United States
Department of
Agriculture

Forest Service

Rocky Mountain
Forest and Range
Experiment Station

Fort Collins,
Colorado 80526

Research Paper
RM-247

Wounds and Decay in Residual Corkbark Fir

Thomas E. Hinds, Robert E. Wood,
and Richard L. Bassett

Abstract

Decay associated with 11- to 17-year-old wounds on residual cork-bark fir in the Apache-Sitgreaves National Forest in Arizona was analyzed. Over 95% of the open scars in different positions, sizes, and depth, and 86% of broken or dead tops were infected with decay fungi. Average volume of decay associated with open wounds was small (0.2 cubic feet) but increased with scar size class. *Amylostereum chailletii* and *Hematostereum sanguinolentum* were the most common trunk decayers, and *Fomitopsis annosa* and *Armillariella mellea* the common root rotters.

USDA Forest Service
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August 1983

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Management Implications

Commercial spruce-fir stands occupy 635,000 acres in Arizona and New Mexico. Although Engelmann spruce (*Picea engelmannii* Parry), subalpine fir (*Abies lasiocarpa* var. *lasiocarpa* (Hook.) Nutt.), and corkbark fir (*A. lasiocarpa* var. *arizonica* (Merr.) Lem.) are characteristic of the type, Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco), white fir (*A. concolor* (Gord. & Glend.) Lindl.), and aspen (*Populus tremuloides* Michx.) are fairly common associates. The true firs are gaining in importance for timber use, and they constitute nearly 3 billion board feet of the commercial sawtimber volume of the two states (Choate 1966, Spencer 1966). Past partial cutting in these stands has resulted in logging injuries to the residual trees. Injuries, particularly on nonresinous tree species such as corkbark fir, are common entrance points for decay fungi. Therefore, logging practices designed to protect future crop trees from wounding should be adopted.

Presale preparations to reduce tree injuries should include the following: (1) delay logging in the spring and early summer when the sap is flowing and the bark not tight; (2) lay out skid trails in advance of logging with no sharp turns and designate "bump trees" to be removed last; (3) mark the residual trees rather than trees to be cut; and (4) select appropriate size and type of logging equipment for the size of the residual trees and topography. Logging techniques would include the following: (1) limb, top, and cut trees into short logs prior to skidding to minimize injury to the residual stand; (2) cut stumps low in the skid trails; (3) fell trees either toward or away from skid trails; (4) use end-line skidding so that skidders can remain on the skid trails; and (5) gain the logging contractor's cooperation through training and supervision to convince him that much damage to residual trees is unnecessary and will not be tolerated. These guidelines have been recommended by Aho et al. (1983), and a slide-tape program is available to show how to minimize comparable logging injuries to residual trees in true fir stands in California (Aho et al. 1981). These guidelines can be adapted to the spruce-fir stands of Arizona and New Mexico. Using these methods and convincing the logger of their importance will lessen the decay losses in trees left for future harvest.

Introduction

Timber has been harvested in the spruce-fir and mixed conifer forests of the the Southwest for a number of years. Residual trees are often damaged during entries, but the significance of this damage, mainly trunk and root wounding, is unknown. The association of tree injuries and decay in some western true firs is well documented (Aho 1966, Aho 1977, Aho and Roth 1978, Hinds et al. 1960, Maloy and Gross 1963). The importance of logging wounds and associated decay in residual crop trees in intensively managed fir stands is being recognized, mainly in the Northwest (Aho 1960, Aho and Filip 1982, Aho et al. 1983, Parker and Johnson 1960, Wright and Isaac 1956). However, studies on the association of logging injuries and decay have not been made in the Southwest.

The objectives of this study were to determine (1) the influence of factors such as wound age, depth, position, and size on infection by decay fungi of wounds presumed to be old logging injuries; (2) the relative amounts of decay; and (3) the decay fungi associated with such scars. The study was limited to corkbark fir on the Alpine Ranger District of the Apache-Sitgreaves National Forest in Arizona, as previous observations indicated this species to be susceptible to wound infection following logging.

Methods

Four stands on the Alpine District were sampled: two along Double Cienega Creek in August 1979, and two along Corduroy Creek in June 1980. All stands had been logged 11 to 17 years earlier and were representative of the logged spruce-fir stands in the National Forest. Trees were selected, not randomly sampled, to give as large a sample of wounds of different types as possible. Broken and dead-top trees were common in the four stands. Since many of the wounds and damaged tops had occurred during the cutting period, it was assumed that most were logging injuries. Sample trees were felled and cut into 8- or 16-foot logs. Tree diameter at breast height (d.b.h.), height, age, and diameter inside bark (d.i.b.) for all cuts were recorded. Smalian's formula was used to calculate cubic foot volumes from a stump height of 1 foot to a 4-inch top d.i.b.

All wounds were classified according to their age, size, depth, and position on the tree. Scar area was determined by multiplying the longest length by width of the open face inside the callus growth around the wound, and scar size was classified as follows:

Scar size *class*	**Surface area** *square inches*
1	<37
2	37–144
3	>144

Two depths were recognized: a scrape that did not damage the underlying wood was considered a bark wound; if the injury penetrated any noticeable part of the sapwood, it was considered a gouge wound. Wounds were classified as to their position on a tree: roots, ground-contact, basal, and upper-bole. The upper surfaces of all lateral roots were uncovered for a distance of 3 feet from the base of the sample trees and examined for root wounds and rot. Scars entirely below the ground were considered root wounds; those on the bole in contact with the ground, including those that extended onto roots, were classed as ground-contact wounds; those above ground line and below d.b.h. were classed as basal wounds; and those entirely above d.b.h. were classed as upper-bole wounds. Wounds completely callused over were considered healed.

Each scar was sectioned to determine the extent of stain or decay. Isolations were made from one or more stain or decay samples from each scar for identification of the decay fungi. Discoloration associated with incipient decay was considered active decay based upon the isolation and identification of a decay fungus. Stain and decay volume was computed by Smalian's formula. More than half of the injuries had less than 0.1 cubic foot of associated decay; however, the volumes were rounded off to the nearest 0.1 cubic foot in the final analysis.

Results

There were 152 scars and 23 dead or broken tops on the 53 trees examined, indicating that multiple injuries were common on individual trees. Scar ages ranged from 1 to 25 years; however, only 132 of those ranging from 11 to 17 years of age, the period of logging, and 21 dead or broken tops in the same age range were used in this analysis. The average scar age in this range was 13 years. Tree diameters ranged from 5.1 to 17.7 inches (average 11.0 inches), tree ages from 57 to 156 years (average 88 years), tree heights from 24 to 86 feet (average 60 feet), and individual gross tree volume from 1.0 to 63.7 cubic feet (average 18.9 cubic feet).

Because of the small sample size and nonrandom selection, the significance of the relationships between wound infection and volume loss to scar position, size, and depth was not tested. Consequently, only general trends can be interpreted from the data.

Wound infection.—Because of the high incidence of unhealed wounds infected by decay fungi (95%), differences between sampled stands can be considered insignificant. Infection decreased with increasing height above ground (table 1), from 100% in root and ground-contact scars to 86% in broken or dead tops (figs. 1, 2). Healed wounds were likewise more often infected when located in the basal portion of a tree (fig. 3).

The differences between scar sizes and incidence of infection were small (table 1). The confidence intervals ($P = 0.05$) for scar size 1 and 2 were ±5% and ±10%, respectively, indicating that wound size probably did not influence rate of infection. Wound depth probably does not influence infection, for gouge scars were 100% infected and bark scars 91±8%.

Decay associated with scars.—The average volume of decay per scar and the percentage of tree volume associated with the 11- to 17-year-old wounds is given in

Table 1.—Wound infection and decay in 11- to 17-year-old corkbark fir scars

Type of wound	Wounds	Infected	Average decay volume per scar	Average tree volume loss per scar
	number	*percent*	*cubic foot*	*percent*
Root	13	100	0.1	0.4
Ground contact	22	100	0.3	1.7
Basal	44	93	0.2	1.4
Basal—healed	8	63	<0.1	0.2
Upper bole	18	89	0.3	0.8
Upper bole—healed	27	33	<0.1	0.3
Broken top	14	86	0.5	2.1
Dead top	7	86	0.6	2.6
Scar size class (nonhealed)				
1	51	96	0.1	0.4
2	32	91	0.1	0.6
3	14	100	0.9	4.2
Wound depth (nonhealed)				
Gouge	42	100	0.2	1.2
Bark	55	91	0.2	1.0

table 1. The average cubic foot and percent volume loss per wound is based on the total number of scars involved. Loss per scar would be somewhat greater when only infected scars are considered. The amount of decay associated with the various wounds varied from a trace, that is, less than 0.1 cubic foot, to as much as 5.8 cubic feet in one tree that had a broken top.

In this study, 100% of the root and ground-contact scars and 93% of the basal scars were infected with decay fungi which were causing tree volume losses 11 to 17 years after tree injury. Ground-contact scars and scars greater than 144 square inches in size resulted in the highest average tree volume loss, which amounted to 1.7% and 4.2%, respectively, of the gross tree volume. Volume loss associated with root scars was smaller because the decay had to reach stump height before it caused measurable loss. Seventy-seven percent of the root scars had less than 0.1 cubic foot associated butt decay.

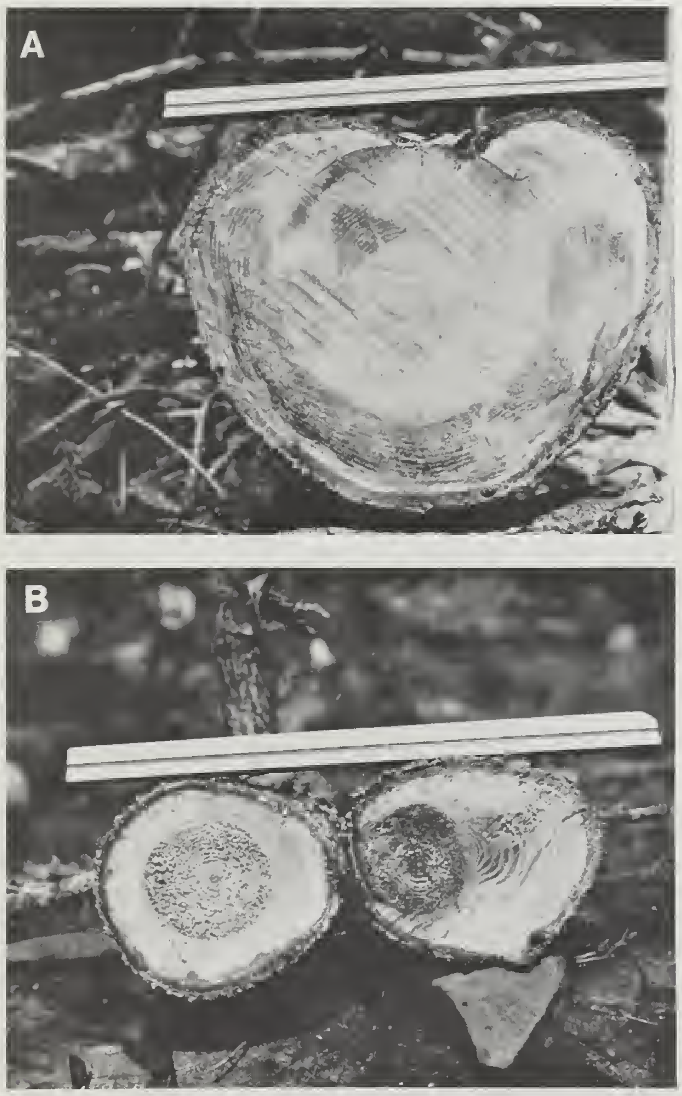

Figure 1.—A. *Armillariella mellea* incipient decay (bottom) associated with 14-year-old root wound, and decay (top) associated with 14-year-old ground-contact wound. B. *Amylostereum chailletii* incipient decay (left section) 3 feet below 15-year-old dead top (right section) with advanced decay. Scale is 12 inches.

Figure 2.—A. Decay behind 14-year-old basal wound (left section) and 3 feet above wound (right section). B. Decay behind 14-year-old upper-bole wound. Scale is 12 inches.

The average volume loss for wound depth was the same for gouge and bark wounds (0.2 cubic foot), probably because the radial penetration of decay was similar. However, the radial penetration of decay and the volume loss did vary with scar size. The average radial penetration of decay associated with size 1, 2, and 3 scars was 1.0, 1.5, and 2.4 inches. The larger the scar, the greater the decay penetration and subsequent volume loss.

Fungi associated with scars.—Fifteen fungi were identified from decay associated with the wounds (table 2). Although only 86% of the infections were identified, they accounted for 97% of the decay volume. Of these fungi, only four appear to be important in number of infections and decay volumes. *Amylostereum chailletii* and *Hematostereum sanguinolentum* were found infecting most types of wounds and caused similar amounts of decay—an average of 0.3 cubic foot per infection. Both can cause a white pocket rot throughout a tree, and each caused about one-fourth of the total decay volume.

Fomitopsis annosa (=*Fomes annosus*) and *Armillariella mellea* were associated with root, ground-contact, and basal wounds. Although the average amount of decay associated with these infections was small (less than 0.3 cubic foot), the fungi are considered root pathogens commonly causing tree mortality. Forty-five percent of the 53 trees had root rots. Eight trees had 13 root wounds and associated decay in the butt log, and 16 other trees had one or more dead roots or roots containing decay. Root rot was associated with either ground-contact or basal wounds in 11 of these trees; consequently, it was impossible to determine whether or not the rot entered through the wound and was extending downward in the root or whether the rot was spreading upward into the wound in the butt. Of the 53 trees sampled, *F. annosa* was found on 15%; *A. mellea* on 28%; and both were present on 9%.

Of the scars considered noninfected by decay fungi, most had dried out and become case-hardened. *Ceratocystis piceae* (Munch) Bakshi and various unidentified species of *Leptographium*, *Graphium*, *Phialophora*, and *Verticicladiella* were isolated from stain behind these scars, as well as from decay-infected scars.

Figure 3.—A. Decay associated with 14-year-old healed basal wound. B. Incipient decay behind 17-year-old callused upper-bole wound. Scale is 12 inches.

Decay not associated with visible or detectable wounds was found in 30% of the sample trees, and the amount of decay varied from a trace to 5.3 cubic feet in one tree with extensive heart rot. The decay averaged 0.5 cubic foot per infection. Fungi isolated from these infections included *A. chailleti*, *A. mellea*, *Coniophorella olivacea*, *H. sanguinolentum*, *Polyporus tomentosus* var. *circinatus* Satory et Marie, and *Phellinus nigrolimitatus*. Most of these infections were root and butt rots.

Discussion

Although only minor amounts of decay were found associated with the wounds on corkbark fir, it is important that 95% of the unhealed scars examined were infected. All basal wounds that extended to the ground line were infected, as were 93% of the unhealed wounds in the lower portion of a butt log. This incidence of infection is similar to scar infection found by Parker and Johnson (1960) on 451 fifteen-year-old scars on balsam (alpine fir) (*Abies lasiocarpa* (Hook.) Nutt.) in the Prince George region of British Columbia. There, they found all basal wounds that extended to the ground infected, 92% of the butt scars infected, and 89% of broken tops infected. They also found that each ground-contact, butt, and upper-bole scar resulted in an average loss of 1.5% of the tree volume 15 years after partial cutting. The average loss for similar scars 11 to 17 years after partial cutting in this study of corkbark fir was 1.7% for ground contact, 1.4% for basal, and 0.8% for upper bole scars, or an average of 1.3% for comparison purposes. This loss is not as great as that associated with 8- and 13-year-old thinning wounds on red and white firs, respectively, in northern California. There, Aho et al. (1983) found that all wounds were infected by decay fungi which resulted in a loss of 1.9% of the gross merchantable cubic foot volume in red fir and 4.5% in white fir.

Much of the decay associated with wounds was considered incipient; that is, the wood appeared to be firm but showed discoloration that did not extend more than 3 or 4 feet above or below the scar. Decay loss associated with most wounds was a rather small percentage of the total tree volume; however, if a tree has multiple wounds, and considering the increase in decay with time, the loss can add up to a much higher percentage of a tree than indicated by the percentage of decay associated with a single scar. For example, the total number of wounds per tree in this study, excluding dead or broken tops, and the total amount of associated decay were as follows:

Number of wounds	Number of trees	Percent decay
1	15	1.0
2	12	1.9
3	6	3.2
4	8	2.9
5–7	8	4.6

Table 2.—Fungi associated with 11- to 17-year-old wounds on corkbark fir

Fungi	Wounds								
	Root	Ground contact	Basal	Basal—healed	Upper bole	Upper bole—healed	Broken top	Dead top	Total infections
	number								*percent*
Amylostereum chailletii (Pers. ex Fr.) Boid.		3	8	2	3	8	2	4	24
Hematostereum sanguinolentum (Alb. et Schw. ex Fr.) Pouz.	1	3	9	1	1	1	6	1	18
Fomitopsis annosa (Fr.) Karst	1	6	5	1					10
Armillariella mellea (Vahl. ex Fr.)	8	2	1						9
Hirschioporus abietinus (Dicks. ex Fr.) Dorsk.			2		2			1	4
Coniophora arida (Fr.) Karst.		1	3	1					4
Coniophora puteana (Schum. ex Fr.) Karst		1	1						2
Coniophorella olivacea (Fr. ex Fr.) Karst.		1			2				2
Athelia bicolor (Pk.) Parm.		2	1						2
Flammula alnicola (Fr.) Kummer					2		1		2
Fomitopsis pinicola (Swartz ex Fr.) Karst.		1			1				2
Resinicium bicolor (Fr.) Kummer)	2								2
Peniophora septentrionalis Laurila			2						2
Pholiota squarrosa (Fr.) Kummer			2						2
Phellinus nigrolimitatus (Rohm.) Bourd. et Galz.		1							1
Unknown	1	2	7	0	5	0	3		14

A tree with any of the above number of wounds and a dead or broken top would likely sustain an additional 2 or 2.5% decay.

Although the volume loss associated with individual scars was small, and at first glance might be considered nearly insignificant, the volume loss associated with the particular part of a tree affected should not be overlooked. That is, the percentage of tree loss occurring with root, ground-contact, and basal scars should be approximately doubled for an estimate of loss in the butt log, as approximately one-half of the total tree volume is in the basal log in the residual trees. For instance, a 2% tree volume loss due to basal wounding would amount to approximately a 4% volume loss in the butt log. And, although a loss resulting from a broken or dead top was more than 2% of the total tree volume, the loss would be concentrated in the top log.

Many of the trees left after the first logging entry were too small for sawlog material, and one or more decades of growth will be required to attain sawlog size. Fungi already established in the wounds will increase defect or, perhaps, cause tree mortality. *Hematosterum sanguinolentum* is capable of rapid growth in other tree species. Davidson and Etheridge (1963) found that regardless of type of infection court in balsam fir (*Abies balsamea* (L.) (Mill.)) in natural stands in Quebec, decay developed at a fairly uniform linear rate of 0.3 to 0.4 foot per year. Injuries to the stem, including leaders, broken tops, and stem wounds, were almost twice as frequently infected as injured branches, and infection occurred only during the year following injury.

Inoculation studies by Whitney and Denyer (1970) showed that the average growth of *H. sanguinolentum* into balsam fir extended over an area of 65 square inches and a distance of 1.0 foot per year in infections that were 22 months old. Winter injuries were extremely susceptible to infection because of the competitive ability of the fungus to grow at low temperatures and the capacity of it to penetrate wood rapidly over a wide range of temperatures. Fruiting bodies of the fungus appeared on slash during July of the third year after felling. Spores were liberated during favorable conditions from April until the onset of freezing temperatures in October or November. Based on limited observations of corkbark fir in this study, the linear rate of spread of *H. sanguinolentum* decay behind 12 trunk scars amounted to 0.3 ± 0.1 foot per year and 0.4 ± 0.2 foot per year in six broken tops. The rate of spread of 13 *A. chailletii* and 12 *F. annosus* infections was more erratic, being 0.4 ± 0.4 and 0.3 ± 0.3 foot per year, respectively.

Amylostereum chailletii was isolated from 50% and *H. sanguinolentum* from 37% of the scars on balsam fir in Quebec (Parker and Johnson 1960). They were associated with 24% and 18%, respectively, of the scars in this study of corkbark fir. While both fungi have been associated with similar infection courts in grand fir (*Abies grandis* (Dougl.) Lindl.) in the Blue Mountains of Oregon and Washington (Aho 1977), their frequency of occurrence was of minor importance. In subalpine fir (*A. lasiocarpa* (Hook.) Nutt.) in Colorado, *H. sanguinolentum* was the most important decay fungus and accounted for two-thirds of the trunk rot infections (Hinds et al. 1960). Both fungi appear to behave similarly on corkbark fir; however, their relative importance remains to be determined.

Other decay fungi isolated in this study are also known root rotters. *Phellinus nigrolimitatus* commonly causes root rot of grand fir (Miller and Partridge 1973) as does *P. tomentosus* (Aho 1977), *Resinicium bicolor* (= *Odontia bicolor*) (Nobles 1953), and *Flammula alnicola* (Denyer 1960, LaChance 1975). Infection can originate in the roots below ground and spread into active root tissue causing a white butt rot. Their role in causing tree decline or mortality is unknown.

The only brown rot fungi isolated were the two species of *Coniophora*, *Coniophorella*, and *Fomitopsis pinicola*. They are common in many conifers and are usually associated with various types of wounds, even root wounds. The other white rot fungi, *Hirschioporus abietinus*, *Pholiota squarrosa*, and *Athelia bicolor*, are also common. Decay caused by *Peniophora septentrionales* closely resembles that caused by *H. sanguinolentum*, and field identification made on the appearance of decay alone could be erroneous (Nobles 1956).

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Keywords: *Abies lasiocarpa* var. *arizonica*, wounds, logging scars, decay fungi

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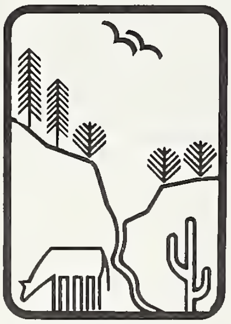

Southwest

Great Plains

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RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

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Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
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Rapid City, South Dakota
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*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526