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Mortality in Southern Ontario Red Pine Plantations: Causes, Consequences, and Management Options

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The plantations

Red pine is a shade intolerant conifer that is among the most extensively planted tree species in southern Ontario. In the 1920s, reforestation programs were initiated to restore idle marginal and waste land to productive use, prevent soil erosion, and conserve water resources. Red pine was an ideal species for these reforestation programs: it thrives on sites too poor for agriculture, it produces high value timber for example for sawlogs, utility poles, and preservative-treated landscape timbers, it grows well in plantations and can provide economic returns to landowners through occasional thinning treatments, and it is resistant to most pests. Over time, these plantations (Figure 1) have become important for providing timber, and for education and recreation opportunities.

Figure 1. *A healthy commercial aged red pine plantation.*

The problem

Recently though, unprecedented rates of decline and mortality in maturing, commercial-sized red pine plantations in southern Ontario (Figure 2) are challenging forest managers who adhere to traditional management strategies and silvicultural practices. Decades of investment in thinning and tending are at risk from widespread mortality in these plantations. Managers face the choice of adhering to traditional cutting cycles and losing volume on the stump or liquidating large tracts of timber and inundating the market. Aside from the financial loss, stand liquidation jeopardizes broader forest management objectives, such as natural stand conversion to mixed forest, and recreational uses of these stands.

Figure 2. *Pockets of declining and dying red pine.*

Causes of mortality

To find out why the trees were dying researchers conducted intensive above- and belowground investigations to assess characteristics of the trees and soils of healthy and dying plantations (Figure 3). They also assessed pathogens and insect pests associated with dying trees.

Figure 3. *(a) Researchers dug 2-m-deep trenches to investigate belowground characteristics of healthy and diseased red pine plantations; (b) They also measured the depth of soil horizons and rooting and soil physical and chemical characteristics.*

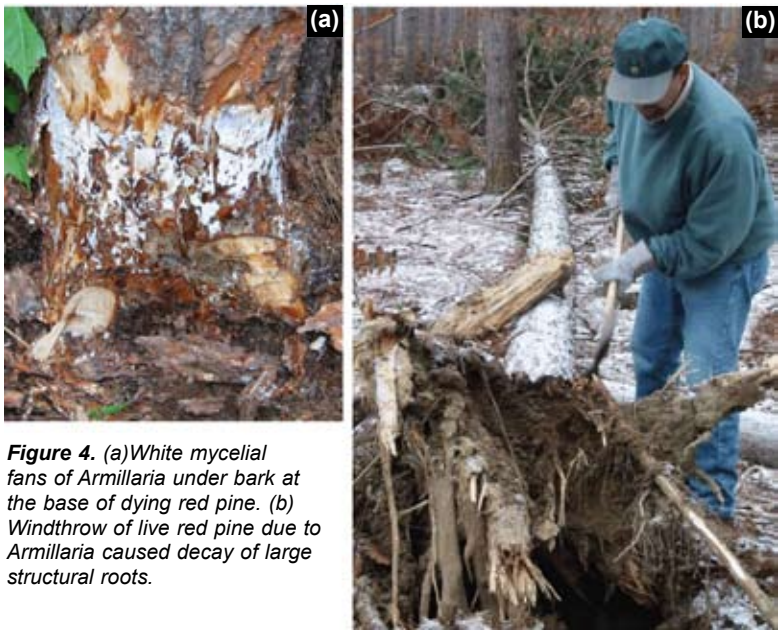

Figure 4. *(a)White mycelial fans of Armillaria under bark at the base of dying red pine. (b) Windthrow of live red pine due to Armillaria caused decay of large structural roots.*

Figure 5. *White "popcorn" stage of Annosus fruiting bodies in duff at base of dead red pine.*

Root disease

In southern Ontario red pine plantations, **Armillaria root disease** (caused by *Armillaria ostoyae*) and **Annosus** (a.k.a. Fomes) **root rot** (caused by *Heterobasidion annosum*) are the most commonly observed killers of trees.

Armillaria infection is recognized by the white *mycelial fan* that grows under the bark, killing individual roots and eventually the whole tree (Figure 4a). Decay of infected roots can make living trees unstable and prone to windthrow (Figure 4b).

Annosus root rot can infect a tree for many years, restricting growth initially as infected roots die but eventually killing the tree. In the fall, white and brown Annosus fruiting bodies may form at the root collar of heavily infected trees. They can be difficult to see/recognize in their young "popcorn" stage (Figure 5).

Nutrient deficiency

Nutrient deficiency, specifically lack of iron, can cause red pine decline and mortality in southern Ontario. This deficiency is sometimes observed in 30- to 40-year-old plantations, with symptoms including chlorosis (yellowing) of the needles(especially the current year's growth), reduced growth, crown thinning, and dieback (Figure 6). These symptoms may be observed throughout the entire plantation or limited to a particular section. Iron deficiency is not necessarily due to low soil iron content; rather, alkaline soil conditions, especially in the upper soil horizons, make the iron insoluble and therefore unavailable to the trees. Drought makes the problem even worse: as soil moisture decreases, the volume of the soil solution decreases, and pH increases.

Insect pests

Trees under stress, for example due to drought, are susceptible to insect pests such as bark beetles and scale insects (Figure 7). Heavy infestations can kill trees already compromised by nutrient deficiency or disease. However, insects do not appear to be the cause of the widespread mortality in southern Ontario.

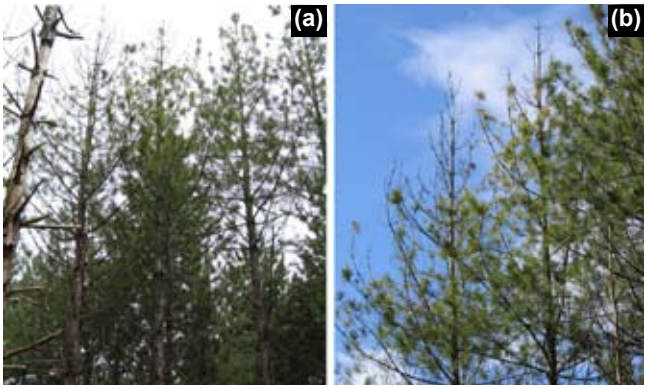

Figure 6. *(a) Iron deficiency-induced chlorosis, and (b) thinning and dieback of red pine crowns.*

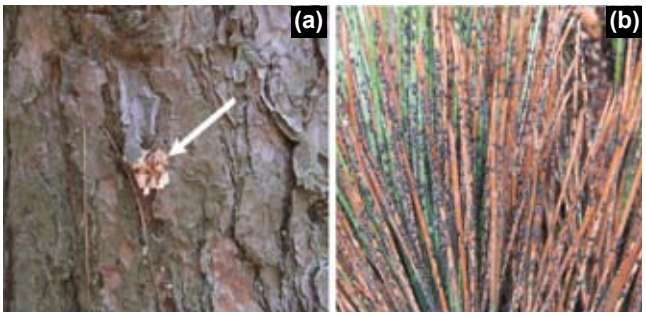

Figure 7. *(a) Resin exuded from a bark beetle exit hole near the base of a recently killed red pine. (b) Heavy infestation of black pineleaf scale on current year needles of a dying red pine.*

A common predisposing factor

Researchers found that healthy plantations could be distinguished from those with mortality based on the pH of the soil C horizon. Red pine grows best in acidic soils. However, where the pH of the upper soil horizons were primarily acidic, if the C horizon was moderately-to-strongly alkaline red pine were dying. In contrast, trees on sites where the C horizon was slightly acidic-to-neutral were healthy. As well, the rooting depth of trees on sites with an alkaline C horizon was much shallower (by more than 50 cm) than that of trees on sites with an acidic-to-neutral C horizon. On sites with alkaline upper soil horizons, iron deficiency seemed to be the main cause of dieback.

Summary

Plantations established on sites with an alkaline C horizon are at high risk of damage from pathogens and insects, largely due to the typically shallower rooting on such sites. Shallower rooting makes trees more likely to suffer drought stress, which acts as an *inciting factor* for decline by reducing their ability to defend themselves from attacks by root disease pathogens or insects such as bark beetles. Plantations established on sites with alkaline A and B soil horizons will likely suffer early decline (i.e., before the plantation reaches 40 years of age) due to iron deficiency. And iron deficiency will be more pronounced in dry years.

Management Options

For existing plantations

The County of Simcoe (Forestry) has recently released *Modified Management Recommendations to Establish and Manage Red Pine Plantations* (appended) to help resource managers cope with red pine decline in county forests. These recommendations include testing soil pH to classify stands based on their risk of decline, monitoring stand health more often, especially after thinning, as well as implementing new tree marking standards aimed at balancing the objectives of minimizing financial loss, maximizing timber harvest, and gradually converting red pine stands to mixedwood forests dominated by tolerant hardwoods.

For new plantations

When selecting sites on which to establish new plantations, assessing soil pH and depth to the C horizon is critical to predict long-term forest health. Red pine should not be planted where the upper soil horizons are alkaline as it will begin to decline within 35 years. Acceptable sites for red pine are those with acidic-to-neutral C horizon pH and combined A and B soil horizons that are at least one metre deep.

Mortalité dans les plantations de pins rouges du Sud de l'Ontario : causes, conséquences et activités de gestion proposées

Les plantations de pins rouges, que l'on retrouve un peu partout dans le Sud de l'Ontario, montrent des signes de dépérissement et de mortalité accélérés. Les chercheurs ont estimé que les plantations des sites à l'alcalinité d'horizon C sont très vulnérables aux dommages causés par les agents pathogènes et les insectes. Un racinement moins profond sur ces sites rend les arbres plus sensibles au stress de la sécheresse, qui agit comme *facteur incitant* au dépérissement en diminuant leur capacité à se défendre contre les maladies des racines provoquées par des agents pathogènes ou des insectes comme les scolytes. Les plantations établies sur des sites à l'alcalinité d'horizons pédologiques A et B dépériront de façon probablement plus prématurée (avant que la plantation n'atteigne 40 ans) en raison d'une carence en fer, laquelle sera exacerbée par des étés chauds et secs. Des recommandations pour l'établissement et la gestion des plantations de pins rouges dans le Sud de l'Ontario sont fournies dans la présente note.

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MODIFIED MANAGEMENT RECOMMENDATIONS TO ESTABLISH AND MANAGE RED PINE PLANTATIONS *Based on the presence or future probability of red pine decline*

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ESTABLISHING RED PINE PLANTATIONS

Before planting red pine, check the pH of the A, B, and C soil horizons. For the C horizon, sample at a depth of about 1.5 m.

1. If A and/or B horizons are alkaline (pH > 7):
   - Do not plant red pine

   Crop is likely to fail by 30 to 40 years of age due to nutrient deficiency.

2. If A and B horizons are acidic but the C horizon is alkaline:
   - Reasonable growth and longer rotations are possible but the stand will be predisposed to root disease, especially if the combined depth of the A and B horizons is <1 metre

   Armillaria root disease will reduce stand health but without post-thinning stump treatment Annosus root rot will also increase.

Sites with compacted soil (bulk density >1.4) will be more susceptible to root rot because red pine does not root well in dense soil – especially if it is alkaline.

Richer soils may result in more root disease and as such are not necessarily better red pine sites.

MANAGING YOUNG (<50 YEARS) RED PINE PLANTATIONS

Check the pH of the C horizon to determine if future decline is probable. (If the plantation is in reasonable health at this stage it is unlikely that the A or B horizons are alkaline.)

If the C horizon is alkaline:

- If not already present in the understory, consider options to establish desirable species as soon as possible
- Ensure that an aggressive thinning regimen is in place (i.e., consider light selection thinning in addition to row removal at first thinning)

RECOMMENDATIONS BASED ON LEVEL OF PLANTATION DECLINE

The recommendations provided below are applicable where a typical prescription for a healthy stand in the 50 to 70+ year age class would include a 25 to 35% reduction in suppressed or poorly formed stems and improved spacing (typical residual target basal area of 28-30 m ha^{-2}).

Management objectives include maximizing timber values and moving towards stand conversion.

1. Stand is relatively healthy but has occasional decline pockets and/or scattered individual mortality:
   - Mark as for regular selection cutting but with more emphasis on trees of smaller diameter class and poorer quality or declining health and that affect final stand spacing
   - Mark two live trees surrounding decline pockets or unhealthy stems
   - PLUS, when approaching decline pockets switch to marking from above and remove larger diameter trees (maintaining prescribed % reduction) within 50 to 75 m around the declining stems.

2. Stand has scattered decline pockets and/or scattered individual mortality throughout:
   - Mark entire stand from above for selection cutting but emphasize the removal of larger diameter classes and unhealthy trees with declining crowns regardless of diameter

   OR if marking from above seems unnecessary:
   - Mark all trees with thinning or declining crowns (some openings will be created and basal area may be substantially reduced)
   - Where basal area remains above the target, reduce it to 26 to 28 m^2ha^{-1} using spacing as the main criteria.

3. Stand exhibits severe decline throughout:
   - Remove overstory leaving only white pine (if present)
   - Consider retaining areas with little commercial value to minimize damage to regeneration and to provide wildlife habitat

For all scenarios, monitor stands biannually to check for continued spread of decline. If so further measures (marking and removal) may be necessary.

Complete overstory removal is a feasible option where adequate advanced regeneration is present. Where this is not the case, consider other approaches to ensure adequate regeneration following harvest.

In younger (30-50 years) stands, sampling soil may help to determine the likelihood of future decline problems. Where the C horizon is alkaline, decline is more likely and it is prudent to assume a younger rotation age and consider options to ensure adequate advanced regeneration.

For more information about management recommendations for red pine plantations, contact Graeme Davis, R.P.F., County of Simcoe [Graeme.Davis@Simcoe.ca; (705) 726-9300 ext.1177] or John McLaughlin [john.mclaughlin@ontario.ca; (705) 946-7419].

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