INHERITANCE OF COMPARTMENTALIZATION OF WOUNDS in Sweetgum (*Liquidambar styraciflua* L.) and Eastern Cottonwood (*Populus deltoides* Bartr.)

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Abstract

Studies of half-sib progeny tests of sweetgum (*Liquidambar styraciflua*) and clonal plantings of eastern cottonwood (*Populus deltoides*) in Mississippi indicate that rate of wound closure and size of discolored columns associated with the wounds are both heritable traits. Both are independent of stem diameter, which was used as a measure of tree vigor in these studies. Selection for rate of closure would not be useful, but selection for compartmentalization of discoloration and decay resulting from wounding would be valuable in forest and amenity trees and could be applied immediately to existing improvement programs for these species.

INTRODUCTION

MOST PLANT BREEDING programs emphasize improved yield. In some instances resistance is sought to insects or diseases that either kill the host or produce visible damage. For annual crops these may be the most important goals, but for perennial plants, including trees, the long cycles present some unique problems that will require some unique approaches to improvement. We are talking about organisms that produce *internal* discoloration and decay that only becomes apparent when the tree is felled.

Some recent estimates of cull in northern hardwood stands indicate a volume loss of between 25 and 35 percent (Schmitt et al. 1978). Similar estimates for hardwood stands in North Carolina have been published (U.S. Forest Service 1976). There may be some disagreement about methods used to derive these figures, but no one who has looked at these stands would question the fact that considerable losses are occurring.

Wounds of all types, including branch stubs, are the principal infection ports where the processes leading to infection, wood discoloration, and eventually decay in living trees start. Previous wounding studies have concentrated on rate of callus formation and wound closure, and for many years closure and "wound healing" were almost synonymous. But the ability of the tree to cope with external damage is much more complex than that, and, in fact, may not be related to closure at all. If we accept the medical definition for healing, "restored to the original condition," then plants do not heal wounds. While it is true that trees may physically seal off and overgrow visible wounds, it appears that there are at least two internal defense mechanisms that start to operate when wounding occurs. There are chemical barriers that keep out most wood-destroying microorganisms, and to combat those organisms that do manage to get by the first line defenses, trees have another system for

compartmentalized wounds more rapidly than others (Shigo and Wilson 1977). Other studies with clones of *Populus deltoides* × *P. trichocarpa* suggested that closure and compartmentalization might be under genetic control (Garrett et al. 1976, Shigo et al. 1977a, Shigo et al. 1977b). If it is possible to select trees that are strong compartmentalizers, and if this trait is heritable, then wound-resistant trees could be bred. They would find immediate application in the nursery trade and could be equally important in tree improvement programs for reforestation.

Two things are essential for this to work. The first is a nondestructive method of determining response to artificially induced wounds in trees that are to be preserved as parental stocks in seed orchards. The Shigometer, which requires only a 2.4 mm (diameter) hole, enables us to differentiate between healthy and discolored or decayed wood associated with wounds (Shigo 1974). The other essential is that disease resistance by compartmentalization be a heritable trait that can be incorporated into a breeding program. Heritability was tested using half-sib families of *Liquidambar styraciflua* L. (sweetgum) and clones of *Populus deltoides* Bartr. (eastern cottonwood). The results of those tests are summarized in this paper.

MATERIALS AND METHODS

Sweetgum

A 12-year-old one-parent progeny test of sweetgum involving 81 families collected in the lower Mississippi Valley from Tennessee to the Gulf Coast was used for this study. Forty-four families are from parents selected for phenotypic superiority and 37 are random selections. Ten replicates were planted on the Delta Experimental Forest near Greenville, Mississippi, in a 9 × 9 balanced lattice design. Survival was good and early growth of seedlings from the random selections was as good as from the superior phenotypes.

One tree in each replicate of each family used to make a wound approximately 2 centimeters in diameter and 3 centimeters into the stem. Wounding was completed in mid-March 1976, before the growing season had begun.

Early wound closure was recorded in mid-June and wounded trees were cut in early October. Cross-sectional discs thick enough to include all discoloration were taken from each wounding level. Late wound closure measurements were taken and then discs were cut vertically through the wounds on a bandsaw to expose any internal discoloration or decay resulting from the treatment.

Genetic, phenotypic, and environmental correlations were calculated; estimates of the variance components were obtained by the analysis of variance method, and heritability was estimated from them for wound closure, discoloration, decay, and tree size.

Figure 1.—Radial view of two trees representing different half-sib families of sweetgum showing extremes of compartmentalization of discoloration associated with artificially induced wounds.

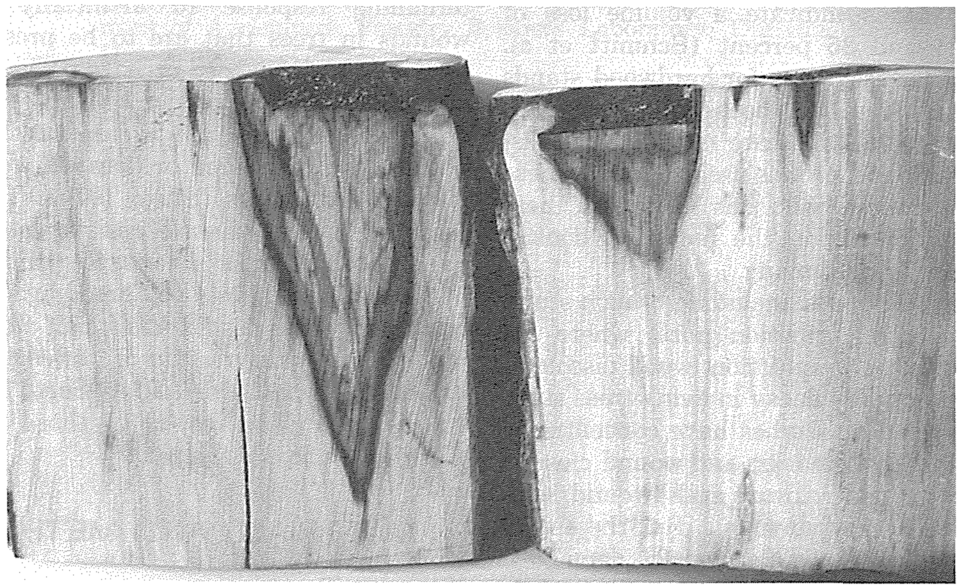

Figure 2.—Transverse view of two clones of eastern cottonwood showing wounds, wound closure, and the degree of discoloration associated with internal compartmentalization.

Cottonwood

A 7-year-old clonal test of eastern cottonwood was selected for this study. Four cuttings each of 59 clones were planted in 5 replicates at Huntington Point near Greenville, Mississippi. A 12 × 12 foot square plot was used and the trees received the standard cottonwood care on these bottomland sites.

Early survival was variable, as expected, with an average for the planting of 66 percent. Growth was also variable, with a mean diameter at age 5 of 7 inches (5.3 to 9.1 inches). The larger clones averaged slightly more than 11 inches by age 7. The same number of wounds were applied in the same configuration as in the sweetgum.

Early wound closure was recorded in mid-June and trees were cut in early October. Cross-sectional discs were cut, and diameter of stems (inside bark) and diameter of discolored columns were recorded.

RESULTS AND DISCUSSION

We had already found that individual trees within a species responded differently to the same level of artificial wounding. What was not known was whether compartmentalization of wound tissue was a heritable trait that would be useful in breeding programs. This study with half-sib material provides conclusive evidence that it would be possible to incorporate this additional trait into a selection program with sweetgum.

The heritability estimates for early closure, discoloration (combined) and decay (combined) are the most interesting traits, and the last two indicate that gains could be achieved through a selection program (Table 1).

By the end of the growing season wound closure of even the slowest closing trees had progressed to nearly the same stage as that of the more active trees. If closure were an important factor in limiting internal decay processes, one would expect that rapid closure would be desirable and negatively correlated with discoloration and decay. In fact, these traits were not significantly correlated, suggesting that even the most rapid rates observed in sweetgum are not sufficient to prevent the entry of the ubiquitous disease organisms.

Heritability figures for discoloration of wood above the wound were very high; those for combined measurements were still fairly high; but those for areas below the wounds were not significantly different. Discoloration was positively correlated with decay but negatively correlated with total stem diameter at 1.0 meters. We did not record the width of the last ring, or the most recent set of rings; consequently, we are using total tree size as an indication of vigor. We recognize the possibility that growth of individuals differs and that some trees may have gotten off to a slow start before entering a period of faster growth. The end result of this would be two trees with the same current diameter but entirely different current growth patterns. The sampling procedure used in this study and the results

Table 1.—Estimates of heritability

Trait	Heritability—plot means	
	Sweet-gum	Cotton-wood
Early closure	1.59	0.74
Late closure	0.00	
Discoloration above wound	1.67	
Discoloration below wound	0.59	
Combined discoloration	1.51	
Decay above wound	1.05	
Decay below wound	1.17	
Combined decay	1.38	
Diameter column/diameter tree		0.69

Equations for estimating heritability:

$$h^2 \text{ (sweetgum)} = \frac{4\sigma_f^2}{\sigma_f^2 + \frac{1}{R}\sigma_e^2}$$

$$h^2 \text{ (cottonwood)} = \frac{\sigma_c^2}{\sigma_c^2 + \frac{1}{R}\sigma_e^2}$$

›tained suggest that our analysis is essenally correct and that in fact there is no cor-lation between rapid growth and wound osure, discoloration, or decay.

Growth rate for cottonwood, and especially ι this planting, is exceptionally fast and ounds closed very rapidly. Many wounds ere closed by the first recording period in une, and all but a very few were completely ealed by October when the discs were cut.

While the numbers are generally smaller han with sweetgum, the heritability estimates or early closure and diameter of discoloration olumns indicate that both are under genetic ontrol, so discoloration could be minimized in tree improvement program (Table 1). Wound losure was extremely rapid in this species and as not significantly correlated with diameter f the discoloration columns.

CONCLUSIONS

Earlier experiments using a variety of wound ressings on red maple and American elm indiated that treatment of trees immediately fter wounding did not help contain decay nd discoloration in the stem. Treated and ntreated trees reacted similarly (Shigo and Vilson 1977).

The results of our studies and the earlier ork with wound dressings are conclusive roof that it is the act of opening the tissue or colonization by disease organisms and not he rate of closure that is important. Once the ound is made, by whatever means, the ineritant capacity of the tree to compartmenalize the affected tissue will decide how much liscoloration and decay will result.

While the numbers were generally smaller in cottonwood than in sweetgum, the heritability estimates for early closure and diameter of discoloration columns indicate that both are under genetic control; again, the second parameter would be useful in a tree improvement program.

The differences in column size in cottonwood were much more spectacular even though the heritability figures are slightly smaller. The ratio of discolored column to stem diameter (inside bark) ranged from 38.2 to 79.2, a difference of 41 percent.

Differences in column size in sweetgum were significantly different; however, the actual differences in family means were only 5.5 centimeters (column above the wound). It should be pointed out that the wound size used in these studies was small in comparison to the natural and man-caused wounds that trees are regularly subjected to, and the larger the wound, the larger the column. While the relative differences may be the same for wounds of different sizes, the actual differences will be substantial.

From this and earlier studies it seems obvious that a new and useful tool has been found, one that can be immediately applied in existing improvement programs where a number of select trees have already been identified. Trees that are now included because of size, volume, branchiness, wood density, insect resistance, etc., can be wounded and their response checked with a Shigometer as one additional selection criterion.

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