LOCUST BORER (COLEOPTERA: CERAMBYCIDAE) ATTACK IN RELATION TO PULSED ELECTRIC CURRENT IN BLACK LOCUST TREES

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ABSTRACT

Resistance to pulsed electric current (ER) applied to the cambium layer was studied in black locust trees, *Robinia pseudoacacia* L., in relation to tree thrift indices, and particularly to intensity of current-season attacks by the locust borer *Megacyllene robinia.* A total of 415 borer attacks were sustained by 241 trees, with a maximum of 20 attacks per tree. Although variation in the data was high both within and among study sites, ER was positively correlated with borer mines per tree and with increased degrees of tree suppression, represented by dominance classes. ER ranged from 2 to 32 kohms per tree, with roughly 95% of the trees reading less than 25 kohms. Borer mines per tree were also correlated with tree dominance class, with more attacks incurred by increasingly suppressed trees.

Key Words: Locust borer, *Megacyllene robiniae,* electric current, black locust, *Robinia pseudoacacia*

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INTRODUCTION

The locust borer, *Megacyllene robiniae* Forester, is a native pest of black locust, *Robinia pseudoacacia* L., throughout the tree's natural range. Larvae tunnel in the sapwood and heartwood of living hosts, causing weakening and decay. The locust borer completes one generation per year. Overwintering occurs in the egg or newly-hatched larval stage in the outer bark of the tree. Larval activity resumes with onset of favorable weather in early spring. Larvae develop during summer and pupation occurs within the larvel tunnel during late July-early August. Adults emerge and begin ovipositing in August and September. Oviposition continues in the Fall as long as temperatures remain favorable. An overview of life history and control implications has been presented by Galford (1984).

The locust borer is considered to be a primary invader of healthy trees. As discussed by Nielsen (1981), wood borers of the family Cerambycidae which are considered primary invaders are greatly outnumbered by those considered to be secondary, or capable of invading only decadent or dying trees. Nielsen added that some of the borers considered to be primary invaders might be reclassified as secondary if more adequate characterization of tree thrift were possible. The relationships between tree thrift and borer damage was emphasized by Solomon and Payne (1986) who suggested improvement of thrift as a means of reducing

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borer damage in pecan and hickory. Previous workers have reported fewer locust borer attacks in black locust trees with greater apparent thrift (Hopkins 1906, 1907; McAndrews 1932; Hall 1942; Berry 1945). Thrift of the host tree has been associated with many aspects of the locust borer/host relationship, including the ability of the tree to repair surface wounds (Harman and Dixon 1984) and the occurrence of more borer attacks per tree on strip-mined soils than on non-minded lands (Harman et al. 1985).

Tree thrift has traditionally been a difficult feature to quantify. Indices such as growth rate and crown class to describe thrift have provided only a general evaluation. A new method that utilizes electrical conductivity in the cambium layer of the tree offers better quantification of tree thrift. A number of authors have shown that trees which are stressed or non-thrifty, have increasingly higher resistance (ER) to the pulsed electric current (Shigo and Shigo 1974; Wargo and Skutt 1975; Kostka and Sherald 1982).

Herein we addressed the use of pulsed electric current to predict tree thrift and the intensity of locust borer attack in black locust. Borer mines per tree were examined in relation to resistance (ER) to pulsed electric current in the cambium, with greater ER implying lowered thrift and possibly more borer attacks. The objective was to find an easier and more accurate method for assessing borer risk for black locust.

METHODS AND MATERIALS

Electrical resistance (ER) measurements were taken with a Shigometer, model OZ-67 (Osmose Wood Preserving Co. of America, Inc., 980 Ellicott St., Buffalo, N.Y.). The procedures recommended by the manufacturer for measuring tree vigor with the Shigometer prescribed estblishment of a regional mean ER for the species utilizing a minimum sample of 20 randomly selected trees (Anon. 1980). The manufacturer asserts that an inverse relationship exists between tree vitality and ER, and suggests comparing ER readings for individual trees against the mean. Previous studies showed that trees below the mean grew faster on the average than trees with ER above the mean. In this study, larval mines per tree were compared above versus below the ER mean and against the entire gradient of ER readings.

To establish the mean, the sample size was increased to 360 trees, and samples were taken from 4 site types common to black locust, i.e., old fields, strip mines, mixed forests, and roadsides. Three strands within each stand type were sampled, utilizing 30 trees per stand. ER readings for the regional mean sample were taken during the first half of May, 1985. Sites selected to establish the mean were marked and subdivided using a grid at 12.2 × 12.2 m intervals. Quadrats within the grids were selected randomly. Readings were taken beginning with locust trees at the northern-most point of a quadrat, rotating clockwise and concentrically inward, including every tree until 30 trees were sampled. Where necessary, additional quadrats were selected randomly from the grid to accumulate the 30-tree sample.

Two ER readings were taken at each tree. A pair of Shigometer needle probes was inserted through the outer corky bark into the cambium layer of the tree, where ER is measured. The probes were inserted in a vertical plane, one above the other, gently shifting pressure from one needle to the other. Readings of electrical resistance in kilohms were recorded when the needles reached the cambium. All readings were taken on the southwestern side of the trunks, at 225 degrees from north, at about 1.3 m above the ground.

For the main study discussed herein, a sample consisting of three study sites was also established prior to May 1985. ER readings were taken in early May at these sites immediately following those for the regional mean, using the same instrumental procedure. Summer readings were taken in mid-August. The sites were located within 800 m of each other on a 182-ha tract in Allegany County, Maryland. The study sites were generally similar in topography and were assumed to be within flight range of a single borer population. The land consisted of old fields, pastures, and orchards on which black locust had encroached. The entire tract had been clearcut about 20 years before the study, and stands were essentially even-aged.

The study sites were 2-5 ha in size. There were subdivided by a grid at 12.2 × 12.2 m intervals. Ten quadrats 12.2 × 12.2 m were randomly selected from the grid at each study site. In each study plot all living locust trees were numbered and marked with aluminum tags.

Height, diameter at breast height (dbh), and crown dominance class (dominant, co-dominant, intermediate, or suppressed) for each tree were recorded. Dominance class was subjectively determined and used to indicate thrift. The numbers of active locust borer mines per tree were counted from ground level to a height of 6.1 m, during mid-May. Sap exudate and boring dust were used as indicators of burrowing larvae. Survival of larvae to the adult stage was determined by stapling wire screen traps over attack entrance holes to capture emerging adults in late summer.

The data werer analyzed to test whether dominance class and/or borer mines per tree were correlated with ER. A t-test was used to compare the number of borer attacks per tree with the regional mean. Standard regression and correlation analysis were used to test the relationship between borer attacks per tree and ER in kohms. Nonparametric tests including Pearson's and Kendall Tau were used to test ER and borer attacks per tree against tree dominance classes.

RESULTS AND DISCUSSION

A mean of 12.1 kohms was obtained from the 360 tree sample of black locusts. Old field locusts yielded the lowest mean readings (9.9 kohms), implying that these were the most vigorous trees. The other readings in ascending order were strip-mined lands (11.5 kohms), roadsides (12.4 kohms), and mixed forests (13.0 kohms).

Electrical resistance was related to locust borer attack intensity. A comparison utilizing the ER mean (12.1 kohms) is shown in Table 1. The "above mean" category incurred more than double the number of attacks per tree sustained in the "below mean" category (1.11 versus 2.40). A t-test confirmed that the differences were significant ($p < 0.01$, t value 3.14, df = 237, SE = 0.279).

A question arose whether to include trees "without" attacks in the analysis of ER versus mines per tree. Unattacked trees comprised a sizable sample within each site [35, 47, and 66 percent for sites 1-3, respectively (site numbers as prresented in Tables 1 and 2, and Figs. 1-3], large enough to affect the results. I was not known whether these trees had been attacked because they were missed as oviposition sites or whether eggs were deposited and failed to hatch or died as small larvae. Supposedly trees of higher thrift, expressed as lower ER readings, should be more able to suppress attacking larvae and exhibit fewer mines. ER was

Table 1. Comparison of locust borer attack intensity in trees above versus those below the regional mean electrical resistance (ER) value for black locust.

Study site	Tree ER relative to regional mean*	No. of borer attacks	No. of trees	Average attacks per tree
1	Below	19	11	1.72
	Above	175	58	3.02
2	Below	99	53	1.86
	Above	40	17	2.35
3	Below	23	63	0.36
	Above	59	39	1.57
Sub-totals	Below	141	127	1.11
	Above	274	114	2.40

*Values below regional mean indicate increased tree thrift vitality. Values above the regional mean indicate reduced vitality.

Table 2. Comparison of ER in attacked versus unattacked black locust trees.

	Study site	Tree category	Number of cases	Ave. ER reading (kohms)*
	1	Unattacked	24	12.5
		Attacked	45	16.7
	2	Unattacked	36	10.2
		Attacked	33	11.5
	3	Unattacked	68	11.6
		Attacked	34	13.8
Totals		Unattacked	128	11.3
		Attacked	112	14.3

*T-test indicated ER for attacked trees to be significantly greater than for unattacked trees ($p > .01$)

therefore compared for attacked versus unattacked trees. A summary of data is shown in Table 2. The ER value was significantly greater among the attacked trees than among the unattacked ones ($p < 0.01$, $df = 237$, $SE = 0.44$), indicating an interaction between the "unattacked" condition and tree shift. The differences in ER per site ranged from 1.3 to 4.2 kohms, with the highest ER per site being 16.7 kohms occurring with the "attacked" group in site 1. In this study the common occurrence of unattacked trees may have been partly a function of relatively high tree shift and low borer numbers in the study sites. In some strands, not part of this study, with apparently reduced thrift and higher borer numbers, few or no trees were unattacked. Therefore, a combination of interacting factors, including oviposition habits of the insect could affect the numbers of unattacked trees.

Borer attacks per tree were plotted against ER readings for each study site. Scattergrams with all data points are shown in Fig. 1. Combining all sites, there

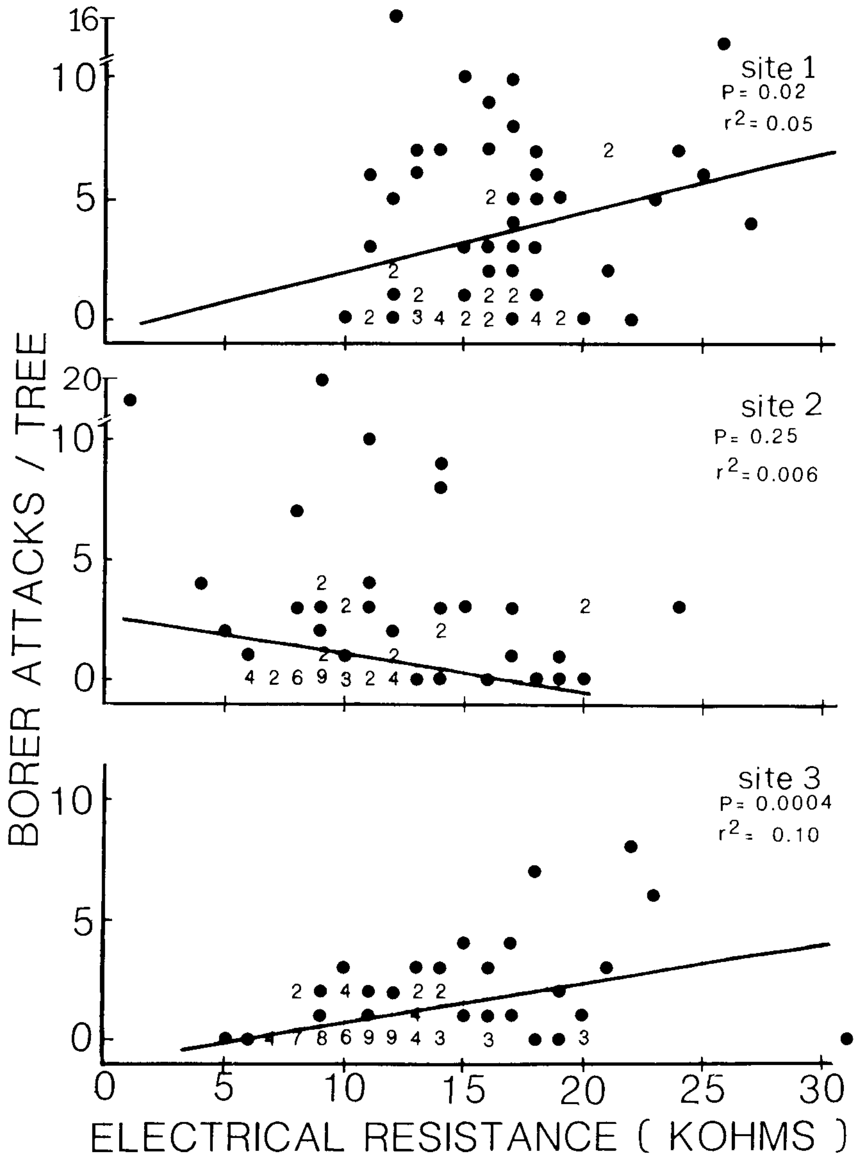

Fig. 1. Scattergram and correlation analysis of borer attacks per tree, in relation to resistance to pulsed electric current (ER) at each study site. Each point on the graph represents one tree, numerals indicate multiple trees.

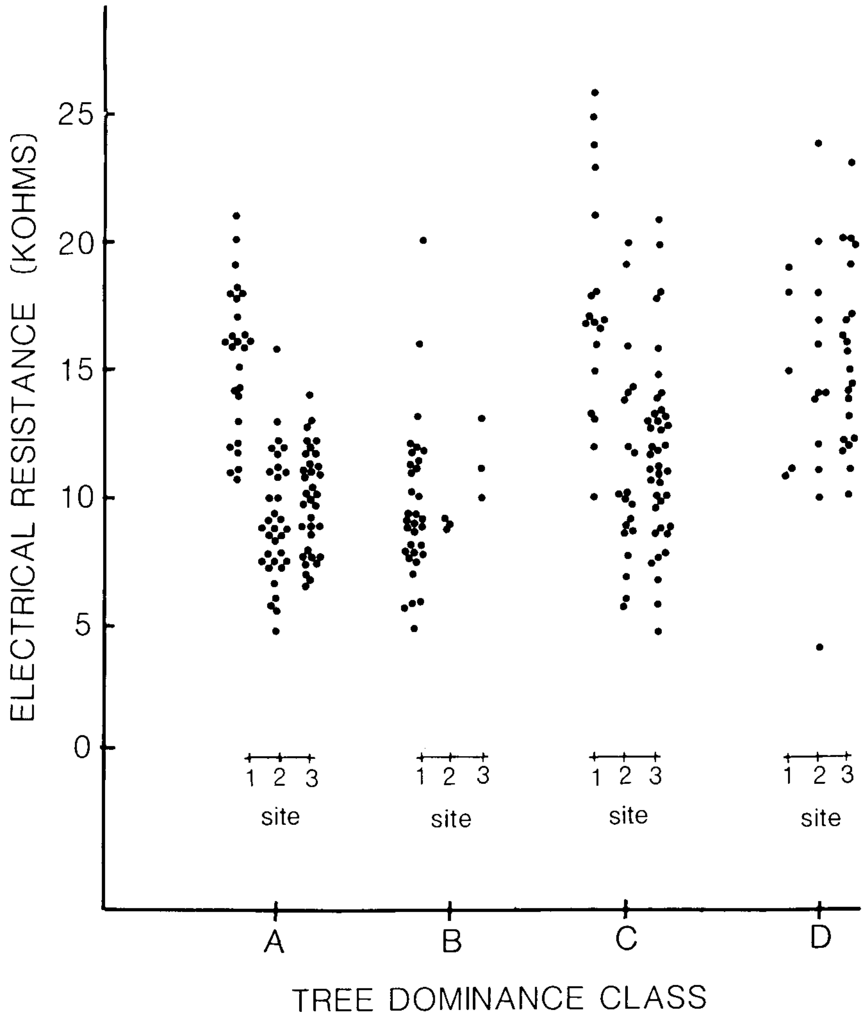

Fig. 2. Electrical resistance (ER) plotted against tree crown dominance class by study site. Dominance classes are respectively, A = dominant, B = co-dominant, C = intermediate, and D = suppressed. Each point on the graph represents one tree.

was a significant positive relationship between borer attacks per tree and ER ($p < 0.001$; $R^2 = 0.04$) despite lack of uniformity among sites. Variability around each ER point was high in Fig. 1, resulting in low R^2 values. These values were low for each site as well as for all data combined, indicating that only a small amount of the variation is explained by the correlation. Separate analysis excluding unattacked trees did not greatly alter the results, nor provide much additional insight.

Another index of tree thrift that was used was the tree crown dominance class, a standard silvicultural approach for comparing the competitive status of trees within a stand (Hawley and Smith 1958). Four dominance classes were recognized:

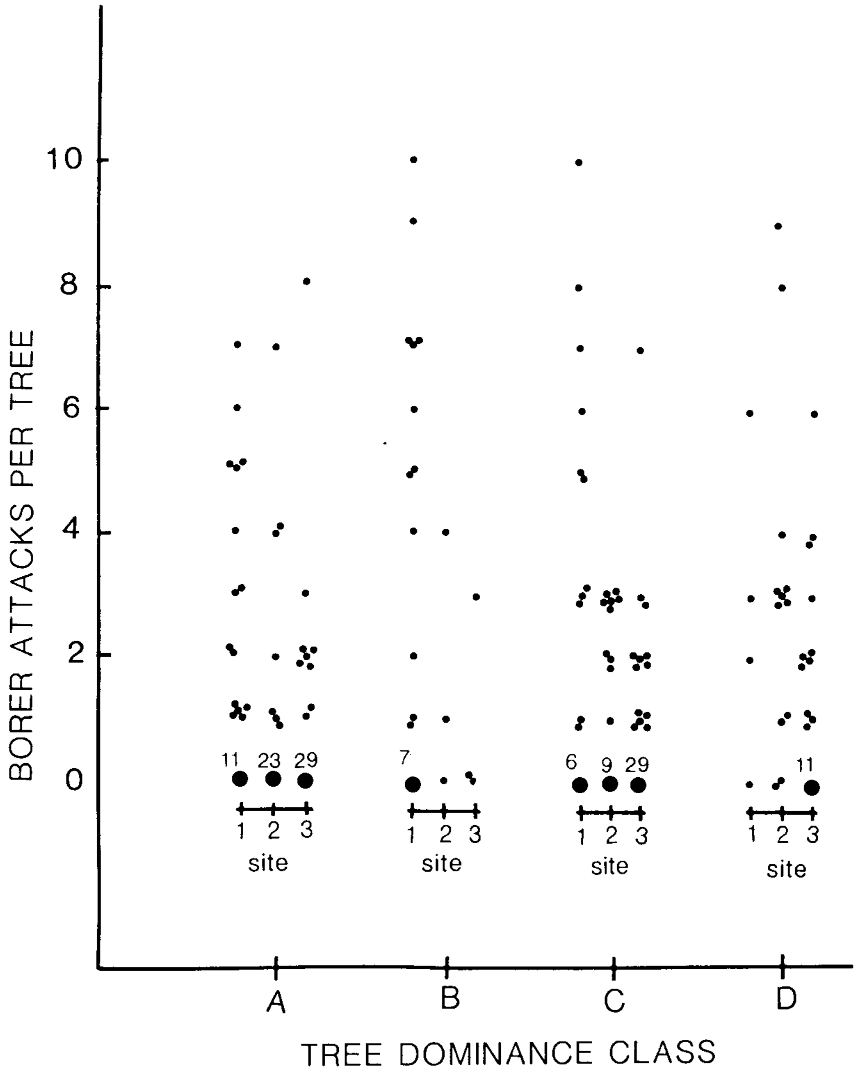

Fig. 3. Locust borer attacks per tree plotted against tree dominance class, by study site. Dominance classes are respectively, A = dominant, B = co-dominant, C = intermediate, and D = suppressed. Small points on graph represent individual trees. Larger points with numerals denote concentrated numbers on trees.

1 = dominant, 2 = co-dominant, 3 = intermediate, and 4 = suppressed. We compared ER readings with crown class for all trees in the study (Fig. 2). We also compared borer mines per tree with crown class (Fig. 3). Each point on the graphs (Figs. 2 and 3) represents one tree. The 4 crown classes included all trees in the study, as each tree was placed in one of the 4 classes. Statistically, crown class was considered to be a qualitative or nondiscreet categorization, and was tested nonparametrically using the Spearman correlation coefficient test. Combining all

sites, both ER and mines per tree were positively correlated with crown dominance class ($p < 0.05$). Comparing sites, there was a correlation of crown class with ER and borer mines per tree in sites 2 and 3, but not in site 1.

Survival of borer larvae to the adult stage, as evidenced by emergence into screen traps, was compared against ER for all attacked trees, utilizing a scattergram and standard correlation analysis. The test proved non-significant ($P = 0.25$) and no distinct trend was seen. For ER increments of 0-5, 6-10, 11-15, 16-20, 21-25, and 26-30 kohms, survival percentages were respectively, 100, 77, 86, 85, 81, and 72 percent. Additional attempts to relate survival to tree shift and attack levels were unsuccessful. ER in trees in which all attacking larvae survived was not significantly different from those with less than 100 percent survival, nor was there a significant relationship between survivial/tree and attacks/tree. Thus, survivial of larvae in the latter stages of mining did not appear to be associated with tree thrift. In unverified observations, high mortality appeared to occur among small larvae as they began activity early in the spring. This was based upon scrutiny of small wounds with sap exudates typical of early borer activity. Many of these continued as active borer attacks; others disappeared, indicating possible larval mortality. However it was not determined what portion of the exhundations which disappeared were actually made by borer larvae as opposed to those resulting from some other source.

The summer ER readings, taken in early August, were compared with the May readings. The two were not statistically different, indicating no apparent reduction in thrift as the summer season progressed. Borer attacks were apparently not numerous enough to result in reduced thrift or altered ER readings. Greater concentrations of borer attacks per tree probably would begin affecting the ER readings at some level which apparently was not approached at the sites in this study.

The data from this study indicates that ER was correlated with crown class and borer mines per tree, and that the Shigometer may be used for assessing borer damage. Reliability of the method will depend upon improvement of the techniques and additional knowledge of borer-tree relationships which will reduce variability among samples.

The use of the mean ER, against which to compare trees and stands provides a simple quantitative assessment of thrift. The information can be useful to the forest manager in making cutting decisions. Although the variability in the results was high, the method should improve with additional use.

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