Young-growth western hemlock stand infection by *Heterobasidion annosum* 11 years after precommercial thinning

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Infection level and course of spread of *Heterobasidion annosum* (Fr.) Bref. in a 26-year-old western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) stand, precommercially thinned 11 years previously, was determined. Impact of infection on height and radial growth of western hemlock was also examined. Tree infection increased from a mean of 8% initially, to an average of 90% in the residual trees. Stump colonization accounted for 61% of the tree infection by *H. annosum*, with stumps within 61 cm of the remaining trees providing most of the inoculum. The fungus also entered through animal damage wounds. Growth rate of *H. annosum* was estimated at 75 cm/year with a range of 23–128 cm/year. Although there was no significant difference between infected and uninfected trees in height or radial growth, infected trees had less height and slightly more radial growth than uninfected trees.

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Les auteurs ont mesuré le taux d'infection et étudié le mode de progression du *Heterobasidion annosum* (Fr.) Bref. dans un peuplement de pruche occidentale (*Tsuga heterophylla* (Raf.) Sarg.) âgé de 26 ans qui avait subi une éclaircie précommerciale 11 ans plus tôt. On a aussi examiné si l'infection avait un effet sur la croissance en hauteur et en rayon des arbres. De 8% qu'il était avant l'éclaircie, le taux d'infection est passé à 90% dans le peuplement résiduel. Dans 61% des cas, les arbres ont été infectés via les souches colonisées par le *H. annosum* après l'éclaircie. Dans la majorité des cas, l'infection des arbres résiduels pouvait être reliée à des souches situées à moins de 61 cm. Les blessures causées par les animaux ont également servi de porte d'entrée pour le champignon. Le taux de progression du *H. annosum* est de 75 cm/an avec un écart allant de 23 à 128 cm/an. Même s'il n'y a pas de différence significative de croissance en hauteur et en rayon entre les arbres sains et infectés, ces derniers avaient une croissance en hauteur moindre et une croissance en rayon légèrement supérieure.

[Traduit par le journal]

Introduction

Heterobasidion annosum (Fr.) Bref. causes root and butt rot disease in mature (Englerth 1942) and young-growth (Wallis and Reynolds 1970) western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) in coastal Oregon and Washington, U.S.A., and British Columbia, Canada. In young-growth stands *H. annosum* infection centers are initiated when roots come in contact with infected roots of adjacent old-growth stumps or wounds (Wallis and Reynolds, 1970). Stump infection following precommercial and commercial thinning has been shown to increase *H. annosum* inoculum in immature stands (Morrison and Johnson 1978; Wallis and Morrison 1975; Wallis and Reynolds 1970). Spread from infected stump roots to residual trees is by mycelial transfer at root contacts (Morrison and Johnson 1978; Wallis and Morrison 1975; Wallis and Reynolds 1970).

Despite our current knowledge of *H. annosum*, the potential magnitude of residual tree infection from freshly cut, untreated stumps is not clearly understood. This study was initiated to examine the course and extent of spread of *H. annosum* into residual young-growth western hemlock trees following precommercial thinning. In addition, the effects of infection by *H. annosum* on growth of western hemlock were investigated. Specific objectives were to determine: (1) extent of *H. annosum* infection in precommercially thinned young-growth western hemlock residuals, 11 years after documented stump infection (Edmonds 1968), (2) rate and pathway of stand infection by *H. annosum*, and (3) impact of infection by *H. annosum* in western hemlock on height and radial growth.

Materials and methods

Site description

The study was conducted on a Washington State Department of Natural Resources site, located approximately 4.2 km southwest of Clallam Bay, on the Olympic Peninsula of northwest Washington, U.S.A. Mean annual rainfall is 250 cm, with a mean annual air temperature of 9.0°C. Summers are relatively dry.

Tree species composition in the primarily second growth stand was western hemlock, with Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco.) and Sitka spruce (*Picea sitchensis* (Bong.)) present, although infrequent. The stand regenerated naturally and is currently aged at approximately 26 years. The predominantly clay soils are of the Astoria and Hoko series (Smith, 1951). Study sites were situated on a north aspect (24% slope) at approximately 91–122 m elevation.

Two of twenty-five 0.04-ha plots, established and described by Edmonds (1968), were selected for the study. The plots were originally precommercially thinned by chainsaw at age 15 from

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TABLE 1. Incipient decay stain height and volume from trees infected with *Heterobasidion annosum*

	Incipient decay stain height (m)			Stain as percent of merchantable volume[a]		
Plot No.	Max.	Av.	Min.	Max.	Av.	Min.
15 (thinned May 1967)	11.0	4.1	1.7	19.9	2.3	0.1
21 (thinned Feb. 1967)	11.8	3.4	0.2	4.8	1.0	0.003
Combined	11.8	3.7	0.2	19.9	1.6	0.003

[a]Volume calculated from root collar to 10.2 cm diameter top.

200 to 30 stems, i.e., from 6182 to 742 stems/ha, and had been used to study the incidence of stump infection by *H. annosum*. One plot, No. 15, was thinned in May, 1967; the other, No. 21, was thinned in February, 1967. Both plots had not been reentered for 11 years.

Determination of stand infection

Twenty trees of comparable size were selected on each plot for detailed examination. Trees were felled and two 5-cm disks were collected from the base of each tree. Height and diameter at breast height (dbh) were recorded. Merchantable volume to a 10.2 cm (4 in.) top and total volume were calculated. Age was estimated by annual ring counts at ground level. Stumps were examined for symptoms of the fungus, i.e., incipient decay. With incipient decay the wood is hard and firm but is abnormally colored (Boyce 1961); in this case a brown stain. When stain was present, 5-cm disks were taken at 61-cm intervals to the terminus of the stain column. All disk samples were immediately placed in heavy plastic bags and sealed for transfer to the laboratory. Disks were then wrapped in moist paper and incubated in specially constructed incubation pans at room temperature to allow *Oedocephalum lineatum* Bakshi the conidial stage of *H. annosum* to develop (Rishbeth 1950; Wood 1970). After 7-14 days, both surfaces of disks were examined under 30× magnification for the distinctive conidia. Volume estimates for incipient decay columns were determined by treating them as cones, since stain pattern changed little as the fungus progressed up the stem, and was roughly conical in shape.

Selected stump groups colonized by *H. annosum* were hydraulically excavated using portable fire pumps. Methods used in excavation work are described by Chavez (1980). Infection sources and pathways of the fungus were determined by sectioning the stumps and necessary roots with a chainsaw, and using incipient decay per stain columns to trace the fungus.

Impact of H. annosum *on tree growth*

Length of internodes for a 15-year period, i.e., from growing tip back 15 internodal spaces, were used to detect differences in height growth between uninfected trees and trees infected with *H. annosum*. Eight infected and eight uninfected trees were selected from comparable growing sites, i.e., same age-class and equivalent tree densities. Internode measurements, determined by external measurement (Jaeck 1980), were recorded for statistical comparison. Infected trees were from plot No. 15, while uninfected trees were from nearby thinned plots used by Edmonds (1968) with similar stand density.

Annual ring width measurements over the last 15 years taken approximately 1.2 m above ground were used to compare radial growth differences between infected and uninfected trees. Eight infected and eight uninfected trees were selected using the same criteria, as above. Infected trees were from plot No. 21, while uninfected trees were from nearby thinned plots.

Results

Stand infection

Tree infection levels 11 years after thinning were found to be high. Of 20 trees felled on plot 15, 17 (85%) were infected by *H. annosum*. Similarly, 19 of 20 (95%) were infected on plot 21. In contrast, tree infection levels prior to the 1967 thinning were 4 and 12% for plots 15 and 21, respectively (Edmonds 1968).

Incipient decay column heights and volumes are shown in Table 1, and typical incipient decay staining is shown in Fig. 1. Decay columns averaged 4.1 m on plot 15 and 3.4 m on plot 21. Additionally, a maximum incipient decay column equivalent to nearly 20% of merchantable tree volume was observed on plot 15. However, the overall plot mean stain volume was considerably smaller, being approximately 1.6% of merchantable volume. Advanced decay was not observed in the trees.

Stumps from the 1967 thinning were found to be the principal source of infection (Table 2). Figure 2 shows typical stump distribution and extent of roots in the stand. Initial colonization by *H. annosum* in these stumps, observed by Edmonds (1968), was 92 and 56% for plots 15 and 21, respectively. A combined total of 61% of all infected trees were traced directly to these residual stumps. Mountain beaver damage and other wounding was the source of 25% of the infected trees (Table 2). Only 11% of infection on average was of uncertain origin.

The greatest infection distance from point of initial stump colonization to terminus of infection column in the stem was 11.6 m. More often, residual stumps were close to infected trees and were often grafted to the remaining crop tree as shown in Fig. 3. Transfer of the pathogen occurred where stump roots, commonly in the root crown region, were grafted to the residual tree root system. Root grafts between roots of the same tree were also quite common, although not a factor at least at this stage of infection (Fig. 4).

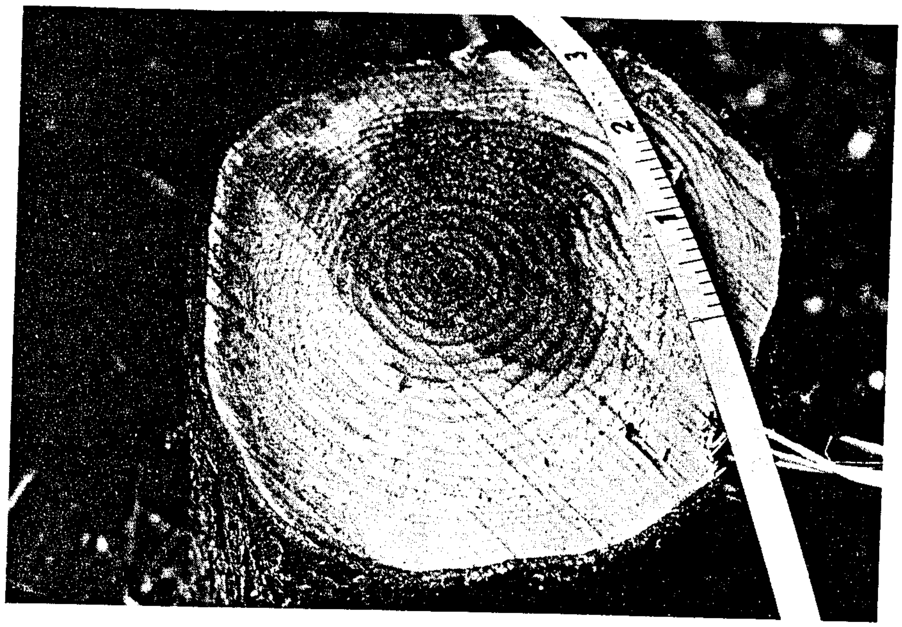

FIG. 1. Stump surface showing incipient decay (scale is in inches).

Heterobasidion annosum grew rapidly at an estimated mean growth rate of 74.6 cm/year, with a range of 23–128 cm/year. Growth rates are based on total distances the fungus traveled over time since thinning. Stumps were examined for colonization by *H. annosum* at least 16 weeks after the precommercial thinning in 1967 (Edmonds 1968).

Assessment of growth impact

There was no significant difference between infected and uninfected trees in height or radial

FIG. 2. A hydraulically excavated site showing distribution of stumps and extent of roots. Approximately 45 cm of soil was removed.

TABLE 2. Source of tree infection after thinning (percent)

Plot No.	Stump	Animal damage[a] and other wounding	Both	Uncertain
15[b]	70	6	6	18
21[c]	53	42	0	5
Combined	61	25	3	11

[a]Caused by mountain beaver (*Aplodontia rufa*).
[b]Seventeen of 20 trees infected.
[c]Nineteen of 20 trees infected.

growth, although infected trees had less height and slightly more radial growth. Cumulative height and radial growth of infected and uninfected trees for a 15-year period are shown in Figs. 5 and 6, respectively.

Discussion

Intensive management of western hemlock, coupled with the high susceptibility of this species to infection and decay by *H. annosum* (Edmonds 1976), threatens to increase disease levels to damaging proportions. Of particular concern is the extent to which *H. annosum* will spread to residual trees from freshly cut, untreated stumps following precommercial thinning.

High levels of stump infection (60-100%) were recorded 16 weeks after the precommercial thinning at Clallam Bay (Edmonds 1968). Driver and Wood (1968) and Russell et al. (1973) found stump infection to range from 40-90% following thinning in other stands in western Washington and Oregon.

The levels of tree infection by *H. annosum* after thinning found in this study (85-95%) were extremely high. This degree of infection is higher than any previously detected level in unthinned western hemlock stands. Schmidt (1979) found infection levels to range from 6.6 to 67.4% in unthinned stands in western Washington and Oregon. Driver and Wood (1968) and Blair and Driver (1977) found ranges of 0-50 and 21-23% in unthinned stands in western Washington and British Columbia, respectively.

The growth rate estimate of *H. annosum* of 74.6 cm/year compares favorably with prior estimates. Wallis and Reynolds (1970) reported that once established in hemlock stumps *H. annosum* can grow at a rate of approximately 76.2 cm/year through wood.

Gillete (1975) established that height growth of Douglas-fir infected by *Phellinus weirii* impeded as much as 15 years before visual symptoms appear. However, *H. annosum* had a statistically insignificant effect on height of western hemlock, as shown in Fig. 5, but infected trees did have consistently

FIG. 3. An excavated stump group including a freshly cut crop tree stump (left) and two smaller 1967 thinning stumps. Infection occurred at the surface of the thinned stump (top arrow) which became the pathway to the crop tree via root grafting (bottom arrow).

less height growth than uninfected. Similarly, radial growth was not significantly different between infected and uninfected trees, but the difference shown in Fig. 6 appears to be increasing with time. The apparent increase in radial growth of infected trees is unexplainable at this time. It is interesting to note that the increase apparently began shortly after the 1967 thinning.

Wallis and Reynolds (1970) predicted that airborne spore infection of coniferous stumps, if not controlled, would cause a rapid build up of *H. annosum* in thinned immature stands in coastal British Columbia. In a more recent study, Morrision and Johnson (1978) concurred with this prediction and noted that untreated stumps were a source of inoculum for new *H. annosum* infection centers in immature western hemlock. In addition, they pointed out that if the amount of inoculum on a site

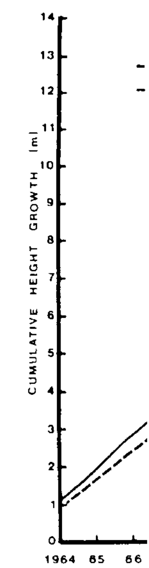

FIG. 4. Exposed western hemlock roots showing numerous root grafts.

is allowed to increase, losses may begin sooner and will be more serious in succeeding rotations. Results from our study appear to support these concerns. Detection of the 90% average infection levels of *H. annosum* in the residual trees at Clallam Bay represents a large increase (more than 10-fold) over the mean of only 8% infection observed by Edmonds (1968) prior to thinning. Although

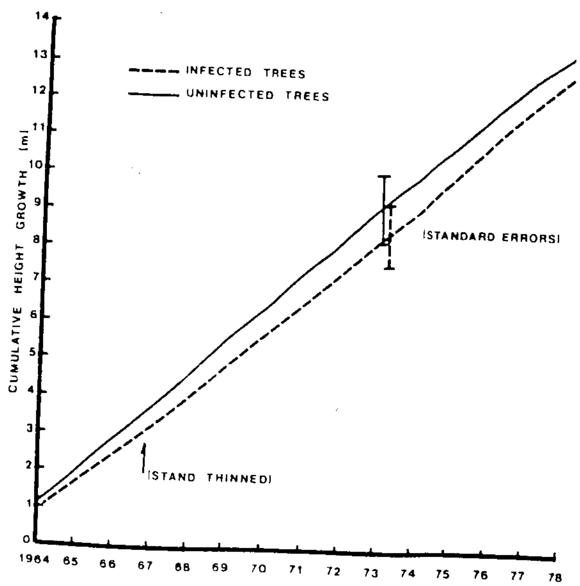

FIG. 5. Cumulative height growth of uninfected and *Heterobasidion annosum* infected western hemlock trees for the last 15 years.

mountain beaver damage and other wounding accounted for a combined 25% of the infection, most (61%) was traced directly to stump colonization

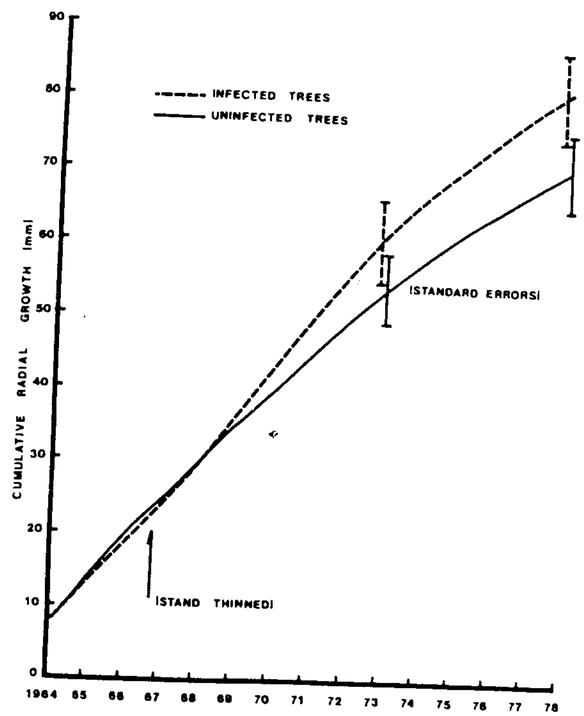

FIG. 6. Cumulative radial growth of uninfected and *Heterobasidion annosum* infected western hemlock trees during the last 15 years.

(Table 2). Further, stump distance from the residual trees appeared to be an important factor in spread of *H. annosum*. However, transfer of *H. annosum* can occur at root contact points and at root grafts, regardless of stump proximity to residual trees (Wallis and Reynolds 1970). Obviously, leaving stumps close to residual trees increases the likelihood of contacts and (or) grafts between infected and uninfected root tissue, as observed in this study.

The highly significant increase of infection by *H. annosum* in remaining trees is mostly attributable to the untreated stumps left from the precommercial thinning. The mountain beaver damage which is common in young western hemlock stands is also an important factor. It appears that precommercial thinning may be unfavorable as a continuing stand management practice in western hemlock, unless measures to retard or prevent colonization by *H. annosum* on the cut surface of stumps are taken (Russell et al. 1973).

There are a number of considerations that must be taken into account before cost effective stump treatments are recommended operationally. Extent of western hemlock product degrade resulting from various degrees of decay induced by precommercial thinning must be evaluated as early in the rotation as possible. Careful incorporation of data presented in this study with decay loss data from older stands, both thinned and unthinned, will help determine final impact.

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