DECAY RESISTANT TREES

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ABSTRACT.--Compartmentalization of discolored and decayed wood in trees seems to be under genetic control. CODIT is a model that explains compartmentalization in living trees. The Shigometer is an electrical pulsed-current meter that can nondestructively detect discolored and decayed wood in living trees. CODIT and the Shigometer now make it possible to start selecting for trees that can effectively compartmentalize discolored and decayed wood to smaller volumes than other trees of the same species. In this sense, we can identify decay-resistant trees.

Tree decay, like death, is accepted as an event we can not stop. This may be so, but, must we die today? We can live a long and productive life if we take the necessary precautions. And, so with trees. They can live long, defect-free lives if the necessary precautions are taken.

We now have new information from many wounding experiments, new tools, and a new model that gives us new opportunities to minimize greatly the damage caused by discolored and decayed wood in living trees. It is now possible to identify decay-resistant trees.

THE DATA

Dissections of thousands of trees during the last 19 years suggested that some trees of the same species with similar experimentally inflicted wounds had smaller columns of discolored and decayed wood than other trees. This phenomenon also was observed in trees dissected in wound dressing experiments. In some trees, the experimentally inflicted wounds had very small columns of discolored and decayed wood; in other trees, the wounds had longer columns. There was no relationship among treatments; it was the tree itself more than the wound dressing that promoted wound closure (Shigo and Wilson 1977). The phenomenon was again observed in a group of logs from a hybrid poplar cutting. Trees from some clones had large central cores of discolored wood, while trees from other clones had small central cores. The discolored cores were associated with branch stubs (Garrett and others 1976).

Experiments were designed to determine whether the compartmentalizing of discolored wood was more associated within clones than as a random feature. Nine trees in three clones of *Populus deltoides* X P. *trichocarpa* compartmentalized effectively the discolored wood associated with wounds: after 6 months, only small columns of discolored wood were associated with the 14 experimentally inflicted wounds per tree. Eighteen trees in six other clones compartmentalized poorly the discolored wood associated with the wounds: after 6 months, large columns of discolored wood were associated with the wounds. Wound closure and tree diameter were not related to percentage of stem that was discolored. The results suggested that compartmentalization of discolored wood associated with wounds may be under genetic control (Shigo and others 1977a) (Fig. 1). Additional studies on the 60 trees from the 9 different clones showed variations in patterns of compartmentalization (Shigo and others 1977b).

Studies on cottonwood, sweetgum, and black walnut now in progress also suggest that the compartmentalizing capacity of trees is under genetic control.

WHAT IS COMPARTMENTALIZATION?

Trees are highly compartmented plants. In a sense, each growth ring can be considered a tree. Each growth ring is subdivided into compartments. The radial sides are formed by ray cells, tangential sides by the last cells that form in the growth ring, and the transverse top and bottom by fiber ends, and, after wounding, plugged vessels or aspirated pits in tracheids.

After wounding, the defense system of the compartmented tree is activated to compartmentalize the injured and infected wood. Trees evolved under the constant stress of wounding. The wound healing process had limited survival value for long-lived trees. Heal means to repair, replace, or restore injured or infected tissues to a previous healthy condition. When wood is injured and infected, it is never repaired or replaced or restored to its previous healthy state. In this sense, trees do not heal wounds. Instead they wall off, confine, isolate, or compartmentalize the injured and infected wood. So compartmentalization has greater survival value for long-lived trees than the healing process.

Figure 1.--Hybrid poplar A was a strong compartmentalizer. Small columns of discolored wood were associated with 14 drill holes inflicted 1 year ago. All trees in this clone reacted the same way. Hybrid poplar B was a weak compartmentalizer. Almost the entire trunk was discolored as a result of the 14 drill holes inflicted 1 year ago. All trees in this clone reacted the same way. Growth rate and wound closure were not related to the capacity to compartmentalize the discolored wood.

Another very important feature of compartmentalization is the activity of the cambium after wounding. The cambium begins to form a new protective tissue called the barrier zone. This zone separates the tissues present at the time of wounding from those that will continue to form in subsequent years.

Compartmentalization is a combination of biochemical and anatomical processes.

WHAT IS CODIT?

To help explain how a tree is compartmented and how it compartmentalizes injured and infected wood, a model called CODIT was developed; CODIT is an acronym for Compartmentalization Of Decay In Trees (Shigo and Marx 1977). The model uses terms such as Walls 1,2,3, and Wall 4. Walls 1 are the top and bottom of the compartment. After wounding, a tree exerts a force to minimize the longitudinal spread of the infection. Walls 1 are the weakest walls, because microorganisms usually infect upward and downward first. Walls 2 are tangential walls. They are moderately strong. Walls 3 are the strongest walls in the tree at the time of wounding. Wall 4 is the protective wall or the barrier zone formed by the cambium after wounding. The barrier zone or Wall 4 should not be confused with callus tissue.

Some trees have very strong preset anatomical Walls 1, 2, and 3. They also have very active or responsive systems of chemical protection that are activated after wounding. This active wound response results in a very small defect column. But if a tree has very weak Walls 1, and a slow chemical protection system, the infecting force of the microorganisms can result in very large columns of defect.

If Walls 1, 2, and 3 fall to the infecting microorganisms, Wall 4 is the final barrier. A tree with a weak Wall 4 probably will die soon after it is first wounded.

In the genetics of compartmentalization and the identification of strong compartmentalizers, the focus is on Walls 1, 2, and 3 that are preset in the tree before wounding, and the capacity of the tree to activate the compartmentalizing system immediately after wounding. The chemical protection system is activated even when trees are wounded during the dormant season. The formation of Wall 4 and other processes begin later when growth resumes.

It should be emphasized that CODIT is a model and is not intended as an anatomical or biochemical explanation for compartmentalization.

WHAT IS THE SHIGOMETER?

The Shigometer is an electrical device that delivers a pulsed electric current and measures electrical resistance to it up to 500 kΩ (Shigo and Shigo 1974; Shigo and others 1977). When used properly with a variety of probes and probing methods, the Shigometer provides valuable information on patterns of resistance that are associated with changes in wood tissues. The Shigometer can be calibrated in a few minutes.

Many changes take place in wood as it progresses from sound to infected, to invaded, to early decay, and finally advanced decay. In the early stage of infection and invasion, there is very little weakening of the wood. As the decay progresses, the moisture content of the wood may increase, and microelements may concentrate in the invaded tissues. The wood then begins to lose some of its weight--the specific gravity decreases. At this point we say that decay has set in.

When a pulsed current is passed through wood in progressive stages of decay, the current encounters decreasing resistance. The exact reason for this is not known, but it is probably because of the effect of several factors leading to higher concentrations of microelements in the wood, and decreased specific gravity.

The Shigometer functions only above the fiber-saturation point of wood tissues, the point at which the walls of the wood cells are saturated with moisture. The fiber-saturation point is approximately 27 percent (weight/weight).

Measurements for internal decay are made with a special twisted-wire probe; an abrupt drop in electrical resistance indicates decay. A hole 3/32 inch in diameter is drilled into the tree horizontally.

A hole is made with an 8- or 12-inch drill bit mounted on a lightweight battery-powered drill. The time it takes to drill the hole depends on the skill of the operator; usually it takes 5 to 20 seconds.

Insert the probe slowly with an even motion. While inserting, hold the probe with your fingers as close to the tree as possible to keep the probe from bending. Read the resistance on the meter frequently while the probe is being pushed in. When there is an abrupt decrease, the probe may be pulled out slightly, and pushed in again very slowly to determine the exact depth at which the decrease occurred.

For very accurate measurements to determine the exact position of the decay, check where the needle begins to drop abruptly. Hold the probe at that position and pull it out. The depth of the rear knuckle on the probe tip will indicate the position of the outer rim of decay.

NOW WHAT?

The data from wounding experiments, CODIT, and the Shigometer now give us an opportunity to identify trees that are strong compartmentalizers; it seems that effective compartmentalization is under genetic control.

Decay resistance here means smaller columns of decay, not an intrinsic resistance to decay-causing microorganisms. Stated another way, it is not as important to say whether or not a tree has decay as it is to say how much decay there is. There are many species of decay-causing microorganisms, and the process of decay is further complicated because these microorganisms infect in succession. So it is nearly impossible to select for decay resistance on the basis of resistance to attack by microorganisms. As a result, the search for a decay-resistant tree continues without success. Strong compartmentalization means that decay that does set in will be confined to a very small volume.

To determine whether a tree is a strong or a weak compartmentalizes, it should be wounded and dissected to measure the extent of the defect associated with the wound. This has been done, and is being done now with several species of trees. But how can you do this if you cannot afford to cut the tree?

Here is where CODIT and the Shigometer can be of value. CODIT tells us that the columns of discolored and decayed wood associated with experimentally inflicted wounds will develop in a predictable pattern or configuration. The Shigometer can be used to nondestructively assess the internal condition of the wood associated with the wound.

HOW IS IT DONE?

To test the capacity of a tree to compartmentalize, first drill at least 4 holes, 5 cm deep with a large drill bit, at least 2 cm in diameter. The wounds should be in a whorl, equally spaced around the bole at approximately 1.4 m above ground. The number of wounds and their size will, of course, depend on the size of the tree.

After a year, drill a hole 5 cm deep, at 20 cm above the old wound. Use the 3/32-inch drill bit that is part of the Shigometer package. Drill a similar hole 5 cm to the left or right of the first hole. For both new holes, use the twisted-wire probe to determine the electrical resistance of the wood at 5 cm. The hole directly above the wound will penetrate discolored or decayed wood; the hole to the left or right will be in sound, healthy wood. The electrical resistance of the sound wood will be the control measurement. A lower resistance reading for the treatment hole indicates the amount of deterioration of the wood relative to the control.

For example, if the control hole and the treatment hole both have a reading of 100 kΩ, then a few short columns of wood is associated with the treatment hole. But if the control is 100 kΩ and the treatment hole is 10 kQ, then the ratio is .1, indicating a great departure from the control. As the ratio decreases from 1, the wood in the treatment hole is more deteriorated. In some cases, additional holes at 40 cm above the wound should be made. To determine the length of the column, continue to drill probe holes above the wound until both readings are approximately the same (Fig. 2).

With this technique the tree is only slightly wounded, and it can be used for seeds or cuttings. A similar technique can be used without wounding trees. The Shigometer can determine the width of clear, sound wood in trees that have been selected as superior trees, on the basis of growth rate and form. The internal condition will then show the capacity of the tree to compartmentalize branch stub wounds.

THE FUTURE

Because a tree is growing rapidly and has good form does not mean that it is free of defects--the tree may have escaped wounding. As we select trees for our plantations and for the city, we must know the compartmentalizing capacity of the trees because wounding will occur eventually.

We must start selecting for strong compartmentalizers now to develop decay-resistant trees.

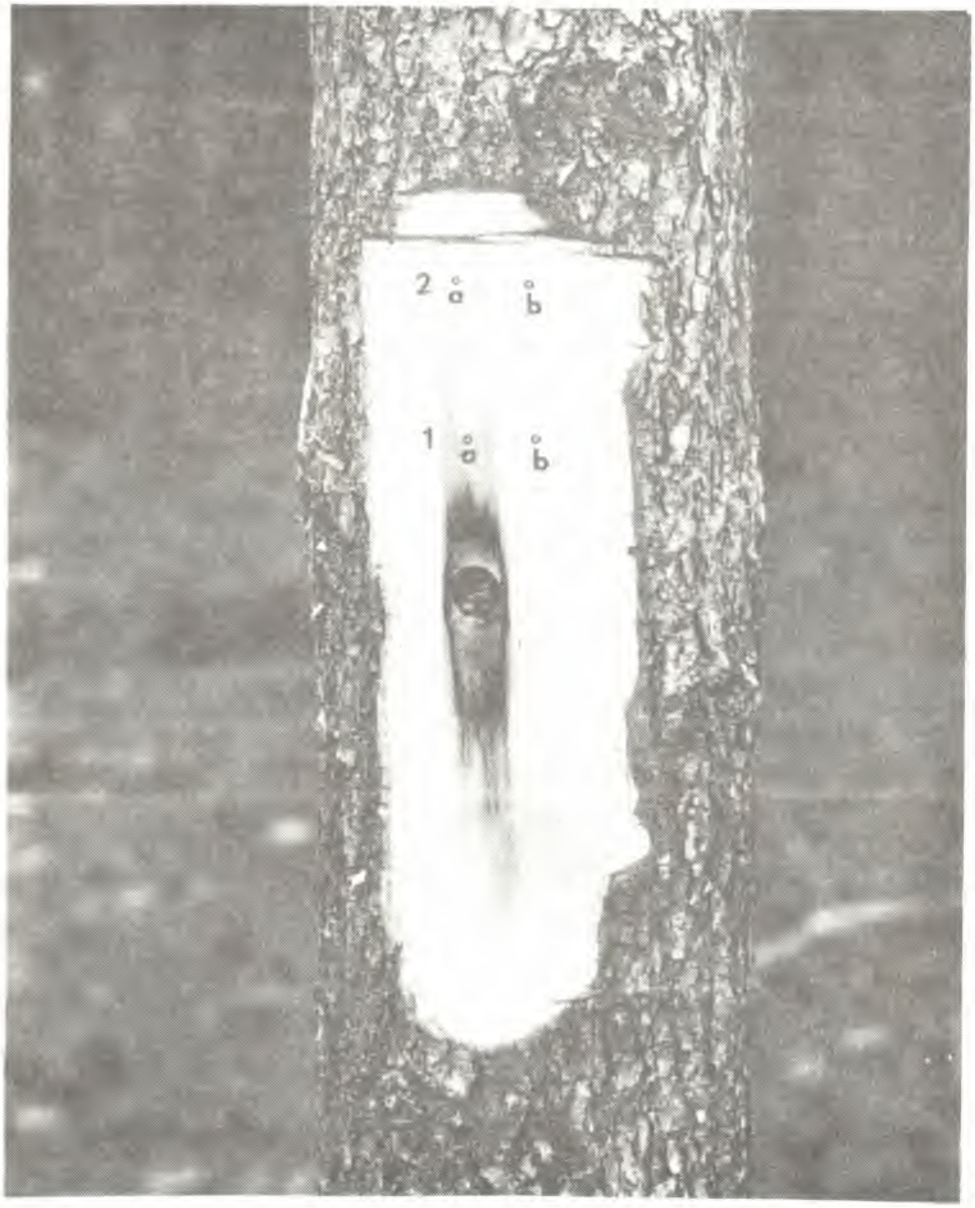

Figure 2.--Bark and wood removed from a 1-year-old drill wound show how the Shigometer nondestructively determines the extent of discolored wood associated with experimentally inflicted drill wounds. Drill 3-cm deep holes at positions 1a and 1b. Insert the twisted wire probe attached to the Shigometer. Record resistance at this point. If 1a is much lower than 1b, drill additional holes above as shown for 2a and 2b. When the control holes (2a and 2b) have resistance similar to the holes vertically above or below the drill hole, the end of the column will be determined.

LITERATURE CITED

Garrett, Peter W., Alex L. Shigo, and Jonathan Carter. 1976. VARIATION IN DIAMETER OF CENTRAL COLUMNS OF DISCOLORATION IN SIX HYBRID POPLAR CLONES. Can. J. For. Res. 6:475-477.

Shigo, Alex L., and Richard Campana. 1977. DISCOLORED AND DECAYED WOOD ASSOCIATED WITH INJECTION WOUNDS IN AMERICAN ELM. J. Arboriculture 3:230-235.

Shigo, Alex L., and Alex Shigo. 1974. DETECTION OF DISCOLORATION AND DECAY IN LIVING TREES AND UTILITY POLES. U.S. Dep. Agric. For. Serv. Res. Pap. NE-294. 11 p.

Shigo, Alex L., Walter Shortle, and Peter Garrett. 1977a. COMPARTMENTALIZATION OF DISCOLORED AND DECAYED WOOD ASSOCIATED WITH INJECTION-TYPE WOUNDS IN HYBRID POPLAR. J. Arboriculture 3:114-118.

Shigo, Alex L., Walter Shortle, and Peter Garrett. 1977b. GENETIC CONTROL SUGGESTED IN COMPARTMENTALIZATION OF DISCOLORED WOOD ASSOCIATED WITH TREE WOUNDS. For. Sci. 23:179-182.

Shigo, Alex L., Walter C. Shortle, and Julian Ochrymowych. 1977. DETECTION OF ACTIVE DECAY AT GROUNDLINE IN UTILITY POLES. U.S. Dep. Agric. For. Serv. Tech. Rep. NE-35. 26 p.

Shigo, Alex L., and Charles L. Wilson. 1977. WOUND DRESSINGS ON RED MAPLE AND AMERICAN ELM: EFFECTIVENESS AFTER FIVE YEARS. J. Arboriculture 3(5):81-87.

Footnote

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