DURABILITY OF A CHANGING WESTERN REDCEDAR RESOURCE[1]

Camille M. Freitag
Senior Research Associate

and

Jeffrey J. Morrell†
Associate Professor
Department of Forest Products
Oregon State University
Corvallis, OR 97331

(Received February 2000)

ABSTRACT

The heartwood of western redcedar (*Thuja plicata*) is known for its natural resistance to fungal attack, but some users of western redcedar utility poles have suggested that its durability may be diminished as suppliers begin to harvest trees from younger stands. The decay resistance of western redcedar samples from the Pacific Northwest and Idaho was tested by using *Postia placenta* in a soil block test. Weight losses varied widely among and between sites and were not correlated with position in the heartwood cross section, tree age, or silvicultural factors. With results similar to those from a 1957 study, we can infer that the durability of the currently used younger material has not changed from that of earlier, older stocks.

Keywords: Western redcedar, decay resistance, sapwood/heartwood interface, antimicrobial compounds, effect of tree age.

INTRODUCTION

The heartwood of western redcedar (*Thuja plicata* Donn) is valued for its resistance to fungal and insect attack (Scheffer 1957). Utility poles of this species have performed well under a range of climatic conditions (Lindgren 1989). As the ray parenchyma cells in the sapwood senesce and eventually die, the stored carbohydrates are converted into a series of potent antimicrobial compounds (Bamber 1976), notably thujone and thujaplicin. The relative amount of these compounds has been studied extensively (Anderson et al. 1962; Eades and Alexander 1934; Jin et al. 1988b; Nault 1988; Rennerfelt 1948; Roff et al. 1962; Southam and Ehrlich 1943a, b). These compounds are present at the highest levels at the sapwood/heartwood interface.

In addition, durability varies among trees and, to some extent, with tree source. Little attention has been given to the potential decrease in durability as the sources change from old-growth logs harvested from virgin forests to wood from more intensively managed second-growth forests. Trees from these forests often have faster growth rates. This could conceivably result in higher levels of carbohydrates in the ray parenchyma at cell death, and, therefore, possibly elevated protective extract levels. However, limited studies have shown that the durability of coast redwood (*Sequoia sempervirens* (D. Don) Endl.) is lower in second-growth lumber (Clark and Scheffer 1983), whereas the durability of second- and old-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) differs little (Scheffer and Englerth 1952). Such declines in durability have important implications for the use of these species without supplemental preservative protection.

[1] This is Paper 3225, Forest Research Lab., Oregon State University.
† Member of SWST.

Wood and Fiber Science, 33(1), 2001, pp. 69–75

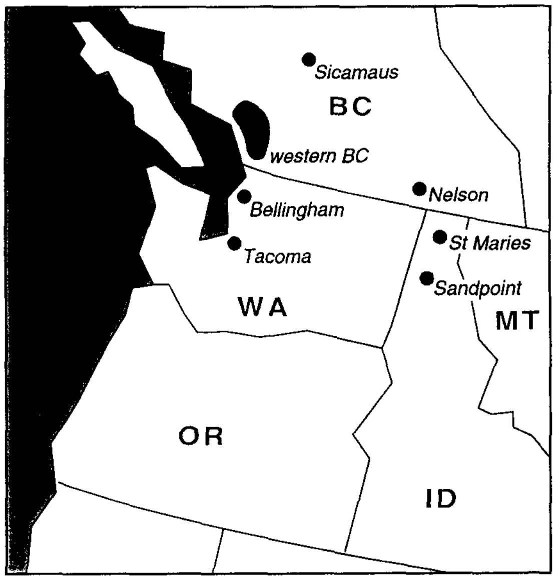


FIG. 1. Locations from which western redcedar pole cross sections were obtained for assessing natural durability.

Englerth and Scheffer (1954, 1955) found that average soil block weight losses for western redcedar samples cut from the inner, middle, and outer heartwood of the lower, central, and upper trunk ranged in the outer heartwood from 11% in the lower trunk to 27% in the central trunk. The weight losses at any given geographical site, however, varied much more widely. Scheffer (1957) evaluated the durability of blocks cut from 74 western redcedar trees from sites throughout the Pacific Northwest. Weight losses caused by *Postia placenta* again varied, although there were distinct trends in durability with tree source. Weight losses were greatest in samples from western Washington near Mt. Rainier and lowest in samples from the Olympic Peninsula. The number of trees from any given site in this study, however, was limited, making it difficult to draw definitive conclusions on the relationship between geographic source and durability.

As we move to a more intensively managed forest, silvicultural practices may strongly affect durability. Understanding the magnitude of these changes will help foresters develop the most appropriate management techniques and alert wood users to a possible change in wood quality. In this report, we describe a preliminary survey of durability of western redcedar from various locations in the Pacific Northwest.

MATERIALS AND METHODS

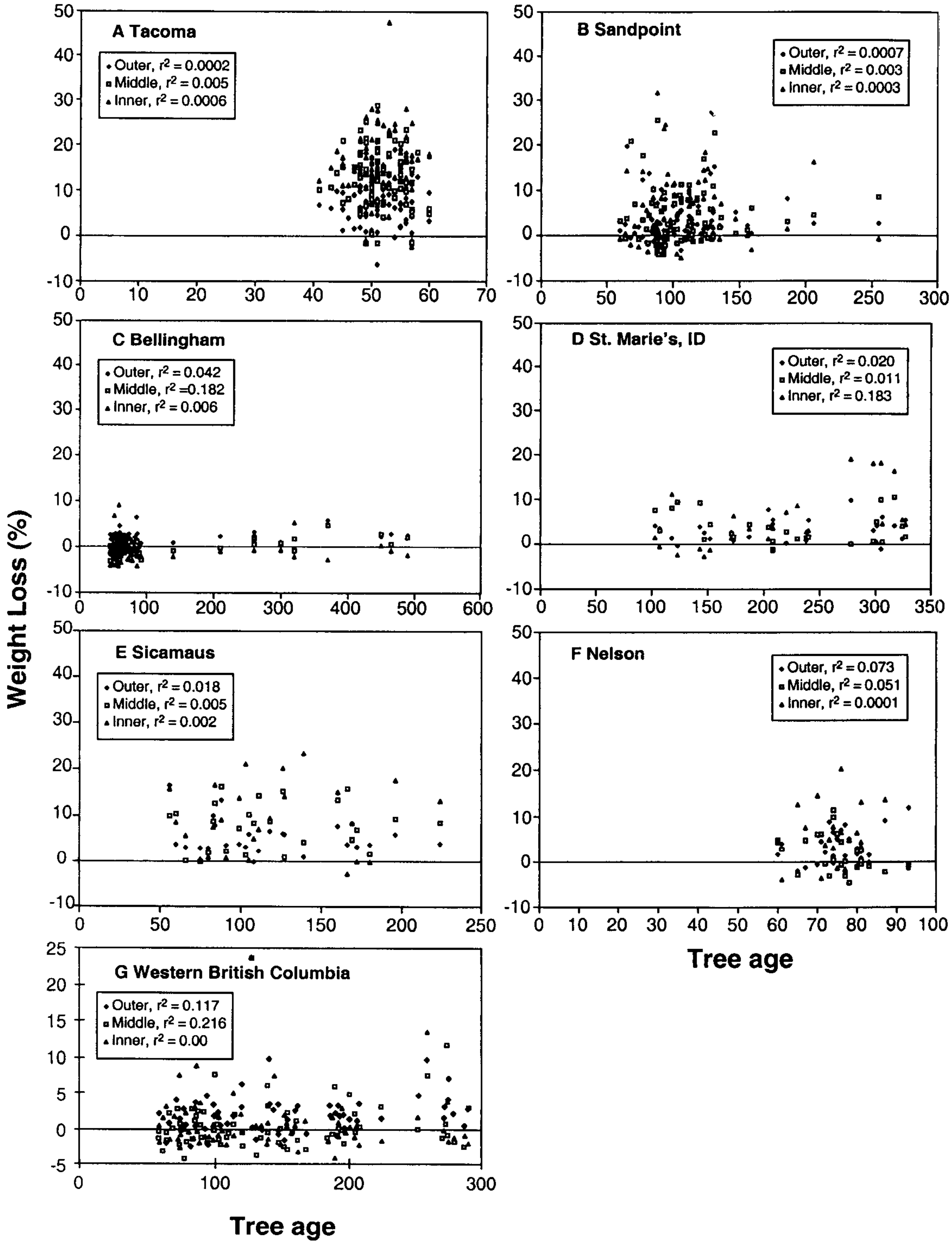
Disks (75 mm thick) were cut from the butt ends of western redcedar logs at seven locations (Fig. 1). In general, logs were obtained from a relatively narrow zone around each site. The exception was the western British Columbia (B.C.) site, where logs were obtained from a wide variety of areas. The logs were all destined for use as utility poles, the bark and some of the sapwood having been removed during the peeling process. In some cases, the location was known in detail (e.g., the individual timber sale), while in others, only the region was known. At least 75 disks were collected from each of four locations; 25 disks each were sampled from three other locations: Sicamaus, B.C., Nelson, B.C., and the Idaho Panhandle. A total of 376 trees were examined.

The number of rings on each disk was counted to estimate age, and the depth of remaining sapwood was noted. Eighteen cubes (1 cm^3) were then cut from each cross section along two radial lines. Cubes were cut from just inside the sapwood/heartwood interface, the middle of the heartwood, and the pith.

The cubes were oven-dried at 54°C,

→

FIG. 2. Relationship between wood source, tree age, and position with heartwood on weight losses of western redcedar heartwood cubes from a) Tacoma, Washington, b) Sandpoint, Idaho, c) Bellingham, Washington, d) St. Maries, Idaho, e) Sicamaus, British Columbia, f) Nelson, British Columbia, and g) western British Columbia. Outer = inside sapwood/heartwood interface; middle = young heartwood; inner = old heartwood to pith.


A Tacoma
• Outer, r² = 0.0002
▫ Middle, r² = 0.005
▴ Inner, r² = 0.0006
B Sandpoint
• Outer, r² = 0.0007
▫ Middle, r² = 0.003
▴ Inner, r² = 0.0003
C Bellingham
• Outer, r² = 0.042
▫ Middle, r² =0.182
▴ Inner, r² = 0.006
D St. Marie's, ID
• Outer, r² = 0.020
▫ Middle, r² = 0.011
▴ Inner, r² = 0.183
E Sicamaus
• Outer, r² = 0.018
▫ Middle, r² = 0.005
▴ Inner, r² = 0.002
F Nelson
• Outer, r² = 0.073
▫ Middle, r² = 0.051
▴ Inner, r² = 0.0001
G Western British Columbia
• Outer, r² = 0.117
▫ Middle, r² = 0.216
▴ Inner, r² = 0.00
Weight Loss (%)
Tree age
Tree age

weighed to the nearest 0.001 g, and then soaked in water and sealed in plastic bags. The bags were then sterilized with 2.5 Mrads of ionizing radiation from a ^{60}Co source. Afterward, the sterile cubes were exposed to *Postia placenta* in a modified soil block test. Briefly, 56-ml glass bottles were half-filled with forest loam soil. Enough moisture was added to increase the soil moisture content (MC) to 60% (wt/wt). A 15-by-15-by-3-mm-thick feeder strip of western hemlock (*Tsuga heterophylla* (Rafn.) Sarg) was placed on top of the soil. The bottles were then loosely capped and autoclaved for 45 min at 121°C. The bottles cooled overnight, then were reautoclaved for 15 min at 121°C. After cooling, a small agar plug cut from the actively growing edge of a *P. placenta* culture was placed on the surface of the feeder strip. The bottles were incubated at 28°C until the fungus had thoroughly covered the feeder strip; then a single western redcedar cube was placed, cross section down, on the strip. The bottles were incubated for 12 weeks at 28°C.

At the end of the incubation period, the cubes were scraped clean of adhering mycelium and weighed to determine wood MC. The cubes were again oven-dried at 54°C until their weights stabilized. The difference between the initial and final oven-dried weight was used to determine fungal-associated weight loss.

The data were analyzed on the basis of tree source, age of the tree, and position in the cross section. Data were also compared to the report by Scheffer (1957) on durability of western redcedar, in which trees were obtained from a wide geographic area, to determine if durability had changed since the earlier survey.

RESULTS AND DISCUSSION

Effect of cross-section position

The most recently formed heartwood of many species is believed to be more durable than heartwood in other parts of the stem. As the heartwood ages, reactions between extractives and microbial inactivation are presumed to decrease the toxicity of these chemicals (Jin et al. 1988a). In addition, there is some evidence that heartwood in the juvenile wood core is less resistant to decay than mature wood (DeBell et al. 1999). Weight losses in samples cut from outer, middle, and inner heartwood in our study differed little from one another (Table 1). Weight losses were only slightly higher in inner heartwood samples from 5 of 7 locations. Overall durability probably does not change significantly with heartwood zone, although variability of decay resistance increases distinctly, as shown by the elevated standard deviations associated with means of inner heartwood weight losses.

Effect of tree age

Changes in management that include fertilization and thinning of forests containing western redcedar might be expected to accelerate growth. It has long been presumed that heartwood of older, thus slower-growing, trees is more durable. Therefore, managed western redcedar forests could produce trees containing less durable heartwood. This must be viewed cautiously. In this study, durability was little affected by tree age, except at Tacoma (Table 1). Younger trees (less than 100 years old) from that location experienced higher weight losses, but there were no older trees available at this site for comparison.

In many regions, western redcedar has not been intensively managed with practices such as thinning, pruning, or fertilization. Such practices may influence the heartwood extractive content; this possibility merits further study. Our study results indicate that tree age does not affect durability in currently harvested forests. The results, in fact, differ little from those reported 40 years earlier (Englerth and Scheffer 1954, 1955; Scheffer 1957).

In part, the similarity of the results reflects the ages of the trees examined in both studies. Forty years of growth is likely to have little effect in a sample where trees exceed 150 years old. Additional studies would be warranted as western redcedar forests move to

TABLE 1. *Weight loss of cubes cut from zones of the heartwood of western redcedar trees from 7 sites in the Pacific Northwest and Idaho. Values represent means and (standard deviation); n = number of trees examined.*

Location	No. of trees	Average weight loss by zone			Average weight loss (%) of all samples	Average weight loss by tree age					
		Outer	Middle	Inner		0–50	51–100	101–150	151–200	201–250	250+
British Columbia											
Nelson	25	3.4 (6.1)	1.7 (6.3)	4.8 (8.8)	3.3 (7.3)	—	3.3 (7.3) (n = 25)	—	—	—	—
Sicamaus	25	5.5 (5.5)	7.8 (7.3)	9.3 (10.1)	7.5 (8.0)	—	7.3 (7.8) (n = 10)	8.2 (8.9) (n = 8)	6.9 (6.7) (n = 6)	8.7 (9.4) (n = 1)	—
Western	75	2.0 (2.6)	1.2 (4.4)	−1.0 (3.2)	0.7 (3.6)	—	0.5 (2.9) (n = 30)	0.6 (3.6) (n = 17)	0.4 (2.7) (n = 15)	0.8 (2.0) (n = 4)	2.5 (6.1) (n = 9)
Idaho											
Sandpoint	76	3.18 (5.5)	3.7 (8.6)	5.2 (9.9)	4.0 (8.2)	—	3.5 (8.6) (n = 38)	4.7 (7.9) (n = 33)	2.2 (4.5) (n = 3)	5.6 (8.9) (n = 2)	—
St. Maries	25	3.2 (4.0)	3.8 (5.9)	5.1 (8.5)	4.1 (6.4)	—	—	3.3 (6.9) (n = 6)	2.5 (3.8) (n = 4)	2.9 (4.3) (n = 7)	6.4 (8.0) (n = 8)
Washington											
Bellingham	75	1.5 (1.8)	−0.4 (1.8)	−1.1 (2.5)	0.0 (2.3)	−0.3 (2.2) (n = 3)	0.1 (2.2) (n = 61)	0.2 (2.2) (n = 1)	—	0.6 (2.0) (n = 1)	1.2 (2.6) (n = 9)
Tacoma	75	8.0 (6.1)	12.7 (7.5)	16.2 (8.1)	12.3 (8.0)	11.6 (7.6) (n = 30)	12.8 (8.3) (n = 45)	—	—	—	—

shorter rotations and more intensive silvicultural practices.

Effect of geographic sources

Western redcedar has a tremendous range, from the coastal forests of Oregon, Washington, and British Columbia, to the Cascade Mountains, and all the way to the Inland Empire. As a result, environmental conditions under which individual trees grow can vary tremendously. Scheffer (1957) has shown some variations in durability with geographic source, but the natural variation in decay resistance between trees within the same stand is often of a similar magnitude, masking any site differences.

Average weight losses at the 7 locations ranged from 0 to 12.3%. Heartwood from sites in northwestern Washington and British Columbia was the most durable. Samples taken near Tacoma, Washington, experienced the greatest weight losses, but even this level of decay would still place the wood in the highly durable classification (Scheffer 1981; Scheffer and Cowling 1966). As expected, weight losses varied widely within a location (Fig. 2). Most losses were less than 10%, but weight losses nearing 50% were occasionally found.

Changes in durability

This study was initiated because of concerns that the western redcedar resource was changing. While changes may be under way, our results indicate that the durability of the current supply differs little from that investigated 40 years ago (Fig. 2). An emphasis on longer product serviceability by cedar users will likely magnify the importance of limiting the risk of early failures, because reporting will become more frequent. One method for limiting this risk would be the use of full-length treatments to ensure complete protection of the wood. Small-scale studies suggest that such supplemental treatments increase the uniformity of performance of naturally durable woods such as western redcedar and redwood (Newbill and Morrell 1993).

CONCLUSION

While natural resistance of western redcedar heartwood to fungal attack in laboratory tests differed widely, the variation was not correlated with location, age, or heartwood position. Heartwood durability appears similar to that found in a study 40 years ago. Further monitoring is advised as management practices change for this species.

ACKNOWLEDGMENTS

The authors gratefully acknowledge McFarland-Cascade Inc., B.J. Carney Co., and Bell Pole for supply materials.

REFERENCES

ANDERSON, A. B., T. C. SCHEFFER, AND C. DUNCAN. 1962. On the decay retardant properties of some tropolones. Science 137(3533):859–860.

BAMBER, R. K. 1976. Heartwood, its function and formation. Wood Sci. Technol. 10:1–8.

CLARK, J. W., AND T. C. SCHEFFER. 1983. Natural decay resistance of the heartwood of coast redwood *Sequoia sempervirens* (D. Don) Endl. Forest Prod. J. 33(5):15–20.

DEBELL, J. D., J. J. MORRELL, AND B. L. GARTNER. 1999. Within-stem variation in tropolone content and decay resistance of second-growth western redcedar. Forest Sci. 45:101–107.

EADES, H. W., AND J. B. ALEXANDER. 1934. Western redcedar: Significance of its heartwood colorations. Forest Serv. Circ. 41. Dept. of the Interior, Ottawa, Canada. 17 pp.

ENGLERTH, G. H., AND T. C. SCHEFFER. 1954. Tests of decay resistance of four western pole species. Rep. 2006. USDA Forest Serv. Prod. Lab., Madison, WI. 11 pp.

———, AND ———. 1955. Tests of decay resistance of four western pole species. J. Forestry 53:556–561.

JIN, L., B. J. VAN DER KAMP, J. WILSON, AND E. J. SWAN. 1988a. Biodegradation of thujaplicins in living western redcedar. Can. J. For. Res. 18(6):782–786.

———, J. W. WILSON, AND E. P. SWAN. 1988b. Thujin, a novel lactone from the discolored heartwood of *Thuja plicata* Donn. Can. J. Chem. 66:51–53.

LINDGREN, P. A. 1989. Bonneville Power Administration's Wood Pole Management Program. Pages I1–I14 *in* Proc. International Pole and Piling Conf., Fort Collins, CO.

NAULT, J. 1988. Radial distribution of thujaplicans in old growth and second growth western redcedar (*Thuja plicata* D. Don). Wood Sci. Technol. 22(1):73–80.

NEWBILL, M. A., AND J. J. MORRELL. 1993. Ability of overthe-counter preservatives to protect western wood species from fungal attack. Forest Prod. J. 43(10):35–40.

RENNERFELT, E. 1948. Thujaplicin, a fungicidal substance in the heartwood of *Thuja plicata.* Physiol. Plant. 1: 245–254.

ROFF, J. W., E. I. WHITAKER, AND H. W. EADES. 1962. Decay resistance of western redcedar: Relative to kiln seasoning, color, and origin of the wood. Tech. Note 32. Forest Prod. Res. Branch, Canadian Dept. of Forestry, Vancouver, B.C. 19 pp.

SCHEFFER, T. C. 1957. Decay resistance of western redcedar. J. Forestry 55:434–442.

———. 1981. Decay resistance of Alaska cedar. Forest Prod. J. 33(1):25–26.

———, AND E. B. COWLING. 1966. Natural resistance of wood to microbial deterioration. Ann. Rev. Phytopath. 4:146–170.

———, AND G. H. ENGLERTH. 1952. Decay resistance of second-growth Douglas-fir. J. Forestry 50:439–442.

SOUTHAM, C. M., AND J. EHRLICH. 1943a. Decay resistance and physical characteristics of wood. J. Forestry 41: 666–673.

———, AND ———. 1943b. Effects of extract of western redcedar heartwood on certain wood-decaying fungi in culture. Phytopath. 33:517–524.