Survival of *Inonotus tomentosus* in Spruce Stumps After Logging

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ABSTRACT

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Survival of *Inonotus tomentosus* was investigated by isolating the fungus from excavated stumps of blue spruce (*Picea pungens*) and Engelmann spruce (*P. engelmannii*) that had been harvested 9, 13, or 20 yr previously in southern Utah. The fungus was isolated from 62, 100, and 75% of 9-, 13-, and 20-yr-old stumps, respectively. The diameter of the smallest roots that yielded *I. tomentosus* ranged from 1.3 cm (9-yr-old stumps) to 2.5 cm (13- and 20-yr-old stumps). The maximum distances that *I. tomentosus* was found from the stumps were 3.4, 6.1, and 5.5 m for 9-, 13-, and 20-yr-old stumps, respectively. Isolates of *I. tomentosus* from stumps of all ages killed artificially inoculated Engelmann spruce seedlings.

Tomentosus root disease, caused by the fungus *Inonotus tomentosus* (Fr.:Fr.) S. Teng, affects many coniferous species in North America (8). This fungus causes root and butt decay and death of blue spruce (*Picea pungens* Engelm.) and Engelmann spruce (*P. engelmannii* Parry ex Engelm.) on the Aquarius Plateau in southern Utah (5). A survey of a 520-ha area there revealed that 9% of the stems, representing 8% of the volume, had been killed by the disease. An additional 29% of the stems, representing 38% of the volume, were infected (5). The fungus survives in roots of stumps and snags and can infect young trees through root contact (2,6). The longest documented survival of *I. tomentosus* in roots of dead trees is 30 yr (2). Losses attributable to this and other root diseases can be reduced by establishing immune species and allowing the fungus in previously colonized roots to die before reintroducing susceptible trees (8). How long *I. tomentosus* can survive in stumps and infect susceptible seedlings will determine how long forest managers must wait to reintroduce them. The objective of this study was to learn whether *I. tomentosus* can survive as long as 20 yr in spruce stumps in southern Utah.

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MATERIALS AND METHODS

The methods for determining fungal survival were patterned on Hansen's (1) study of survival of *Phellinus weirii* (Murrill) R. L. Gilbertson in stumps of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Three study sites were located within 3.2 km of the area previously surveyed (5). Records of spruce harvests were reviewed to find the oldest and two more recent harvests. Sample stumps within each site were selected by examining the surfaces of all stumps along transects through the site for evidence of past decay by *I. tomentosus*. Advanced decay caused by *I. tomentosus* is characterized by elongate, spindle-shaped white pockets separated by reddish brown firm wood (4). All sample stumps were considered to have been colonized by *I. tomentosus* at the time of harvest. On the Grass Pond site, 40 9-yr-old stumps were grouped into four diameter classes: less than 15 cm across the top, 15–30 cm, 30–45 cm, and larger than 45 cm. On each of the Dog Lake (13-yr-old stumps) and Lake Philo (20-yr-old stumps) sites, 20 stumps between 30 and 76 cm in diameter were selected.

During the summer of 1985, all sample stumps were excavated with hand tools. Three main roots were exposed from the stump out to the farthest extent of apparently viable *I. tomentosus*. The fungus was classed as apparently alive if the advanced decay retained characteristic color and texture as described by Partridge and Miller (4). Sections of roots were extracted near the stump and at the interface between apparently living and dead *I. tomentosus*. The sections were labeled to identify their location on the root and the diameter of the root at that point, placed in polyethylene bags, and kept in coolers until isolations were made. In a laboratory, four chips were extracted from each section and plated on malt extract agar containing 1 mg of benomyl (50WP) and 50 mg of streptomycin sulfate per liter. Plates were incubated at room temperature and examined for growth of *I. tomentosus* or other decay fungi weekly for up to 2 mo. Cultures of *I. tomentosus* and other basidomycetes were transferred to clean malt agar plates for identification according to Nobles (3).

Four isolates of *I. tomentosus* from each study site were randomly selected to test their pathogenicity to Engelmann spruce seedlings. One isolate of *I. tomentosus* from a living Engelmann spruce on the Grass Pond site was also used in the pathogenicity test. Inoculum blocks were prepared by growing the isolates on sterilized hardwood dowels. The dowels (0.6 cm in diameter and 5.1 cm long) were placed in glass jars, autoclaved in a malt extract solution for 1 hr, allowed to cool to room temperature, and reautoclaved for another hour. The malt solution was decanted, and disks of agar colonized by *I. tomentosus* were placed on the dowels. The jars were incubated at room temperature for 3 mo.

Engelmann spruce seedlings that had grown for two seasons in a peat-vermiculite medium in seedling tubes (98 cm^3 in volume) in a greenhouse were inoculated. Dowels colonized by *I. tomentosus* (or sterile dowels for controls) were inserted into the medium near the stem to assure contact with roots. Ten to 13 seedlings, according to the number of well-colonized dowels available, were inoculated with each isolate.

The agar cultures used to infest the dowels were divided in halves and used to inoculate one or two additional seedlings per isolate. For these inoculations, seedlings were removed from the tubes, a block of agar with mycelium was placed on the root mass, and the root mass was replaced in the growing tube. For controls, two groups of 10 seedlings were sham-inoculated with sterile dowels, and one group of 10 seedlings was not treated.

One year after inoculation, all seedlings were removed from the tubes. Sections of the tap and lateral roots were surface-sterilized and plated on malt agar with 1 mg of benomyl (50WP) and 50 mg of streptomycin sulfate per liter. Plates were incubated at room temperature and examined for *I. tomentosus* after 6 wk.

RESULTS AND DISCUSSION

I. tomentosus was isolated from 62% of the 9-yr-old stumps, all of the 13-yr-old stumps, and 75% of the 20-yr-old stumps. Survival of *I. tomentosus* was not related to size of the 9-yr-old stumps, therefore, data for all stumps at the Grass Pond site are pooled. If *I. tomentosus* was isolated from any root of a stump, the stump was classed as currently colonized. The fungus was isolated from 69, 90, and 71% of the roots on currently colonized 9-, 13-, and 20-yr-old stumps, respectively. The fungus was detected in roots as small as 1.3 cm in diameter on 9-yr-old stumps and 2.5 cm in diameter on 13- and 20-yr-old stumps (Table 1). The maximum distance from the stump to the farthest extent of living *I. tomentosus* in roots was 3.4, 6.1, and 5.5 m for 9-, 13-, and 20-yr-old stumps, respectively.

Decay caused by *I. tomentosus* was typically found in the centers of roots. In some cases, the fungus was isolated only from roots, whereas the advanced decay in the stump was water-soaked and the fungus absent from it. Columns of decay caused by *I. tomentosus* were sometimes surrounded by decay caused by other fungi. Other fungi isolated from stumps and roots included *Armillaria* sp., *Phellinus pini* (Thore.:Fr.) A. Ames, and several other unidentified basidiomycetes. *Armillaria* sp. occurred on some roots with *I. tomentosus*. Some stumps without living *I. tomentosus* yielded isolates of *Armillaria* sp. and/or *P. pini*, indicating that the decay at the stump surface may have been misdiagnosed and *I. tomentosus* was never present. Only the latter fungi were found in six of the 9-yr-old stumps and three of the 20-yr-old stumps. Excluding these stumps from the results would increase the survival rates for *I. tomentosus* in the 9- and 20-yr-old stumps to 75 and 88%, respectively. Advanced decay caused by *P. pini* is very similar to that of *I. tomentosus* (4), but the two fungi can be distinguished in culture (3). *P. pini* typically inhabits the bole of trees; however, we isolated it from roots as well as stems of stumps.

Ten of the 20-year-old stumps were in areas that had been burned after clear-cutting. The proportion of roots infected with *I. tomentosus* on the burned stumps was identical to that on unburned stumps. Therefore, survival of *I. tomentosus* was not affected by burning after the clear-cutting. Although the areas we sampled had been planted with Engelmann spruce seedlings, the plantations were not very successful and few spruce seedlings or saplings were present. We found only one instance where *I. tomentosus* had apparently spread from a stump to a young tree. The fungus was isolated from the roots of a dead Engelmann spruce, 7.6 cm in diameter at breast height, near one of the 20-yr-old stumps. The roots of the young tree had grown into contact with an infested root of the stump.

Eleven isolates of *I. tomentosus* from the stumps in our study area were pathogenic to inoculated Engelmann spruce seedlings, and nine isolates killed some seedlings (Table 2). The inoculations attempted with colonized agar disks failed (*data not presented*). Total infection rates (living and dead seedlings/total inoculated) ranged from 10% for isolates from 9-yr-old stumps to 40% for the live-tree isolate. The proportion of seedlings infected might have been greater if the fungus had survived better on the dowels (Table 2). Whitney (6) considered *I. tomentosus* a weak pathogen of small white spruce seedlings, because only 18% of his aseptically grown, inoculated seedlings were killed after 8 mo. However, this fungus is more aggressive on roots of older trees (6) and killed two out of 26 large seedlings planted near heavily infected older trees after 16 yr (7).

Our investigations provide quantitative evidence for survival of *I.*

Table 1. Size and length of roots from which *Inonotus tomentosus* was isolated in relation to time since trees were cut

Years since harvest	Root diameter[a]		Distance from stump[b]	
	Average ± SD (cm)	Minimum (cm)	Average ± SD (m)	Maximum (m)
9	5.0 ± 2.6	1.3	1.1 ± 0.9	3.4
13	6.1 ± 2.5	2.5	2.1 ± 1.3	6.1
20	6.5 ± 2.7	2.5	2.1 ± 1.2	5.5

[a] At distal point of isolation of *I. tomentosus*.
[b] To distal point of isolation of *I. tomentosus*.

Table 2. Engelmann spruce seedlings infected and dead 1 yr after inoculations with *Inonotus tomentosus* and survival of the fungus in dowels used for inoculum[a]

Treatment	Number of seedlings					
	Total	Dead with *I. tomentosus*[b]	Other dead	Alive with *I. tomentosus*[b]	Total with *I. tomentosus* (%)	Dowels with *I. tomentosus*[c] (%)
None	10	0	3	0	0	...
Sterile dowels	20	0	4	0	0	0
I. tomentosus from						
9-yr-old stumps	41	5	3	0	12	32
13-yr-old stumps	43	1	3	6	16	35
20-yr-old stumps	46	7	3	6	28	24
Live tree	10	2	1	2	40	10

[a] Agar disk inoculations were not successful and are not included in the results.
[b] Presence of *I. tomentosus* was ascertained by isolation.
[c] After 1 yr.

tomentosus in Engelmann and blue spruce stumps after logging in southern Utah. The fungus was still alive, often in roots of relatively small diameter, in two-thirds of the 20-yr-old stumps and was capable of killing artificially inoculated spruce seedlings. Therefore, even after 20 yr, susceptible species growing near infested stumps could potentially become diseased. Attempts to reduce losses through rotations to immune species would require rotations longer than 20 yr. The longevity of *I. tomentosus* in stumps and stump roots could not be determined by this study and would require excavating much older stumps. Unfortunately, precise records of older harvests were not available.

I. tomentosus was still viable after 30 yr in stumps of white spruce (*Picea glauca* (Moench) Voss) that Lewis and Hansen (2) studied in British Columbia. They observed a rapid increase in the volume of advanced decay in stumps between the ages of 2 and 13 yr, which was attributed to continued colonization by the fungus after the tree was cut. The volume of decay from which the fungus could be isolated remained constant until age 26–30, when competing organisms invaded wood initially colonized by *I. tomentosus*. *I. tomentosus* was found in roots less than 2 cm in diameter and in the ends of roots up to 4.5 m long (2). These results are similar to our results for Engelmann and blue spruce in Utah, where *I. tomentosus* was found in roots as small as 2.5 cm in diameter and up to 5.5 m from the stump. Research is needed on the effects of tomentosus root disease on spruce stands over time and the effectiveness of various control tactics, including crop rotation and stump removal.

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