Management Strategies for Annosus Root Disease in Pacific Northwest Coastal Western Hemlock[1]

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Abstract: Actual loss from annosus root disease infections in hemlock stands is difficult to determine. As political trends move toward protecting old-growth timber, greater market demand will be placed on second growth western hemlock. These stands must be kept healthy for maximum productivity. The paper compares the following 70-year rotation timber management scenarios: The first has a single juvenile spacing entry and low infection. The second has early spacing plus a commercial thinning with considerable crop tree wounding and high infection. Operational guidelines are presented for management of coastal western hemlock to minimize losses due to annosus root disease.

Annosus root disease (Heterobasidion annosum (Fr.) Bref.) in the second-growth coastal western hemlock (Tsuga heterophylla) timber type of western Washington and Oregon has been investigated and discussed for more than 25 years. Although much progress has been made in understanding annosus root disease, the picture of its true impact is not yet complete (Chavez and others 1980; Edmonds 1968; Morrison and Johnson 1978; Russell and others 1973; Wallis and Morrison 1975).

The advent of recent concern over saving more old-growth timber, particularly in the western Cascade Mountains and Coast Ranges of Washington and Oregon, means that greater demand for wood fiber may be placed on second-growth stands of coastal western hemlock. This means probable increases in multiple stand entries and a potential for higher losses from annosus root disease. After observing and working on disease aspects of western hemlock in this region for almost 25 years, I am convinced that skilled and careful entries for periodic removal of fiber can be done without excessive losses caused by annosus root disease.

The actual amount of fiber loss is difficult to pinpoint. Losses caused by annosus root disease in coastal western hemlock in Washington and Oregon do not arise from tree mortality as in other regions such as in eastern Oregon Cascade Mountains, or in the southeastern United States. Annosus-caused mortality in coastal western hemlock is rare; usually another root disease, such as armillaria, is responsible.

Loss caused by annosus root disease generally starts as stands reach precommercial spacing size. Contacts by young trees with roots of old infected stumps may be the first stage of disease transfer to the new crop. The next stage of infection occurs at root closure, or root contact and grafting, resulting in tree-to-tree spread within the stand. Spores germinating on freshly cut precommercial thinning stumps channel Heterobasidion annosum into crop trees through the root grafts and contacts. Crop trees may also be directly infected from spores that land on mountain beaver or bear wounds. When stands are commercially entered, logging equipment makes additional wounds on roots and lower stump areas, creating opportunity for more decay development. Any of these modes of entry throughout the rotation result in either annosus decay columns or wetwood columns without decay. Of course, it is understood that other decay organisms as well may enter the tree, but they will not be discussed in this paper.

When stands are well into maturity, or after about age 45 to 50 years, annosus-caused root degradation can result in localized severe windthrow from periodic winter storms. Windthrow from "major event" storms could, on occasion, destroy stands that have roots infected by annosus root disease.

How does the forest manager estimate yield loss? In theory, it seems relatively easy to assess the decay from each event and subtract it from the total potential yield over the length of the rotation. One of the most logical ways, when stands are timber oriented, is to use rotation age as the sideboard for visualizing quantitative loss. What is the difference in yield produced between a stand without annosus over a 60-year rotation and a similar but infected stand with the same rotation? There is a valid loss of fiber. When does it occur?

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Foresters commonly use decades as convenient time units in forest management. Beginning with about the third decade of the managed western hemlock stand rotation, losses caused by annosus or shrinkage in any form of cubic volume measurement can be pinpointed at the end of each succeeding decade. It is important to carefully define the kind of loss. Is incipient decay (which may not really be a loss) included in the estimate or is only advanced decay considered? The kind of manufactured wood product may determine the degree to which loss must be considered.

Obtaining the amounts of decay in some form of cubic measure takes years of detailed and time-consuming studies that gradually piece the puzzle together. From studies done thus far, decay loss may not be as bad as we once thought. Yield tables in use today usually account for normal mortality only. They do not account for the insidious decay that creeps up through infected roots. The amount of decay may in some cases be substantial or it may be considered a normal and acceptable loss. Forest managers need to know what is happening to their managed stand yields.

VISUALIZING LOSSES FROM ANNOSUS ROOT DISEASE

Two western hemlock management regimes have been prepared to illustrate when annosus losses may occur in a rotation. These management regimes portray the growth of hemlock stands from 30 to 70 years and are typical for those managed by any large timber organization in the western hemlock zone described above. Each regime shows a normal yield and a yield with an estimated amount of loss from annosus root disease.

The first management regime is a western hemlock stand that is programmed for entry only at age 15 for precommercial thinning. This stand will carry more stems per acre, resulting in smaller-diameter trees that might be used for pulp or a special export log. The assumption for this regime is that incidence of annosus root disease would be relatively low because of both the single entry and little infection from previous stands.

The second regime is a "worst case" situation in which the stand is precommercially thinned in normal fashion at age 15 and then commercially thinned at age 35 during which many trees are damaged by careless logging. It is assumed that this stand could have substantial loss caused by annosus root disease.

These two stand management regimes are presented in a series of tables showing yield at each decade from 30 to 70 years. Trees were dissected into standard 32-foot logs with volumes in board feet and stand volumes in board feet per acre. The tables were generated from a Washington Department of Natural Resources computer program (DNRIMPS) developed for intensive management of stand yield projections (Chambers, 1988). The program computes volumes in Scribner log scaling rules for western Washington, based on stems per acre, diameter at breast height, and tariff tables for a given 50-year site index. A few shortcuts were taken in calculations in the tables presented here, and volumes were rounded off for clarity. Final volumes in the tables are similar to those strictly generated by the computer. Losses caused by annosus root disease are shown as a percent of the normal yield under an intensively managed regime.

The tables that form a model for typical western hemlock stands could be useful for managers and researchers alike to aid in pinpointing when and how much decay occurs in managed stands. The tables could be used in making better yield predictions once regional, local, or stand incidence of annosus root disease is known. The tables will also help researchers plan better investigations in pinpointing where and how to measure loss. The model also illustrates to loggers how careless damage to crop trees can cause serious yield loss.

Management Scenario for Low Annosus Impact

Tables 1-3 depict the yield and loss by annosus root disease through each decade for the low-decay incidence regime. The only entry before the rotation harvest was the precommercial thinning at age 15. The tables flow from one to the next. The final percent of loss caused by annosus root disease for each decade is found in table 3.

Management Scenario for High Annosus Impact

Tables 4-6 depict the yield and loss by annosus root disease through each decade for the high decay incidence regime. This stand was precommercially thinned at age 15 and then commercially thinned at age 35. Many crop trees were damaged during the logging. Decay may be significant if the rotation harvest is more than 20 years away. If the stand harvest is within about 10 years, much of the decay resulting from logging damage will be outside the scaling cylinder (Quam, 1977). The Scribner log scaling rule used in the Pacific Northwest measures logs from the small end, allowing a cone of unmeasured wood. In larger logs unmeasured wood amounts to considerable volume. If the unmeasured volume has been damaged by careless logging, the buyer receives less "free wood". The tables below flow from one to the next as in the low-impact regime. The final percentage of loss caused by annosus root disease percent for each decade is found in table 6.

The discussion and Tables 3 and 6 presented thus far predict only managed rotation losses from annosus

root disease for standing trees. Additional volume loss of green timber may occur during storms of near-hurricane proportions if trees had excessive root decay. Windthrow loss is difficult to predict, but could be reasonably estimated if the stand infection is known.

MINIMIZING LOSS CAUSED BY ANNOSUS ROOT DISEASE IN MANAGED STANDS

Foresters need to become familiar with incidence of annosus root disease in western hemlock stands within their local area. By sampling stands of various ages, a

Table 1--Yield of an intensively managed site index 105 (105 ft, 50 yrs) western hemlock stand from age 30 to 70 with a single precommercial spacing entry at age 15. Normal stand mortality is accounted for, but loss from annosus root disease decay is not included.

Age	Diameter Breast Height	T/Ac[1]	No. 32' Logs[2]	BF/log[3]	BF/tree[4]	Scribner BF[5]
yr.	in.					vol acre
30	11.4	249	1	40	40	10,000
40	14.1	239	2	90,20	110	26,300
50	15.2	230	2	140,30	170	39,100
60	16.0	223	3	160,60,10	230	51,300
70	16.5	215	3	190,70,10	270	58,000

[1]Number of trees per acre (T/Ac) generated by DNRIMPS computer program.
[2]Number of 32-forrt-long logs per tree.
[3]Board feet per log.
[4]Board feet per tree.
[5]Scribner volumes rounded off to nearest 100 board feet; Age 30 volume per acre calculation: 249 x 40 = 9,960, etc.

Table 2--Breakdown of loss from annosus root disease in a western hemlock stand (precommercially spaced at age 15).

Age	T/Ac[1] Healthy	T/Ac[2] Infected	Pct[3]	Volume Loss[4] Pct/log	BF/log	BF/tree
yr.				Pct/log	BF/log	BF/tree
30	174	75	30	5	38	38
40	155	84	35	9,0	81,20	101
50	138	92	40	15,3	119,29	148
60	111	112	50	17,6,0	133,56,10	199
70	75	140	65	22,10,0	148,63,10	221

[1]The number of healthy trees per acre.
[2]Calculation for number of infected trees at age 30, per acre is: .30 x 249 9T/ac col. table 1) = 75, etc.
[3]Percentage of trees infected by annosus root disease is a regional estimate of the average number of infected western hemlock trees per acre (T/Ac). These values may vary considerably.
[4]Percent log volume lost is a regional estimate of decay loss. The estimates are a composite of completed and on going studies. These numbers may vary. Compare Board-foot-per-log and board-foot-per-tree columns with the same columns in table 1.

rotation long, decade-by-decade estimate of impact can be obtained. The incidence of annosus root disease in an existing stand should influence harvesting method, number of stand entries, season entered, and rotation length of the replacement stand. For example, it would not be wise to shelterwood harvest a hemlock stand with a high incidence of annosus root disease because of the possibility of windthrow from decay weakened roots. High incidence of annosus root disease could also initiate changing the new crop to Douglas-fir, a species rarely impacted by the disease.

Table 3--Yield of the intensively managed stand of western hemlock (precommercially spaced at age 15) that estimates percent loss from annosus root disease for decades 3 through 7.

Age	Healthy Trees[1]	Trees Infected by Annosus[2]	Net Volume	Loss due to Annosus[3]
Yr.	BF/acre	BF/acre	BF/acre	Pct
30	7,000	2,800	9,800	2
40	17,000	8,500	25,500	3
50	23,500	13,600	37,100	5
60	25,500	22,300	47,800	7
70	20,200	30,900	51,100	12

[1] Volume per acre of 30-year-old healthy trees is: 174 (Healthy T/Ac col. table 2) x 40 (BF/tree col. table 1) = 7,000, etc.

[2] Volume per acre of 30-year-old trees infected with annosus root disease is: 75 (Infected T/Ac col. table 2) x 38 (BF/tree col. table 2) = 2,800, etc.

[3] Percent loss due to annosus root disease at age 30, is: $100 - \left[\frac{\text{9,800 net board feet per acre}}{\text{10,000 Scribner volume (table 1)}} \times 100 \right] = 2$, etc.

Table 4--Yield of an intensively managed site index 105 (105 ft, 50 yrs) western hemlock stand from age 30 to 70, precommercially spaced at age 15 and commercially thinned at age 35 with crop tree damage. Normal stand mortality is accounted for, but loss from annosus root disease decay is not included.

Age	Diameter Breast Height	T/Ac[1]	No. 32' Logs[2]	BF/log[3]	BF/tree[4]	Scribner BF[5]
yr.	in.					vol./acre
30	11.4	249	1	40	40	10,000
40	14.5	146	2	110,20	130	19,000
50	17.2	138	2	150,50	200	27,600
60	19.2	131	3	230,120,20	370	48,500
70	20.5	127	3	320,120,20	460	58,400

[1]Number of trees per acre (T/Ac) generated by DNRIMPS computer program.

[2]Number of 32-foot-long logs per tree.

[3]Board feet per log.

[4]Board feet per tree.

[5]Scribner volumes rounded off to nearest 100 board feet; Age 30 volume per acre calculation: 249 x 40 = 9,960, etc.

All thinning operations must be carefully planned to minimize chances for entry by the annosus organism. The following operational guidelines are useful in the Pacific Northwest region for reducing infection potential.

* Conduct juvenile spacing only; no commercial entry until rotation end.

* Conduct juvenile spacing plus 1 or more commercial thinnings.

Table 5--Breakdown of loss from annosus root disease in a western hemlock stand (precommercially spaced at age 15 and commercially thinned at age 35).

Age	T/Ac[1] Healthy	T/Ac[2] Infected	Pct[3]	Volume Loss[4]		
Yr.				Pct/log	BF/log	BF/tree
30	174	75	30	5	38	38
40	88	58	40	12,0	97,20	117
50	69	69	50	20,4	120,48	168
60	39	92	70	23,8,0	117,110,20	307
70	25	102	80	26,11,0	237,107,20	364

[1] The number of healthy trees per acre.
[2] Calculation for number of infected trees at age 30, per acre is: .30 x 249 (T/Ac col. table 4) = 75, etc.
[3] Percentage of trees infected by annosus root disease is a regional estimate of the average number of infected western hemlock trees per acre (T/Ac). These values may vary considerably.
[4] Percent log volume lost is a regional estimate of decay loss. The estimates are a composite of completed and on going studies. These numbers may vary. Compare board-foot-per-log and board-foot-per-tree columns with the same columns in table 4.

Table 6--Yield of the intensively managed stand of western hemlock (precommercially spaced at age 15, commercially thinned with crop tree damage at age 35) that estimates percent loss from annosus root disease for decades 3 through 7.

Age	Healthy Trees[1]	Trees Infected by Annosus[2]	Net Volume	Loss due to Annosus[3]
yr.	BF/acre	BF/acre	BF/acre	Pct
30	7,000	2,800	9,800	2
40	11,000	6,800	18,200	4
50	13,800	11,600	25,400	8
60	14,400	28,200	42,600	12
70	11,500	37,100	48,600	17

[1] Volume per acre of 30-year-old healthy trees is: 174 (Healthy T/Ac col. table 5) x 40 (BF/tree col. table 4 = 7,000, etc
[2] Volume per acre of 30-year-old healthy trees infected with annosus root disease is: 75 (Infected T/Ac col. table 5 x 38 (BF/tree col. table 5) = 2,800, etc
[3] Percent loss due to annosus root disease at age 30, is $100 - \left[\frac{\text{9,800 net board feet per acre}}{\text{10,000 Scribner volume (table 4)}} \times 100 \right] = 2$, etc.

* Shorten the rotation age.

* Educate the logging crew about consequences of damage to crop trees.

* Restrict logging during the bark slipping season in the spring.

* Match logging equipment to terrain and timber size.

* Use low ground pressure skidders.

* Avoid commercial thinning of steep slopes.

* Plan skid trails before logging and make them permanent.

* Build straight line skid trails.

* Leave turn and bump trees until last turn of logs.

* Log skid roads first.

* Cut low stumps in skid roads.

* Mark leave trees.

* Use directional falling for best log access to skid roads.

* Match log length with final spacing.

* Limb and top trees prior to skidding.

* Apply borax to commercial thinning stumps only when degree of protection is greatest.

* Prevent wounds on crop trees.

Note that applications of borax to stumps for controlling annosus root disease are not advocated in juvenile or precommercial thinnings. Even though the successful use of borax has been demonstrated, we have not elected to recommend it for all timber harvesting in the region (Russell and others 1973). Borax may be recommended when the incidence of annosus root disease is low or when trees to be protected are in a recreation site where people are concentrated.

Foresters using the above guidelines when contemplating stand entries will not suffer excessive losses from annosus root disease. Continued investigations by regional forest pathologists will fill in the gaps in the impact numbers and improve understanding of annosus root disease in western hemlock.

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