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ELECTRICAL TECHNIQUES FOR DISEASE DIAGNOSIS[1]

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Abstract. Electrical measurements are currently being used to detect and diagnose cold temperature injury, internal discoloration and decay, root rot, vascular wilt disease, air pollution injury, cankers, and proliferation disease in trees. Research relating electrical measurements to vigor continues. Additional advances are expected from current research on remote sensing, electrotherapy, and on the development of new electrical diagnostic tools. Electrical measurements, when used in addition to presently available techniques, should yield increased accuracy in diagnosis and in many cases early detection of tree disease.

Arborists need more effective means for early diagnosis of diseases in trees. Control of many plant diseases is often dependent on early diagnosis. However, in some diseases such as internal discoloration and decay, the amount of tissue infected can rarely be determined accurately at any time during the disease progression. Nondestructive techniques to enable early diagnosis and early treatment would allow more effective control of many tree diseases.

Electrical techniques have been used extensively in human medicine. Plant electrophysiology, the study of the electrical properties of plants, has been applied for a long time in the investigation of normal plant functions. The application of this field to the study of plant diseases, however, has been limited. Recently an increased amount of this research has been conducted on the diseases of both trees and crop plants.

History

Electrical measurements were taken on plants soon after the discovery of electricity. Most of the early researchers were concerned with using electrical currents to stimulate growth of agricultural crop plants (Warner 1893). One of the first researchers to become interested in the electrical measurements on trees was George E. Stone. Stone, who was a plant pathologist at the Massachusetts Agricultural Experiment Station, is best known to arborists as the founder of the Massachusetts Tree Wardens and Foresters Association in 1913. He was concerned with the injury that occurred to shade trees growing adjacent to uninsulated power lines and railroads (Stone, 1903, 1914). Combining extensive field observations of electrical injury with laboratory experiments, Stone demonstrated that direct current (DC) caused more injury to trees than alternating current (AC). He also measured the electrical resistance of wood and bark in living trees, and determined the stimulatory and inhibitory effects of various levels of voltage and currents on the growth of bacteria and yeasts.

After Stone's pioneering electrical research in arboriculture, there was a period of decreased interest. A resurgence occurred in the 1950's. Electrical research again began with fruit trees and continued with forest and shade trees.

Applications of Electrical Measurements for Disease Diagnosis

Cold temperature injury.—Cold temperature injury is a serious health problem of woody plants

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in temperate climates (Levitt 1973). Electrical resistance measurements have been used extensively to detect cold temperature injury (Evert 1973, Vanden Driessche 1973, Wilner 1967). This information is particularly useful in plant breeding, where laboratory tests on experimental scions can determine their potential for winter hardiness. Early detection of injury is possible because electrical resistance of tissues changes immediately after injury. The extent and degree of success of research with electrical measurements and cold temperature injury served to encourage additional research in infectious diseases as well as research with other noninfectious diseases.

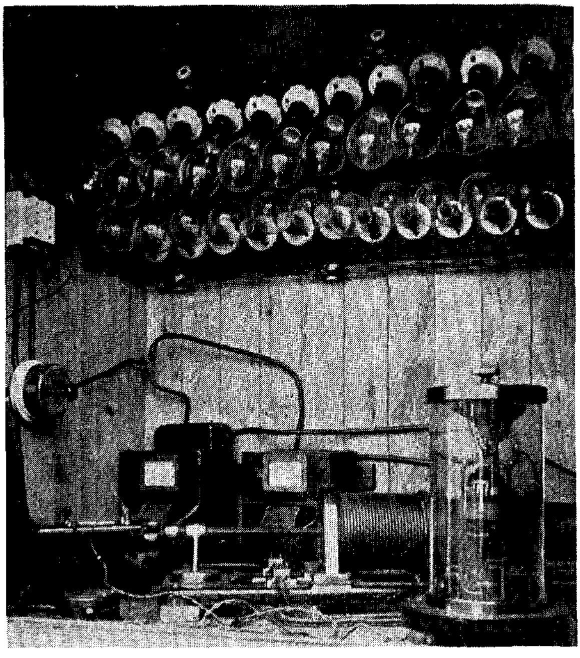

Figure 1. Laboratory at Massachusetts Agricultural College where electrical research was conducted on plants during George Stone's time (1893).

Internal defects, discoloration and decay.—Arborists often need to determine accurately the internal conditions of a tree. This information helps them to decide the degree of hazard of a tree and whether it should be removed. Electrical resistance of wood in living trees is an accurate indicator of internal defects. In general, the sound wood, whether sapwood or heartwood (age altered), is high in resistance while discolored wood (wound altered) and decayed wood are progressively lower in resistance according to severity of defect (Tattar et al. 1972). By inserting a probe-electrode into small drill holes (3/32 inch) in a few spots on the trunk of a suspected hazard tree the amount of internal defect and sound "holding wood" can quickly be determined (Shigo and Shigo 1974, Shigo 1976). A similar relationship between electrical resistance and decay has been found in utility poles, and the internal condition of utility poles can also be determined by the same technique.

Root rot.—Detection of root disease is often difficult. Positive identification often requires the presence of conks, mushrooms, rhizomorphs or mycelial fans, a microbial culture in the laboratory, or extensive excavation and a subsequent examination of the root system.

The same type of electrical resistance measurements used to determine internal decay in the trunks has also been used to detect decay by *Fomes annosus* in red pine. The decayed root tissues were low in electrical resistance. Pitch pockets, commonly associated with the disease, were high in electrical resistance (Shigo and Berry 1975). This pattern of alternating high and low electrical resistance readings has been found only in trees infected with *Fomes annosus* root rot. It is possible that other root diseases may also be diagnosed by electrical resistance measurements.

Vascular wilts.—Vascular wilt diseases are often diagnosed by the presence of vascular discoloration, or streaks in the wood of twigs. In Verticillium wilt the pathogen enters the roots or lower trunk and passes through the stem and branches before reaching the twigs. In many cases wilting and even death of the tree may occur without any detectable twig discoloration. Dissection of the trunk and large branches have revealed extensive discoloration in the outer sapwood. Early diagnosis of Verticillium wilt in Norway maple has been achieved by the detection of this discoloration by measurements of electrical resistance (Tattar 1976). Detection of wilt-associated discoloration may also be important in other vascular wilt diseases.

Tree vigor.—An accurate health index for shade trees has long been the hope of both the arborist and the shade tree pathologist. Preventative medicine and early diagnosis would be most effective if a periodic check of the vigor could be taken. Measurements of the electrical resistance of cambial zone tissues (innerbark, cambium, outer xylem) with uninsulated electrodes has been somewhat related to tree vigor. Wargo and Skutt (1975) found the cambial zone electrical resistance to be indirectly related with growth rate and to be directly related to stress from insect defoliations. It has been hoped that these type of measurements could be applied to arboricultural practice (Money, 1976). However, Newbanks (1976), working with sugar maple trees, found little correlation between electrical resistance and vigor (as determined by visual crown classification). His studies indicated considerable variability of cambial zone electrical resistance measurements between trees of the same species, and that the determination of the vigor of any one tree species could not be related to electrical resistance. These conflicting reports indicate both the promise of a new diagnostic technique and a note of caution in its present application in arboriculture practice. Clearly more research is needed.

Other applications.—Injury from sulfur dioxide (SO_2) gas was detected by decreases of electrical resistance of bark tissue extracts of spruce, *Picea abies* (Hartel and Grill 1973). The electrical measurements were more accurate for detecting injury than the standard chemical analysis of foliage.

The extent of canker development was related to electrical resistance of cambial zone of black birch with Nectria cankers and American chestnut with chestnut blight (Sylvia and Tattar 1976). Information about extent of tissue alteration at the margins of cankers could be useful during excision.

Detection of mycoplasma diseases has been most difficult because of the inability to culture the pathogens (Wilson and Seliskar 1976). The proliferation disease of apple trees, caused by a mycoplasma, was detected by electrical resistance of infected rootstocks (Dostalek 1973). The development of similar electrical diagnostic techniques for other important mycoplasma diseases such as elm phloem necrosis and coconut lethal yellows would enable early detection and therapy.

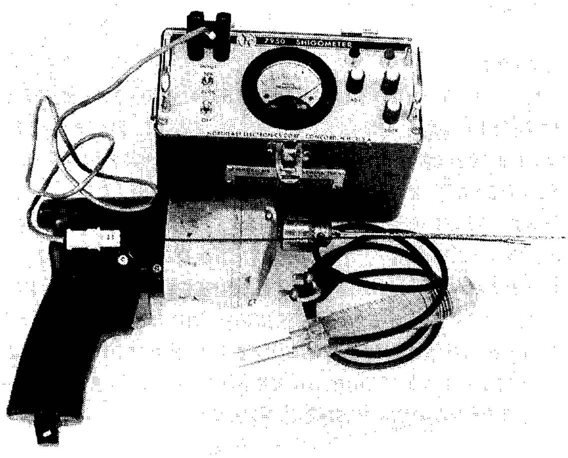

Figure 2. Field ohmmeter and electrode accessories for measurement of internal discoloration and decay and for measurements of the cambial zone.

Current Research and Future Developments

Remote sensing.—Remote sensing of electrical measurements of trees in cold temperature injury experiments has recently been developed (Brach et al. 1973, Wilner and Branch 1970). Electrical measurements were taken automatically on the trees and monitored in a laboratory ¼ mile away.

Frequency spectrum analysis.—Although the current research on electrical measurements for disease diagnosis has been primarily with electrical resistance measurements, other types of electrical measurements are being tested. One such method is frequency spectrum analysis, an electrical measurement of a broad band of frequencies at the same time. This method has shown promise in studies in soft rot of potato and carrot and is currently being tested in research on tree diseases (Tattar and Sylvia 1976, unpublished data).

Electrotherapy.—Scientists have also attempted to use electric currents in therapy. Blanchard (1974) found that application of high voltage (6500 volts) currents shortly after wounding resulted in almost a complete absence of invading microorganisms in the wood behind the wound. These results indicate that various sublethal electrical treatments may have therapeutic value in limiting the invasion of pathogenic microorganisms after wounding.

Summary

We have entered into a new era of disease detection and diagnosis. The plant pathologist has begun to utilize electronic technology to obtain objective information about the health of shade trees just as the medical doctor has used similar technology to detect and diagnose human diseases. Electrical measurements from shade trees, just as those in human medicine, will not replace diagnostic procedures in current use, but will provide additional information to achieve more accurate detection and diagnosis.

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Literature Cited

1. Blanchard, R.O. 1974. *Electro therapy: a new approach to wound healing.* Proc. Am. Phytopath. Soc. 1:133-134 (Abstr.).
2. Brach, E.J., J. Wilner, and G. St. Armour. 1973. *Data acquisition of winter-hardiness and temperature from living plants via telemetry.* Med. & Bio. Eng. 1:164-175.
3. Dostalek, Jr. 1973. *The relation between the electric impedance of apple tree tissues and the proliferation disease.* Biologia Plantarum 15: 112-115.
4. Evert, D.R. 1973. *Factors affecting electrical impedance of internodal stem sections.* Plant Physiol. 51:478-480.
5. Hartel, V.O., Grill, D. 1973. *The conductivity of bark-extracts from spruce, a sensitive indicator for air pollution.* Eur. J. For. Path. 2:205-215.
6. Levitt, J. 1973. Responses of plants to environmental stresses. New York, N.Y., Academic Press 697pp.
7. Money, W.E. 1976. *Magic myths and misconceptions.* Weeds, Trees and Turf 15:44-45.
8. Newbanks, D. 1976. The relationships between electrical resistance of cambial tissues of *Acer saccharum* and physiologic stress. M.S. Thesis Univ. of Mass. 59pp.
9. Shigo, A.L., Shigo, A. 1974. Detection of discoloration and decay in living trees and utility poles. *USDA For. Serv. Res. Paper* NE-294, 11pp.
10. Shigo, A.L., Berry, P. 1975. *A new tool for detection of decay associated with Fomes annosus in Pinus resinosa.* Pl. Dis. Reptr. 59:739-742.
11. Shigo, A.L. 1976. *The Shigometer: what it will and will not do for you.* Weeds, Trees and Turf (In Press).
12. Stone, G.E. 1909. *Influence of electricity on microorganisms.* Bot. Gaz. 48:359-379.
13. Stone, G.E. 1914. Electrical injuries to trees. Mass. Agric. Coll. Bul. 156 19pp.
   Sylvia, D., Tattar, T.A. 1976. *Electrical resistance studies of tree canker development.* Proc. Am. Phytopath. Soc. (Abstr.).
15. Tattar, T.A., Shigo, A.L., Chase, T. 1972. *Relationship between the degree of resistance to a pulsed electric current and wood in progressive stages of discoloration and decay in living trees.* Can. J. For. Res. 2:54-56.
16. Tattar, T.A. 1976. *Use of electrical resistance to detect Verticillium wilt in Norway and sugar maple.* Can. J. For. Res. 6:(In Press).
17. Vanden Driessche, R. 1973. *Prediction of forest hardiness in Douglas fir seedlings by measuring electrical impedance in stems at different frequencies.* Can. J. For. Res. 2:256-264.
18. Wargo, P.M., Skutt, H.R. 1975. *Resistance to pulsed electric current—an indicator of stress in forest trees.* Can. J. For. Res. 5:557-561.
19. Warner, C.D. 1893. Electricity in agriculture. Mass. Agric. Coll. Bul. 23 15pp.
20. Wilner, J. and E.J. Brach. 1970. *Comparison of radio telemetry with another electric method for testing winter injury of outdoor plants.* Can. J. Pl. Sci. 50:1-8.
21. Wilner, J. 1967. *Changes in electric resistance of living and injured tissues of apple shoots during winter and spring.* Can. J. Pl. Sci. 47:469-475.
22. Wilson, C.W. and C.E. Seliskar. 1976. *Mycoplasma-associated diseases of trees.* J. Arbor. 2:6-12.

BASIC INFORMATION ON INSECTICIDES AND THEIR USE[1]

by Roscoe Randell

Insect control includes much more than the application of various chemicals in an attempt to eliminate an insect population. Insect control involves everything that suppresses an insect population or prevents it from increasing to damaging numbers.

Insecticides are just one group of tools available for insect control. They are chemical or