SEASONAL VARIATION IN CAMBIAL ELECTRICAL RESISTANCE IN JUVENILE GREEN ASH FROM DIFFERENT PROVENANCES[1]

by Frank S. Santamour, Jr.

Abstract. Electrical resistance (ER) in the cambial zone of juvenile green ash from various provenances was highly correlated with growth rate and with certain climatic features of provenance origin. Initiation of cambial activity in the spring was related to ER but not dependent on provenance origin. Cessation of cambial activity in the fall, as indicated by ER, was significantly related to origin. ER measurements of reciprocally patch-grafted cambia indicated that variation in time of cessation would not be a major cause of graft incompatibility in inter-provenance grafts.

The Shigometer[2] is a device that delivers a pulsed electric current and measures resistance to that current. In recent years, the instrument has been used to relate electrical resistance (ER) to defoliation stress (Wargo and Skutt 1975), growth rate (Smith and Others 1976; Shortle and Others 1977), and stem dormancy (Rietveld and Williams 1977). Davis and Others (1979) showed that ER in the cambial zone of three native tree species in New Hampshire followed a marked seasonal pattern.

As part of our studies on the physiology and biochemistry of graft compatibility, we were interested in using the Shigometer to detect the initiation and cessation of cambial activity. It seemed reasonable to assume that lack of cambial synchronization between stock and scion could result in physiological and physical stresses that might contribute to graft failure, especially when stock and scion were from widely differing geographic origins. Wilcox (1962), in discussing the differences in the periodicity of shoot growth commonly seen in provenance tests, stated that "corresponding differences occur in the beginning and cessation of cambial activity," but provided no references or data to support this statement.

Direct anatomical observations of cell division and differentiation in killed and fixed sections may be the most accurate method of determining cambial activity, but it is not suited to broad surveys involving hundreds of plants. For such work, other techniques must be developed.

The Shigometer, by the very nature of the instrument, may seem to be more "scientific" than the apparently crude dendrometer or bark-peeling device previously used in such studies. All of these instruments measure "something," but whether that "something" has a significant relationship to the intent of any particular study is often a matter of conjecture. We know that the ER measurements taken with the Shigometer reflect an internal chemical situation within a tree. Under the conditions of the present study, the measurements were taken from the cambial region. We do not know what phase of cambial activity is being monitored, but feel reasonably certain that repeatable seasonal fluctuations in ER readings are directly associated with the initiation and cessation of cambial activity.

Materials and Methods

The young green ash (*Fraxinus pennsylvanica*) trees used in this study were part of a range-wide provenance test being conducted by Dr. Kim C. Steiner of Pennsylvania State University. Dr. Steiner had supplied us with one-year-old seedlings of 48 provenances for spring planting in 1978. The seedlings were planted in 2 replicates of 4-tree plots at a 10-foot spacing in Beltsville, Maryland. Although some provenances were represented by as many as 4 mother-tree seedlots and were grown and identified as half-sib progenies in the nursery, these progenies were

[1]Research supported in part by a grant from the Horticultural Research Institute, Washington, D.C. The author thanks to Harold E. Vettel, Frank V. Grant, and Robert D. Clayton for their assistance in this study.

[2] Osmose Wood Preserving Co. of America, Buffalo, N.Y. The use of trade, firm, or corporation names in this paper does not constitute endorsement by the Science and Education Administration or the U.S. Department of Agriculture.

lumped together by provenance for the field testing. Only one tree died between planting time and the spring of 1979.

We began monitoring ER in the cambial zone of these seedlings on March 28, 1979 and continued the measurements at approximately weekly intervals throughout the growing season until November 29, 1979. Because of the small diameter of the seedlings in 1979, we did not use the rather coarse steel needle probes supplied with the Shigometer. Rather, we constructed smaller probes using two stainless steel map pins embedded (with epoxy resin) 1 cm apart in a plastic base. Electrical contact between these pins and the Shigometer was accomplished by a commercial clip-on test lead set.

All measurements were made with the pins in a vertical orientation at the base of the leading shoot produced in 1978. The pins were pushed through the bark and into the xylem. Probes inserted in this fashion measure the point of lowest ER along the probe path, that point being the cambial zone (Wargo and Skutt 1975). Only one reading was made for each seedling at each sampling date. ER of the seedlings was considerably higher than mature trees of the same species, often by a factor of 5 to 8. This difference was not the result of the smaller probe needles, since standard Shigometer needles gave similar readings. Preliminary work did show that the ER of cambia of young stems in several tree genera was consistently higher than that of older (20-year-old) trees.

The data were subjected to standard ANOVA techniques and correlation coefficients were determined by the least squares method.

On July 26, 1979 we made a number of reciprocal patch grafts between potted seedlings of the same provenances that had been field planted. A ring of bark roughly 1 inch wide was removed from the main trunk of each seedling of the pair to be grafted, with care being given to making the cuts at regions of similar diameter. The bark patches were then placed, in the proper polar orientation, around the stem of the other pair member and secured with rubber grafting bands. Thus we were able to make reciprocal grafts between seedlings from Manitoba and Tennessee, New York and Manitoba, Nebraska and Illinois, and several other combinations, including intra-provenance grafts. The grafting rubbers were removed after 10 days. All reciprocal grafts were successful.

Sax and Dickson (1956) showed that the wood produced under the bark of such patch grafts resulted from cambial activity of the donor patch. Thus, we were interested to see whether the ER would be influenced under the new set of environmental conditions caused by grafting.

We began monitoring the ER above, within, and below the patch graft on October 17, 1979 and continued, at weekly intervals until November 29, 1979. In 1980, we made several measurements during the spring and summer months, started weekly testing on August 26, 1980 and continued this until November 15, 1980.

Results and Discussion

Table 1 gives the seasonal variation in cambial ER of seedlings from randomly selected provenances having a wide range of January temperatures and lengths of growing season. The trends that seem obvious from these data are reflected in the correlation coefficients listed in Table 2. Both the length of growing season and the average January temperature of the origin of the provenance were highly inversely correlated with cambial ER on November 29, 1979 but the correlations with ER readings on July 17, 1979 were non-significant. The correlation between ER during the dormant spring period (March 28, 1979) and source January temperature was highly significant but that with length of growing season was non-significant.

The average day of bud break for all seedlings was April 29, 1979 (Day 119) and the average electrical resistance at the time of bud break was 39 K ohms. The day of bud break was not significantly correlated with seed origin climatic conditions and although there was a significant inverse correlation between ER at bud break and length of growing season the significance was at a very low level.

It appeared that the threshold resistance for bud break to occur was near 50 K ohms. Therefore we were interested in the date that the resistance

Table 1. Electrical resistance in cambial zone of green ash seedlings from various provenances during the 1979 growing season (K ohms).

KS-number		*225*	*437*	*073*	*217*	*138*	*046*	*477*
Origin		*MN*	*ND*	*SD*	*VT*	*IND*	*MD*	*ILL*
Growing season (days)		*99*	*121*	*142*	*159*	*182*	*200*	*217*
Ave. Jan. temp (°C.)		*−15.9*	*−11.6*	*−7.4*	*−7.2*	*−0.6*	*2.6*	*2.7*
Date 1979	*Day of year*							
3/28	87	180	213	186	185	155	128	127
4/11	101	78	88	66	84	76	61	65
4/18	108	66	66	58	62	82	69	56
4/24	114	34	34	29	39	38	24	35
5/2	122	51	46	40	42	45	44	46
5/9	129	19	21	18	22	21	30	22
5/16	136	22	19	19	21	18	18	20
5/22-10/2	142-275	15-27	15-27	11-24	13-28	11-22	11-18	10-18
10/16	289	52	50	40	37	35	31	16
10/23	296	46	34	45	31	30	24	27
10/30	303	81	75	72	52	50	30	24
11/6	310	135	109	98	85	78	41	45
11/14	318	146	114	113	119	98	57	51
11/20	324	176	158	108	121	114	78	62
11/29	333	369	321	302	288	245	174	159

of the various provenances rose above 50 K ohms late in the growing season. The data in Table 1 and Table 2 indicate a highly significant correlation between seed source climatic data and the possible onset of dormancy as indicated by rising ER.

ANOVA showed highly significant differences among seedlots in both 1978 and 1979 shoot growth, and the growth was highly significantly correlated with the length of the growing season and average January temperature of the seedlot origin (Table 2). This relationship was not unexpected.

ANOVA also showed highly significant differences among seedlots in ER at 3 sampling dates. There was a consistent highly significant inverse correlation between growth and ER at 3 sampling dates (Table 3). Wargo and Skutt (1975) reported a similar inverse relationship between ER And diameter growth in 3 oak species.

If we assume that 50 K ohms may represent the approach of cambial "dormancy," it would appear from Table 1 that more northern provenances reach that point about 2 weeks earlier than southern provenances. However, the ER in the fall did not reach the level of the first (March 28, 1979) measurement, for any seedlot, until November 29, 1979. The lowest temperature

Table 2. Correlation coefficients of relationships between seed source climatic conditions and measurements on provenance seedlings.

	Length of growing season	*Average January temp.*
Day of Bud Break	−.318	−.128
ER[a] at bud break	−.370*[b]	−.283
Day ER rose above above 50 K ohms	.703**	.707**
ER 3/28/79	−.284	−.626**
ER 7/17/79	−.284	−.126
ER 11/29/79	−.851**	−.904**
1978 shoot growth	.685**	.604**
1979 shoot growth	.540**	.461**

[a]ER = Electrical resistance in cambial zone.
[b]* indicates statistical significance at the 5% level and ** at the 1% level.

Table 3. Correlation coefficients of relationships between shoot growth and cambial electrical resistance of provenance seedlings.

	1978 growth	*1979 growth*
ER[a] 3/28/79	−.568**[b]	−.719**
ER 7/17/79	−.892**	−.462**
ER 11/29/79	−.628**	−.565**

[a]ER = Electrical resistance in cambial zone.
[b]** indicates statistical significance at the 1% level.

recorded during the month of November 1979, up until the last resistance measurement, was only −0.6°C. Lower temperatures may have resulted in wider provenance differences, but we are not

Table 4. Cambial electrical resistance (K ohms) above, within, and below patch grafts between green ash seedlings from various provenances-1979.

Seedling Cambium	*Origin*	*Position*	*Day 290*	*298*	*306*	*312*	*320*	*327*	*333*
KS-146-3	TN[a]	below	55	34	40	80	75	95	150
KS-147-3	TN	patch	55	36	45	80	75	95	135
KS-146-3	TN	above	50	33	40	70	70	90	125
KS-94-1	MAN	below	80	80	70	120	130	105	195
KS-147-4	TN	patch	50	37	40	110	105	75	180
KS-94-1	MAN	above	95	100	90	140	140	110	230
KS-96-8	MAN	below	85	100	100	160	185	125	290
KS-96-5	MAN	patch	75	90	90	150	160	130	275
KS-96-8	MAN	above	85	90	110	165	180	130	300
KS-93-1	MAN	below	70	80	70	110	125	115	190
KS-373-1	NY	patch	70	65	70	105	125	115	230
KS-93-1	MAN	above	70	75	70	115	110	120	215
KS-373-1	NY	below	60	75	60	100	110	105	180
KS-374-4	NY	patch	50	55	50	80	90	90	180
KS-374-1	NY	above	60	60	55	90	95	95	150

[a]Tennessee seedling origins had a 197-day growing season and 40.3°F. average January temperature,Manitoba had 100 days and 1.0°F., and New York had 182 days and 25.1°F.

certain this would be the case. The rise in ER from November 20, 1979 to November 29, 1979 was dramatic, in most instances more than doubling the November 20 reading and in a few seedlots nearly tripling the November 20 measurement. The drop in ER from March 28, 1979 to April 11, 1979 was nearly as dramatic.

The onset of cambial activity in the spring, whether indicated by time of bud break or decreasing ER, was not related to geographic origin of these young ash trees, and may be merely associated with increasing temperature, such as determined by Wilcox and others (1956) for bark peelability. In the present study, the increase of ER in the fall appeared to be related to the cessation of cambial activity and ER was significantly correlated with growth rate. Wilcox and others (1956) also found that increase in resistance to bark peeling was related to tree vigor. Thus, our findings of correlations between ER and the climatic features of provenance origin might be a reflection of the high correlation between growth rate and climate of provenance.

Even with the brief "adjustment" period of patch-grafted cambia in 1979, it can be seen that the grafted cambia became somewhat "synchronized" in ER with the tissue above and below the graft (Table 4). During 1980, the synchronization was practically perfect and the intermediacy of ER in the graft area noted in 1979 was not apparent. Thus, it would appear that there is little potential for tissues in the area of the graft union to maintain distinctive and potentially disruptive physiological behavior.

Literature Cited

Davis, W., A. Shigo, and R. Weyrick. 1979. *Seasonal changes in electrical resistance of inner bark in red oak, red maple, and eastern white pine.* Forest Sci. 25: 282-286.

Rietveld, W.J. and R.D. Williams. 1977. Detection of dormancy in black walnut seedlings with the Shigometer and an oscilloscope technique. Proc. Int. Forest Nurserymen's Assoc., p. 60-72.

Sax, K. and A.Q. Dickson. 1956. *Phloem polarity in bark regeneration.* J. Arn. Arb. 37: 173-179.

Shortle, W.S., A.L. Shigo, P. Berry, and J Abusamra. 1977. *Electrical resistance in tree cambium zone: relationship to rates of growth and wound closure.* Forest Sci. 23: 326-329.

Smith, D.E., A.L. Shigo, L.O. Safford, and R. Blanchard. 1976. *Resistance to a pulsed electrical current reveal differences between nonreleased, released, and released-fertilized paper birch trees.* Forest Sci. 22: 471-472.

Wargo, P.M. and H.R. Skutt. 1975. *Resistance to pulsed electric current: an indicator of stress in forest trees.* Can. J. For. Res. 5: 557-561.

Wilcox, H. 1962. Cambial growth characteristics. **In** Tree Growth, Th. T. Kozlowski (Ed.), Ronald Press, N.Y. P. 57-88.

Wilcox, H., F.J. Czabator, G. Girolami, D.E. Moreland, R.E. Smith. 1956. Chemical debarking of some pulpwood species. Tech. Pub. N.Y. State Col. Foretry, Syracuse Univ. No. 77.