Compartmentalization of Discolored Wood in Heartwood of Red Oak

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ABSTRACT

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Discolored wood associated with holes drilled into heartwood of living red oak (*Quercus rubra*) trees was strongly compartmentalized after 2 yr; discolored wood associated with similar holes in trees that were girdled immediately after wounding was weakly compartmentalized. The results indicate that heartwood in red oak is not a dead, nonresponsive tissue; the classic concept that heartwood-rotting fungi grow unrestricted through heartwood is not true. The concept of heartrot must be revised to include compartmentalization.

Additional key words: host-parasite interactions, wood decay.

The classic concept of heartrot in living trees is that heartrot is a progressive decay by hymenomycetous fungi that infect fresh wounds (1,2,7) of the dead nonresponsive heartwood in trees. Trees of *Acer* spp. and *Betula* spp. have no central core of dead heartwood. How, then, can they have heartrot?

The expanded concept of tree decay is that trees are compartmentalized plants that wall off injured and infected wood associated with wounds (compartmentalization) and that many microorganisms are involved in the processes (succession) that result in discolored and decayed wood (3–5).

This paper further supports the expanded concept of tree decay by showing that heartwood in red oak (*Quercus rubra* L.) compartmentalizes injured and infected tissues.

MATERIALS AND METHODS

Forty red oaks in a 6-ha forested area at Alfred, ME, were selected for freedom from mechanical wounds or large exposed branch stubs. The trees were about 60 yr old, 15–25 cm in diameter at 1.4 m above ground, and 11.5 m tall. Each tree was wounded twice in 1975. Eight drill-bit wounds, 1.4 cm in diameter and 1.5 cm deep, were made during the first period and eight more during the second period (16 wounds total). Wounding periods were: trees numbered 1–10, January and August; 11–20, March and August; 21–30, March and June; and 31–40, May and June. In the first set of wounds for each tree, two holes were drilled opposite each other on the trunk at approximately 0.5, 1, 1.5, and 2 m above ground. Each of the holes in the second set were drilled at 90° from the first set.

Twenty trees, five from each wounding-period group, were girdled with an ax immediately after the first wounding. Ax cuts were made approximately 3 cm into the heartwood completely around the trunk at 0.5 m above ground; the bark below the cut was stripped to the groundline. All trees were harvested in 1977.

The transverse surface of freshly cut 5-cm thick disks exposed both sound and discolored sapwood and heartwood that were measured for electrical resistance to a pulsed current. Measurements were made with a Model 7950 Shigometer® pulsed-current meter and a #2E Delmhorst moisture-detector electrode with #552/A-100 retainer and 4.3-cm contact pins.

Tangential sections (1 × 4 × 5 cm) of sound and discolored sapwood and heartwood (Fig. 1) were split from the disks, air-dried 3 days at 42 C, ground to pass an 850-μm sieve, and oven-dried 24 hr at 104 C. Duplicate 0.5-g samples were taken for mineral analysis. Tissues were wetted and digested by nitric-perchloric acid. Amounts of potassium, calcium, and magnesium were determined with an atomic absorption spectrophotometer.

RESULTS

In nongirdled living trees, the configuration of the drill bit was the configuration of the discolored wood as viewed on the transverse surface 5 cm above the wounds, regardless of when the trees were wounded (Fig. 1). The column of discolored wood above and below each wound was longest along the heartwood-sapwood boundary. The discolored wood associated with the drill-bit

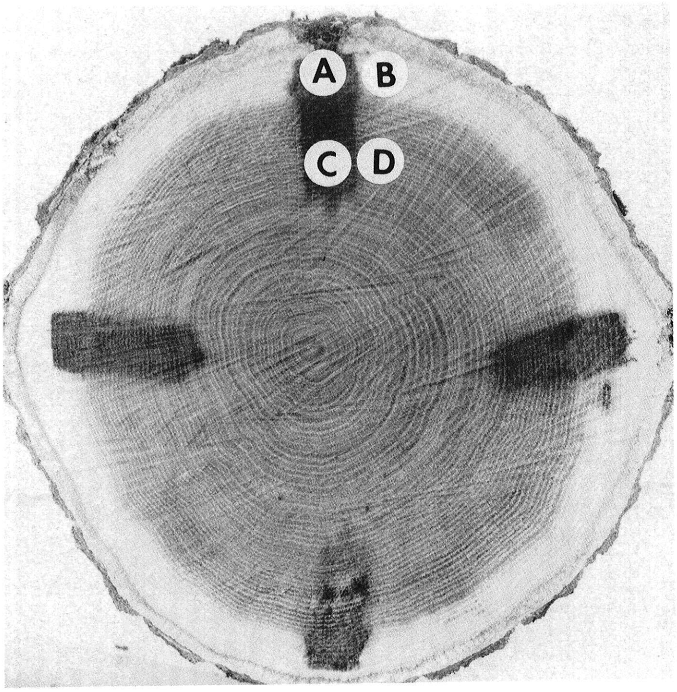

Fig. 1. Compartmentalization of discolored wood associated with drill-bit wounds in red oak after 2 yr. Cross section is 5 cm above the drill wounds. Electrical resistance was measured and wood samples for elemental analysis were taken at positions shown: **A**, discolored sapwood; **B**, sapwood; **C**, discolored heartwood; **D**, heartwood.

wounds did not extend into the center of the tree.

Dead girdled trees showed a diffuse pattern of discolored wood associated with the drill wounds, regardless of when the trees were wounded. There was a mottled pattern of discolored wood throughout the heartwood (Fig. 2).

The electrical measurements revealed that resistance was higher in sapwood than in discolored sapwood, lower in sapwood than in heartwood, and lower in discolored heartwood than in heartwood (Table 1).

TABLE 1. Electrical resistance and concentration of potassium, calcium, and magnesium in normal and discolored sapwood and heartwood of wounded red oak trees

	Tissues analyzed			
	Normal tissue		Discolored tissue	
	Sapwood	Heartwood	Sapwood	Heartwood
Electrical resistance (kΩ)[a]	53	103*	21*	31*
Potassium (μg/g)[b]	980	490[c]	3,500*	2,240*
Calcium (μg/g)	250	170	450*	300
Magnesium (μg/g)	120	10*	170	70

[a] Means of 44 observations from three trees; * indicates means significantly different from normal sapwood at $P < 0.05$; LSD = 6.7 kΩ.

[b] Mean of five observations from five trees; * indicates means significantly different from normal sapwood at $P < 0.05$; LSD: potassium = 1,164 μg/g; calcium = 158 μg/g; and magnesium = 76 μg/g.

[c] Mean of normal heartwood significantly different from mean of normal sapwood when analyzed separately by paired t-test ($P < 0.01$) +: tabular = 4.6; observed = 6.2.

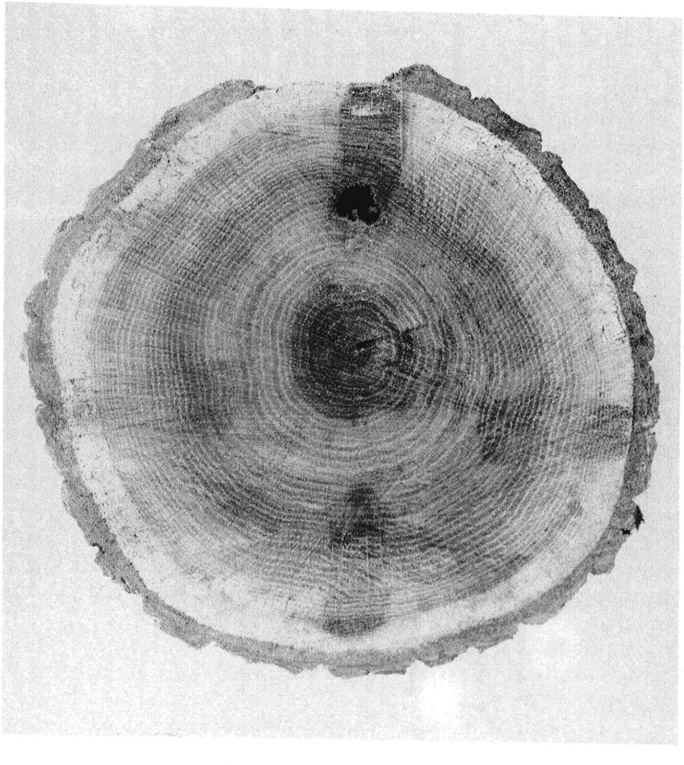

Fig. 2. Incomplete compartmentalization of discolored heartwood associated with four drill-bit wounds after 2 yr in red oak that was girdled immediately after wounding. The trees were dead at harvest. Cross section is 5 cm above the drill wounds.

The analysis of elements revealed higher potassium concentration in discolored sapwood and discolored heartwood than in sapwood and heartwood, highest calcium concentration in discolored sapwood, and lowest magnesium concentration in heartwood (Table 1).

DISCUSSION

Discolored wood associated with the drill-bit wounds was strongly compartmentalized by heartwood in the nongirdled oak trees. Discolored wood was only weakly compartmentalized by the heartwood in the girdled trees that were dead at harvest. The weak compartmentalization may have been due to the slow dying of the trees after girdling. The girdled trees probably reacted in the same manner as the nongirdled trees for a short period after girdling.

Heartwood had higher electrical resistances than sapwood. This difference may provide an accurate way to differentiate sapwood from heartwood. Discolored wood of either sapwood or heartwood origin had a lower electrical resistance than sapwood. The electrical resistance method may also be an accurate way to differentiate heartwood from discolored wood.

Discolored sapwood and heartwood had lower electrical resistance than sapwood and heartwood indicating that cations concentrate in discolored tissues whether the discolored wood is in the sapwood or heartwood. There is some type of microelement translocation into heartwood after injury. The translocation could be passive or it could be the result of invasion by pioneer microorganisms. Microorganisms can concentrate microelements in their cells (6).

The amounts of potassium, calcium, and magnesium were higher in both discolored sapwood and heartwood than in either sapwood or heartwood. These results suggest that some similar chemical processes are involved in the discoloration of sapwood and heartwood.

The strong compartmentalization in nongirdled trees and weak compartmentalization in girdled trees that were dead at harvest indicate that the compartmentalization process is associated with the living cells in a tree. It is not as important to argue whether the heartwood was living or dead in the nongirdled trees as it is to point out that the heartwood strongly compartmentalized injured and infected tissues associated with the wounds.

These results indicate that the classic concept of heartrot in living trees must be revised to include compartmentalization of injured and infected wood in heartwood. Fungi that infect heartwood do not grow indiscriminately through the heartwood as stated in the classic concept.

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