CAMBIAL ELECTRICAL RESISTANCE DOES NOT ASSESS VITALITY OF INDIVIDUAL SWEET GUM TREES

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Abstract. Cambial electrical resistance (CER) was assessed over a year-long period, using the Shigometer, for 109 sweetgum trees (*Liquidambar styraciflua*) planted along streets in Seattle, Washington. CER decreased through the spring, reached a minimum in summer, increased through the fall and was maximal in mid-winter. The seasonal maximum was 200-600% greater than the summer minimum. CER measurements could not be related to growth parameters such as seasonal shoot increment and diameter growth.

Management of urban forests often focuses on the performance of individual trees. This contrasts with traditional forest management, where the aggregate development of trees within a stand is more commonly the concern. Urban trees frequently endure environmental stresses that impair development and shorten life-span. An individual tree can represent either a substantial asset or potential liability. Thus, urban tree managers need a rapid, easy-to-use method to assess tree vigor and predict the pattern of future development. Arborists have relied upon visual examination to assess crown density, shoot elongation and other measures of vegetative growth as indicators of vigor.

Cambial electrical resistance (CER) has been used in forestry to monitor tree vigor. Since CER measures the resistance to electrical flow between two electrodes, it is a function of the number of cells and solute content in a radial file of cambium. The most vigorous trees would be those with thick cambial zones and high cation concentrations. Such trees would have low CER readings. CER has been used to assess the vigor of trees defoliated by gypsy moth (13) and damaged by spruce budworm (2,4). It has also been used to monitor release of *Betula paperifera* following thinning (12), to define the susceptibility of birch to borer attack (1), to differentiate among trenched and watered/untrenched treatment on *Pinus ponderosa* (7) and to assess decline patterns in *Acer saccharum* (8).

If CER integrates the status of an array of physiological processes important to tree health, then measurement of CER might be used to assess the vigor of individual trees. This paper considers the utility of CER measurement as a means of assessing tree vigor in urban settings.

Methods and Materials

Cambial electrical resistance was measured using the Shigometer (Model 7950) and the needle probe attachment (11). The stainless steel probes were 4.2 cm long and 1.8 cm apart. The technique followed the recommendations of Shigo and Shortle (11). The probes were inserted into the stem of the tree, at a point 1 m above ground level, to a depth of 2.5 cm. CER was measured to the nearest 0.5 Kohm at the four cardinal points around the stem on a biweekly (April 11-August 29) or monthly (September 19- March 17) basis. Readings were not corrected for temperature (4).

Cambial electrical resistance was measured on 109 sample trees, distributed among six sites in Seattle, Washington.

1. Wall-Battery: located at the intersection of Wall, Battery and Denny streets.;
2. Fourth Ave.: between Jefferson and Pine Street;
3. Rainier Tower: located on 4th Avenue, between Union and University streets;
4. Seneca Street: between 3rd and 6th avenues;
5. Freeway Park: located on the south Seneca

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Street side of the park;

6. East John: between 19th and 21st avenues.

The sites had widely varying above-ground environmental conditions (Table 1). Sites were characterized as park, plaza and canyon after Federer (3). Radiation intensity ranged from full sun to heavy shade. Soil textures were primarily sandy, with limited fertility. Only two sites, Freeway Park and East John, received supplemental irrigation.

Sweetgums (*Liquidambar styraciflua*) of standard height and root-ball size were planted by the city as street trees between 1967 and 1977 in the planting strip between the curb and sidewalk. Subsequent growth and development of sweetgum varied widely among, but not within, sites (Table 2). Calculated growth rates since planting ranged from 0.2-0.4 m/yr for height and 0.4-1.3 cm/yr for diameter.

A complete diameter core was taken from each tree at the Wall-Battery, Rainier Tower and East John locations (5). Cores were extracted 30 cm above the base of the tree. Ring increments were measured using the TRIMS system (Tree Ring Increment Measurement System, Department of Forestry, Northern Arizona University). Ring increments were doubled and expressed as diameter increments.

Results and Discussion

Seasonal and Positional Variation of CER. Over the course of a year, CER values changed by a factor of 244% at Seneca St, and 576% at East John (compare low and high values in Table 3, pattern for 3 sites in Figure 1). Absolute low CER ranged from 2.1 to 5.6 Kohm and occurred in mid-summer, on August 1, at all sites (Table 3). Absolute high values ranged from 11.0-16.6 Kohm, occurring primarily during the dormant season; in December at Wall-Battery, Freeway Park and East John and in February at Fourth Avenue and Rainier Tower. An exception to this pattern of high CER in the dormant period occurred along Seneca St. where the highest yearly value, 11.0 Kohms, was obtained on April 25.

The location of measurements also influenced the CER values at three of the sites, especially during the growing season (Table 4). In general, mid-summer CER readings were lower on areas of the trunk that consistently received direct sunlight. At East John, CER measured at the four cardinal points around the stem, ranged from 1.3-2.8 Kohm in August and 11.3-13.3 Kohm in December. At Freeway Park, CER values ranged from 4.3-4.7 Kohm in August and 11.2-12.0 Kohm in January.

Relationship of CER to Vegetative Growth. There was neither a consistent nor demonstrable relationship between CER (high or low) and annual diameter increment (Figure 2 and Table 5). CER did not reflect historical patterns of diameter development at the Wall-Battery, Rainier Tower and East John sites. Trees at Wall-Battery exhibited the least growth and highest CER values, while those at East John had the lowest CER and the greatest increment. This pattern was confounded

Table 1. Exposure, radiation intensity, soil texture and availability of supplemental irrigation for six sites in Seattle.

Site	Exposure[1]	Radiation intensity	Soil texture	Irrigation
Wall-Battery	plaza	high	gravelly, sandy loam	no
Fourth Avenue	canyon	low to mod.	coarse to fine sand	no
Ranier Tower	canyon	low	loamy sand	no
Seneca Street	canyon	very low	sandy loam	no
Freeway Park	park	high	fine sand	yes
East John	park	high	sandy loam	yes

After Federer (3)

Table 2. Growth and developmemt of sweetgum at six sites in Seattle.

Site	Number of trees	Year planted	Height (m)	Diameter (cm)
Wall-Battery	12	1977	5.2±0.3[1]	9.4±0.3
Fourth Avenue	41	1967-75	8.0±0.4	15.4±0.4
Ranier Tower	11	1977	7.6±0.1	18.5±0.3
Seneca Street	19	1972	7.6±0.1	13.3±0.3
Freeway Park	12	1976	8.4±0.3	19.2±0.7
East John	14	1975	7.3±0.3	12.3±0.7

1. Average and standard error of the mean

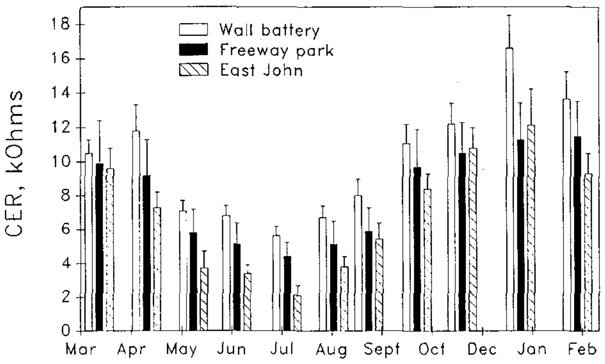

Figure 1. Seasonal pattern of cambial electrical resistance for three locations in Seattle, Washington. Bars represent standard error of the mean.

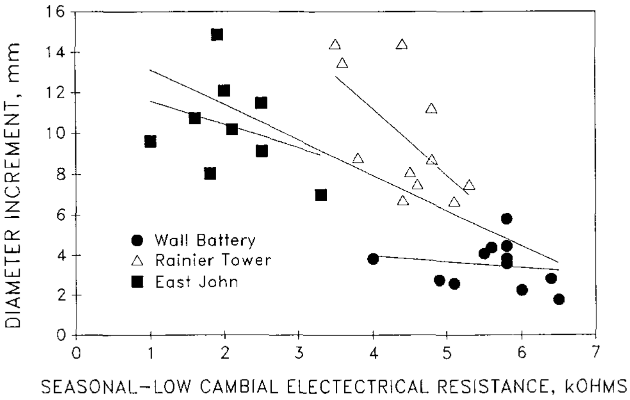

Figure 2. Five-year (1981-1986) average diameter increment (mm) versus CER for three locations in Seattle. Linear equations were fitted to the data within a site (small line) and for all sites (long line). See Table 5 for regression equations and correlation coefficients.

Table 3. Seasonal range of cambial electrical resistance (CER)

Site	Absolute low CER[1]	Date	Absolute high CER	Date	Ratio high:low
Wall - Battery	5.6±0.2[2]	Aug 1	16.6±0.6	Dec 19	3.0
Fourth Avenue	4.6±0.2	Aug 1	11.6±0.4	Feb 17	2.5
Ranier Tower	4.4±0.2	Aug 1	11.2±0.3	Feb 17	2.5
Seneca Street	4.5±0.1	Aug 1	11.0±0.3	Apr 25	2.4
Freeway Park	4.4±0.2	Aug 1	11.5±0.6	Dec 19	2.6
East John	2.1±0.3	Aug 1	12.1±0.7	Dec 19	5.8
All sites	4.2±0.4	Aug 1	12.9±0.9	——	3.1

1. Kohms
2. Average and standard error of the mean.

Table 4. Variation of cambial electrical resistance as a function of collection point on the stem.

Site	Collection point				F-test
	North	South	East	West	
Absolute high values					
Wall - Battery	15.3±0.4	17.5±0.8	16.1±0.7	17.7±0.9	ns
Ranier Tower	10.9±0.3	11.6±0.4	11.1±0.2	11.1±0.3	ns
East John Street	13.3±0.8	11.3±0.7	12.1±0.6	11.7±0.9	sig
Absolute low values					
Wall - Battery	5.9±0.3	4.7±0.2	4.8±0.3	6.9±0.3	sig
Ranier Tower	4.2±0.2	4.2±0.2	4.9±0.2	4.5±0.2	sig
East John Street	2.1±0.2	1.3±0.2	2.2±0.4	2.8±0.4	sig

by trees at Rainier Tower, which had diameter increment as large as those at East John but lower CER values. Across all sites, R^2 values for diameter increment and CER ranged from 0.01-0.40. None was statistically significant.

In the analysis of CER and 5-year diameter increment, R^2 values of 0.48 (absolute low) and 0.50 (absolute high) were obtained when data from all 3 sites were averaged. This result may indicate the ability of CER measurement to reflect past patterns of development rather than current plant condition.

CER values could not be used to predict either shoot elongation or diameter development. Despite highly variable growth rates, trees at different sites had similar CER values. Trees with the most rapid growth rates, those characterized as most vigorous, did not have lowest CER values.

Table 5. Regression equations for cambial electrical resistance (CER) and a five-year average of diameter increment

Site	Equation increment(CER)	R^2
Absolute low values		
Wall - Battery	.535 - 0.33(CER)	0.04
Ranier Tower	24.4 - 3.3	0.40
East John Street	12.7 - 1.12	0.09
All sites	.607 - 0.03	0.48
Absolute high values		
Wall - Battery	7.9 - 0.26	0.20
Ranier Tower	13.2 - 0.30	0.01
East John Street	11.8 - 0.11	0.01
All sites	20.0 - 0.09	0.50

An exception to this pattern occurred with the trees growing at the Wall-Battery site, These trees were clearly the least vigorous of all trees examined. When compared to trees at other sites, they had the largest CER at any point in the year (Figure 1). Thus, the results at this site are supportive of the possible usefulness of CER for evaluating tree vigor.

Summary and Discussion

The most significant limitation to use of CER as a measure of assessing the vigor of urban trees was the failure of CER values to accurately reflect seasonal diameter development. Trees with the poorest vegetative development did not consistently have the highest CER values, and vice versa. These observations were similar to those of Kostka and Sherald (6) with *Pinus strobus*, who noted "Measurements of CER....did not reflect tree vigor as accurately as growth measurement." While this study found CER related to long-term patterns of increment growth in a large population of sweetgum, its ability to predict or assess vigor at such a coarse level of resolution added little to what was seen visually. Put another way, the vigor of trees observed in this study could be easily characterized by observation of crown development, foliage density, etc.

CER showed no relationship to plant vigor and general site conditions. The trees growing in plaza environment at Wall-Battery were the least vigorous of any in the study, but they also had the highest CER values, supporting the usefulness of CER measurement. However, these trees were the clear exception to trees at the other sites, where CER had no relationship to measured growth parameters (Table 5, Figure 2).

Use of CER to indicate vigor in urban trees appears to be flawed for at least two reasons. First, the variation in CER measurements for a given measurement date and sampling point on the stem was considerable. Seasonal variation was generally 300% (Table 3, Figure 1). Thus, data collected in a given month could not be compared to data collected during another. Similar patterns were observed by Santamour (10). McCullough and Wagner (7) also observed this seasonal variation, and suggested that CER measurements were not "sensitive to different levels of vigor in dormant trees."

Significant variation in CER readings were encountered around the stem. Such variation might be due to: 1) anatomical features such as asymmetries in cambial development (10), 2) variations in physical environment, such as temperature (9), radiant energy and relative humidity (4), 3) variations in soil nutrition/fertilization, 4) variations in tissue water status (4), or 5) some combination of factors. Whatever the origin, the variation around the stem was a significant source of error in the use of CER, especially during the summer months.

Whether such sources of variation can be eliminated appears to be an open question. One method of doing so would be to develop reference points for responses of groups of trees growing in the same environment (as suggested by 11). Gagnon *et al.* (4) suggested a correction factor based upon temperature and water potential, to enhance the utility of CER as a measure of tree vigor. However, this application deals with populations and stands rather than individual trees.

CER has been successfully used as a tool to assess the vigor of water-stressed *Pinus ponderosa* (7). However, use of CER in this and similar experimental situations contrasts with its use to evaluate vigor of single trees in diverse urban environments. Simple measurement of CER appears to be insensitive to differences in tree development, and of minor value in the day-to-day management of the urban forest.

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