting frequency of symptoms and signs (dead and windfallen trees with white pocket rot/butt decay or sporophores in fall).

DECISION KEYS

A. Detecting TRR



B. Managing TRR



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