Abstract: Tree mortality caused by root diseases constitutes a major drain on forest productivity of mixed-conifer stands. Factors such as changes in species composition, selective harvesting, unfavorable economic climate, and optimizing of short-term benefits have contributed to current stand conditions. Computer simulation models, such as the "RRMOD Computerized Root Disease Simulation Model", are currently available to managers to evaluate the effects of stand management under different silvicultural prescriptions. Several management strategies are available to managers to reduce losses caused by Annosus root disease.

Tree mortality caused by root diseases constitutes a major drain on forest productivity of "east side" mixed-conifer forests in the western United States. Mixed-conifer stands tend to be most seriously affected. Documented losses averaging as high as 45 percent for 98 randomly selected stands have been noted (Schmitt and others 1984). Numerous individual stand surveys show that mortality of 10 percent-80 percent of the trees with 10 percent-60 percent basal area reduction is common (Goheen and Hagle 1988). In one specific survey of a 2,500-acre (1012 hectare) mixed-conifer stand on the Sisters Ranger District, Deschutes National Forest, 19.0 percent of all trees over 5 inches (12.8 centimeters) diameter breast height (DBH) representing 21.8 percent of the merchantable board foot volume were found to have been killed by root disease during the previous 20 years (Filip 1980).

On east side forests, three fungal pathogens generally are responsible for most losses due to root diseases. These pathogens are Armillaria ostoyae, Phellinus weirii, and Heterobasidion annosum.

In recent years, more attention has been focused on the role and effect of root disease in tree stands. Increased public use of national forests along with increased awareness of forest managers have resulted in a perception of declining forest tree health.

The root disease problems now being faced are probably a direct consequence of past management or utilization activities.

First, a general change in species composition has occurred in east side mixed-conifer forests in the last 75 years. Sites that were once park-like in appearance and dominated by ponderosa pine or western larch are now stocked with more shade-tolerant climax species, primarily the true firs or Douglas-fir. This change is largely due to fire exclusion in these stands (Arno 1980; Gruell and others 1982).

Second, many forest stands have been subjected to past selection harvesting, often with repeated entries over the same ground. Frequently, only high-value, large trees, mainly ponderosa pine or western larch, were removed during these entries. Not only did selective harvesting remove the more root disease-resistant species of a stand, but partial-cutting harvest techniques often left numerous infection sites in the form of damaged residual trees and freshly cut stumps. Stand compositions were altered in ways that steadily increased the proportion of highly susceptible tree species left in the stand.

Third, there has long been an unfavorable economic climate for the harvest and manufacturing use of some species. Many forest operators simply found it uneconomical to remove large volumes of white fir or grand fir material. Consequently, large acreages of highly susceptible species were left on site.

Finally, the long-term consequences of management activities often have not been well thought-out or considered. Some forest managers and public groups are too willing to optimize short-term benefits while foregoing long-term interests. Overriding concerns about short-term benefits may prove detrimental by causing forest managers to give too little weight to significant long-term consequences. Failure to address root rot problems in areas such as National Forest full retention visual management allocations is a good case in point.

MANAGEMENT CONSIDERATION - SILVICULTURAL OPPORTUNITIES

Root disease management is basically an
ecological and social issue. Direct control €
measures are not effective in the management of €
forest tree root diseases because the long-term €
problem is not resolved. However, resolution of €
the root disease problems can be achieved €
silviculturally. Silvicultural control of root €
disease requires some degree of knowledge of root €
disease organisms, how diseases respond to €
management activities, long- and short-term €
consequences of decisions, and silvicultural €
techniques. Silvicultural control of root €
disease requires reversing past management €
patterns, primarily by manipulating tree species €
composition to develop stands less favorable for €
root pathogens (Goheen and Hagle 1988). €

Knowledge of Root Diseases€

Many forest managers are grossly unprepared €
to deal with root disease problems. Some €
foresters working in the field today graduated €
from accredited schools without any formal class €
work in forest pathology. Fortunately, people €
can gain skills on the job. Leaflets, brochures, €
studies, proceedings, papers, and numerous other €
reference materials are available. Most state, €
private, or federal forest managers have access €
to trained forest pathologists to assist with €
disease problems. Recent technological advances €
have provided access to computers and programs, €
including development of simulation models. €

The RRMOD Computerized Root Disease Simulation €
Model €

One such model available in Region Six is €
the root disease model known as "RRMOD". The root €
disease model is linked to several versions of €
the prognosis stand model and is designed to€
work with existing forest inventories. While the €
model was developed primarily for the pathogenic €
fungal species of Armillaria and Phellinus, €
managers are able to generate reasonable "stand €
responses" to H. annosum by manipulating some of €
the model's component interactions. €

The model can be used to evaluate the €
effects of stand management under different €
silvicultural prescriptions with varying levels €
of infection by fungal root pathogen (fig. 1). €

The model can also be used to track the €
effects of stand management decisions for €
long-term planning (Fig. 2). €

The basic components of the model include €
relative susceptibilities of trees to infection, €
resistance of trees to death resulting from root €
pathogen attack, disease-related growth €
reduction, decay of infected root systems, and €
the life span of root disease pathogens. Because €
trees weakened by root disease are subject to €
attack by bark beetles and windthrow, the model €
also simulates the impact of those agents (Eav €
and Marsden 1988). €

Silvicultural Techniques €

Many management alternatives are available €
to land managers to minimize timber losses in €
mixed-conifer stands growing on sites affected €
with annosus root disease. Fortunately, a €
treatment method that works for one particular €
pathogen will often work for other pathogens as €
well. €

Several management strategies to reduce €
losses caused by annosus root disease are €
available. All management strategies consider €
the following recommendations: €

1. Manage stands in short rotations, generally €
less than 120 years. €

2. Minimize wounding of trees during thinning or €
harvest operations. €

3. Retain or favor more disease resistant €
species such as ponderosa pine, lodgepole €
pine, western larch, and western white pine. €

4. Ponderosa pine has not been seriously €
affected by H. annosum in Oregon except in a €
few locations. Special measures to prevent €
damage are needed only in stands within one €
mile of severely infected stands. Borax €
treatment of pine stumps will prevent €
infection (Hadfield and others 1986). €

5. True firs should not be regenerated on sites €
infested with large amounts of well €
distributed inoculum of H. annosum (Hadfield €
and others 1986). €

Some case examples of silvicultural €
prescriptions directed toward minimizing root €
disease losses are: €

1. Clearcut Harvest System €
a. Clearcut harvesting eliminates highly €
susceptible tree species on the site. €
b. Regeneration of harvested sites with €
seral species such as ponderosa pine, €
lodgepole pine, or western larch. €

2. Shelterwood Harvest System €
a. Discriminate against true firs with €
special selection of low disease-risk €
trees of more resistant species to serve €
as leave trees. €
b. Site preparation activities should €
discriminate against true fir advanced €
reproduction. €
c. A major objective should be to €
regenerate the site with seral species. €

3. Selection Harvest (Full Retention Visual €
Objective) €
a. Small patch clearcut around every €
identified infected tree, using 50-ft. €
(15.2 meters) radius from infected tree. €
Figure 1--Comparison of total timber yield (merchantable board feet) in Stand 216 over two rotation periods (240 years). Stand was modeled under 5 different silvicultural prescriptions, each exhibiting 5 different initial annosus infection levels.

Figure 2--Annosus infection center development over time under different silvicultural prescriptions. Initial infection level is 5 percent (scale 0-80 percent). HCC, HSL, HTH, and NONE represent prescriptions of clearcut, selection, thinning, and no treatment, respectively.
b. Plant small clearcut with resistant tree species such as ponderosa pine or western larch.

4. Selection Harvest, Mixed-Conifer Stands

a. Selection harvest (such as commercial thinning or uneven-aged management) of stands with root diseases present is not an attractive alternative. Infection levels as low as 2 percent can cause appreciable long-term yield losses. Volume yield on one modeled stand with 5 percent initial H. annosum was only 66 percent of that obtained from the same stand by using a clearcut harvest system (table 1).

CONCLUSIONS

The mixed-conifer stands of the western United States have been heavily impacted by root diseases. Current levels of root disease are related largely to fire exclusion, selective cutting, uneconomical forest practices, and optimizing short-term benefits.

Silvicultural control of root disease can be accomplished. Control must be considered both a social and ecological issue. Managers must be knowledgeable about root disease biology, and the various publics must be willing to consider the long-term consequences of decisions.

Silvicultural techniques such as clearcutting, shelterwoods, or selection harvest are available to reduce root disease losses. Major emphasis should be given to minimizing wounding in stands, to reducing true fir components within stands, and to regenerating sites with resistant species such as ponderosa.

REFERENCES


Table 1--Total timber yield in Stand 216 (mixed-conifer stand, Sisters Ranger District, Deschutes National Forest) two rotations (240 years).

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<th>Harvest Treatment</th>
<th>0 pct</th>
<th>2 pct</th>
<th>5 pct</th>
<th>10 pct</th>
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<td>Clearcut</td>
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<td>Thinning</td>
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<td>48,109</td>
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<td>43,171</td>
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<td>Shelterwood</td>
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<td>71,865</td>
<td>71,745</td>
<td>73,002</td>
<td>66,380</td>
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<tr>
<td>No Silv. Treatment</td>
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<td>41,378</td>
<td>38,557</td>
<td>39,853</td>
<td>34,831</td>
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