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Electrical Resistance in Tree Cambium Zone: Relationship to Rates of Growth and Wound Closure

W. S. SHORTLE
A. L. SHIGO
P. BERRY
J. ABUSAMRA

ABSTRACT. Resistance to a pulsed electric current in the cambial zone of sprout red maple and hybrid poplar was inversely proportional to rate of growth. In hybrid poplars, resistance was also inversely proportional to rate of wound closure, but not to amount of wood discoloration. FOREST SCI. 23:326–329.

ADDITIONAL KEY WORDS. Bioelectronics, wound healing, wood discoloration, vigor.

VARIATIONS IN RESISTANCE to a pulsed electric current have been used to detect discolored and decayed wood in living trees (Skutt and others 1972, Tattar and others 1972) and to measure the vigor of trees that had been subjected to defoliation by insects. The cambial zone of vigorous, nondefoliated oak trees had a lower electrical resistance than did that of trees (defoliated or nondefoliated) considered less vigorous, i.e., with poor ratings for crown class and condition (Wargo and Skutt 1975).

This study sought to determine whether any relationship exists between electrical resistance in the cambial zone of trees and tree vigor, as measured by growth rate within a clone, or rate of wound healing, as measured by closure of external wounds and extent of internal discoloration of wood.

MATERIALS AND METHODS

Vigor.—In clones of approximately uniform age growing under uniform conditions, trees with the largest and smallest stem diameters were considered to have the greatest and least vigor, respectively. The two types of clones in this study were sprouts of red maple (*Acer rubrum* L.) that originated from the same parent stump at approximately the same time, and 25-year-old plantings of hybrid poplars (*Populus deltoides* × *P. trichocarpa*, *P. balsamifera* × *P.* cv. *Berolinensis*, *P. nigra* × *P. laurifolia*, and *P. maximowiczii* × *P. trichocarpa*). Maples measured 4 to 29 cm in diameter 1.4 m above the ground (dbh) and occurred in 30 clumps, 3 to 8 stems/clump, on Foss Farm, University of New Hampshire, Durham, and on the Massabesic Experimental Forest, Alfred, Maine. The stems of six sprout clumps were felled after all measurements had been made, and the annual rings were

The authors are Research Plant Pathologist, Chief Plant Pathologist, and Biological Technicians, respectively, U.S. Forest Service, Durham, New Hampshire 03824. Portions of this study were supported by a grant from the Northeast Electronics Company, Airport Road, Concord, New Hampshire. The authors thank Mr. Harold Wochholz for making this grant possible. Manuscript received December 3, 1976.

TABLE 1. Mean electrical resistance of cambium (and mean dbh) of largest and smallest stems in 30 red maple clones.

Diameters of pairs[a]	Pairs	Size rank in clone	
		Largest	Smallest
	Number	$K\Omega$ (*cm*)	
Equal	7	12(11)	18*(11)
Unequal	23	11(21)	17**(9)

[a] Stems in unequal pairs are those that are largest or smallest in their clone, but not matched by a stem of equal diameter in another clone. Equal pairs are stems of equal diameter that are the largest in one clone and the smallest in another.

* Significant at 0.05 level.

** Significant at 0.01 level.

counted to confirm that all stems were of similar age. Poplars measured 11 to 29 cm dbh and occurred in 13 clones, 3 to 12 stems/clone, on the Massabesic Forest.

Electrical resistance (ER) of tissues in the cambial zone of these maples and poplars was determined during June and July by use of a meter that delivers a pulsed current and measures resistance to it (Shigometer Model 7950, Northeast Electronics, Concord, New Hampshire).[1] Needle probes of the type used for making moisture readings in wood (Delmhorst Instrument Company, Boonton, New Jersey)[1] were pushed through the bark into the wood in a vertical orientation. Probes of this type operate primarily at the point of least ER, which was determined to be the wood-bark interface (the cambial zone). Once the needles passed through this zone, deeper insertion into wood had little effect on ER. For each tree, ER was determined at four points around the stem, 1.4 m above the ground, and an average ER was calculated.

Healing.—Wound healing was measured only in the hybrid poplars. These trees were wounded by drilling holes, 1.43 cm diameter × 5 cm deep, into the stem. In March, two wounds were made on opposite tree faces 0.5, 1.5, and 2.0 m above the ground. In May, two more wounds were added 3.0 m above the ground and, in June, six more were made at right angles to the earlier wounds. Each tree received a total of 14 wounds.

In July, the percentage closure for each wound was calculated (difference between initial area of wound opening and area of opening at the time of measurement/initial area × 100), and the average percentage closure for all wounds on each tree was determined; 100 percent closure meant that all wounds had closed completely; 0 percent closure meant that all wounds were still completely open. In October, three trees in each clone were felled, and the segment of stem extending from 20 cm below the lowest wound to 20 cm above the highest wound was cut into 5-cm thick discs. The total volume of each disc and the volume of discolored wood in it were determined. The percentage of volume of discolored wood in each disc was calculated (volume of discolored wood/total volume × 100) and an average was found for all discs from one tree.

Relationships between ER and percentage of wound closure, or percentage of internal discoloration in trees of high or low vigor were determined by analyses of variance.

[1] Use of trade, firm, or corporation names in this paper does not constitute endorsement by the Forest Service or the U.S. Department of Agriculture.

TABLE 2. Electrical resistance, wound closure, and wood discoloration in largest and smallest trees in 13 clones of hybrid poplar.

Item	Size rank in clone	
	Largest	Smallest
Mean electrical resistance (KΩ)	5	7**
Wound closure (percent)[a]	28	14**
Wood discoloration (percent)[b]	56	57

[a] Percent closure $= \frac{\text{initial area of wound opening} - \text{final area of wound opening}}{\text{initial area}} \times 100.$

[b] Percent discoloration $= \frac{\text{volume of discolored wood}}{\text{total volume of wood}} \times 100.$

** Significant at 0.01 level.

Results

Vigor.—Electrical resistance (ER) of the cambial zone was significantly less in trees of high vigor than in trees of low vigor (Tables 1 and 2). Red maple stems of the same diameter, but differing in vigor, had significantly different ER (Table 1). For example, a 12-cm diameter stem that was the largest in its clone had an ER of 12 KΩ, whereas a 12-cm diameter stem that was the smallest in its clone had an ER of 15 KΩ. For all stems of unequal diameter, the ER for trees of high and low vigor were 11 and 17 KΩ, respectively. For all stems of equal diameter, the ER for trees of high and low vigor were 12 and 18 KΩ, respectively (Table 1). Only two pairs of high- and low-vigor stems of equal diameter were found among the hybrid poplars, so no meaningful comparison could be made.

Healing.—Wounds closed more quickly in hybrid poplar trees of high vigor (and low ER) than in trees of low vigor (and high ER) (Table 2). The rates of internal wound healing did not differ; trees of both high and low vigor developed equivalent amounts of discolored wood (Table 2).

Discussion

Vigorous trees have a lower electrical resistance in the cambial zone than do less vigorous trees. The reason for this may be a greater concentration of mobile cations in the cambial zone of faster growing trees. ER depends strongly upon the concentration of mobile cations, especially potassium, and is inversely proportional to ion concentration (Tattar and others 1974). Potassium accumulates in young, actively growing regions of plants (Meyer and others 1960).

Hybrid poplar trees with lower ER grew faster and closed their wounds more rapidly than did trees with higher ER. This is consistent with observations that wound closure is directly related to growth rate (Neely 1970). However, wound closure is only part of the healing process in trees. The internal healing process by which infected tissues are walled off or compartmentalized (Shigo 1975) appeared to be independent of vigor as measured by ER, but under possible genetic control (Shigo and others 1977). Thus, a vigorous, fast-growing tree may develop more internal defect than a low vigor, slow-growing tree, if the former has low resistance to infection following wounding.

The use of pulsed electric current to determine relative tree vigor, as evinced by the rates of growth and callus formation, appeared feasible if the method was rigorously standardized and applied to populations of trees. The method is simple and rapid, but readings of ER are affected by weather conditions, orientation of the probe, time of year, and other factors. Tree diameter *per se* did not seem to cause differences in ER. Readings should be taken only on warm days during the growing season, when the temperature is reasonably constant, and only ER measurements made on any one day should be compared.

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