How Can We Improve Southern Hardwoods Through Genetics?

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Before discussing the genetic potential of hardwoods we must define the objectives in hardwood tree improvement. We can safely generalize and say that any tree-improvement program is going to have as its major goal the increase in genetic potential for rapid growth and superior tree quality. Rapid growth is an easily understood characteristic, but tree quality is a more complicated concept.

The quality of a hardwood log is determined by its size and shape, and particularly by degree to which it is free from defects like knots, holes, bark pockets, stain, and rot (Lockard, Putnam, and Carpenter 1950). In general, freedom from defects is more important than species in determining the value of an individual tree. Increasing the proportion of high-grade material within the tree therefore will be an important facet of tree improvement, and will require evaluation for tree form, branching characteristics, and resistance to insects and diseases.

When hardwoods of improved strains have been developed, they will probably be grown in plantations. We don't know how most species will respond to this kind of culture. The performance of cottonwood has generally been good, but unexpected problems may arise such as the stem disease which is attacking cottonwood plantings along the Mississippi River. Undoubtedly, hardwoods grown in plantations are going to require different management procedures from those for natural stands, and tree breeders and silviculturists will have to work in full cooperation to develop such procedures. Among other things, the possibility of plantings of mixed species as well as single species should be explored.

Beyond general concepts we must cease speaking of hardwoods as a group and concentrate on individual species. Some 140 hardwood species are native to the South. Of these, between 60 and 70 are of some commercial importance (Putnam, Furnival, and McKnight 1960). These 60 to 70 species represent 25 genera that differ in morphology, site requirements, and utilization. Are we considering a species of oak or ash? These species commonly grow in mixed stands, a fact which complicates comparisons among individual trees. Or are we considering cottonwood, which usually occurs in pure, even-aged stands in which comparisons of individual trees with their neighbors are quite easy? Some species, such as sweetgum, occur in both mixed and pure stands. How should this affect our criteria of individual tree selection?

In discussing seed production, we must again relate our comments to individual species, for they differ in floral morphology and pollinating agent. Cottonwood is a dioecious species; yellow-poplar has perfect flowers. Yellow-poplar is insect-pollinated while many other hardwoods are wind-pollinated. Differences such as these will influence the development of techniques for controlled pollination and eventual methods of producing commercial quantities of seed of improved stock.

Finally, characters to be improved and their relative importance will vary from one species to another, depending upon species characteristics and utilization practices.

When we have designated the species we want to work with and defined our objectives for that species, we can begin systematic research to attain these objectives. You have heard the various steps in tree improvement discussed in detail at previous meetings. The initial step is to assess the variation present in the species for characters of interest. The next job is to estimate heritability for these characters, i.e., determine how much of the variation is under genetic control and how much is due to environmental effects. The modification of that portion of the variation which is under genetic control is the final phase of the improvement program.

Considering these steps in tree improvement, where do we stand now with some of the major commercial hardwoods of the South? I would like to review what has been done to date on five representative southern hardwood species, or genera, as applicable to the South. These include sweetgum, yellow-poplar, cottonwood, several oaks, and green ash.

Sweetgum and yellow-poplar occur throughout much of the Eastern United States. Their wood is used for a variety of products including lumber, veneer, cabinetwork, and, especially in sweetgum, pulpwood. Cottonwood reaches its maximum development on the bottomlands adjacent to the lower Mississippi River. At the present time the greatest quantity of cottonwood goes into veneer and saw logs, with pulpwood a promising outlet for the future. This species is planted in greater quantities than any other hardwood in the South today. Several species of oak grow rapidly, generally develop good form, and have a variety of uses including lumber, veneer, cooperage, and pulpwood. Ash is a high-value species used primarily in the manufacture of handles, sporting goods, and furniture.

Sweetgum

The literature on variation in sweetgum is limited to variation in leaf morphology (Holm 1930; Duncan 1959). There is no information on inheritance patterns for any characteristics. Studies on patterns of variation in wood quality characteristics are under way at North Carolina State College. Other work there and at the Institute of Forest Genetics, Southern Forest Experiment Station, includes studies of flowering habits and pollination techniques, and progeny tests from individual parent trees. This research will provide information on geographic variation as well as on inheritance patterns for economically important characters.

Characters which are receiving major attention include resistance to epicormic sprouting and, since sweetgum is the leading hardwood pulp species in the South, wood quality. Epicormic sprouting frequently occurs along the upper and middle portions of the bole in response to environmental distuybances such as extreme release from competition. Although careful management can reduce the extent of sprouting, there is an immediate need for some method of evaluating individual-tree variation in this character during the juvenile stage. Otherwise it will not be possible to evaluate progenies for resistance until they have attained considerable size, and improvement for this characteristic will be an extremely slow process.

Wood quality is a complex characteristic involving density, fiber length, and cellulose content. Since hardwood pulps are commonly used in blends with longer fibered pulps, increasing fiber length should increase the proportion of hardwood pulps in these blends. Sweetgum is particularly important in the manufacture of dissolving pulps and, since cellulose is the desired product, high cellulose content would be a desirable feature of improved strains. Any speculation on the improvement potential for these and other characters will have to await results of the research mentioned previously.

Yellow-Poplar

Seed source studies with yellow-poplar show a general north-to-south trend in resistance to cold (Funk 1958; Sluder 1960). Sluder (1960) reported better survival of the local source than of sources from several other geographic locations. Height growth of local yellow-poplar has been reported to be as good as or better than that of seedlings from other locations (Sluder 1960; Lotti 1955). In one study (Limstrom and Finn 1956) significant differences (0.05 level) appeared among six geographic sources in average height of 1-year seedlings. Variation in height of progenies from different trees was equally significant (0.05 level). Often the variation in height among seedlings from a single tree exceeded the mean difference in progeny height among trees and seed sources.

The data just mentioned are from young stands, 5 years or less in age. Whether the patterns will persist to maturity and be evident for additional characters is problematical.

Thorbjornsen (1961) reported variations in wood quality characteristics in natural stands. He found that wood density varied considerably among individual trees within stands but discovered no differences among stands. He concluded that relatively rapid improvement could probably be made by selecting and breeding for high density. In fiber length, the variation within trees exceeded both the variation among trees and among stands, an indication that selection for long fibers would probably not result in a marked increase in fiber length.

Several studies on variation in seed quality and effects of pollination are well worth mentioning, since they will probably influence the methods and techniques used in improvement programs. Limstrom (1959), comparing seed quality from five trees in each of six stands over a 3-year period, found as much variation among individual seed trees within a stand as among stands. Seed quality varied considerably from year to year.

There is general agreement that self-pollination results in markedly reduced seed set as compared to cross-pollination. Self-pollinations yield up to 11 percent filled seed while cross-pollinations yield up to 60 percent filled seed (Boyce and Kaeiser 1961b; Carpenter and Guard 1950; Guard 1943; Wright 1953).

Efficient control-pollination techniques have been developed for the species (Taft 1962). Seedlings from cross-pollinations tend to be more vigorous than seedlings from wind pollinations. Pollen from distant trees tends to produce the greatest increase in vigor (Carpenter and Guard 1950).

Boyce and Kaeiser (1961b) concluded that yellow-poplar trees are not freely interbreeding under natural conditions and that there is a low rate of gene interchange among stands. Self- and cross-incompatibilities are important, as adjacent trees are likely to be closely related and less compatible than trees a mile or more apart.

The results cited indicate that yellow-poplar has a high potential for improvement in growth rate as well as in wood density. The most immediate gains will probably result from interpollinations among stands within broad geographic areas rather than from the use of open-pollinated seed from selected trees. Orchards of outstanding trees from several stands should produce seed of good viability, and subsequent stands with good vigor.

Cottonwood

Several studies have been made on wood quality variation in eastern cottonwood. Kaeiser (1956) reported that fiber length within trees increased as number of rings from the pith increased.

In one study stem diameter and number of annual rings accounted for an estimated 50 percent of the fiber-length variation within and among cottonwoods. The genetic variance was estimated to be about 30 percent. High correlation coefficients were reported for mean fiber length among rings of the same tree. The twentieth ring from the pith had the highest correlation with all other rings and was the best ring for comparing fiber length among trees (Boyce and Kaeiser 1961a).

Statistically significant differences in specific gravity and fiber length have been reported between clones of cottonwood (Gabriel 1956).

In studies being carried on by the Southern Hardwoods Laboratory in cooperation with the Institute of Forest Genetics, progenies from individual parent trees have differed significantly (0.05 level) in growth rate, branching, and resistance to *Melampsore* rust. When the progenies are clonally propagated under commercial planting conditions, they are expected to yield much valuable information on inheritance patterns of these and other characters.

Probably the bulk of the cottonwood planted in the South will be from unrooted cuttings. This asexual method of propagation will undoubtedly influence the kind of breeding program followed and the final product of any improvement program. Once favorable genotypes are developed they can be multiplied with no genetic change, and selected clones can be planted together over extensive acreages for maximum production with no danger of diluting the superior genetic stock.

Cottonwood is very sensitive to apparently minor site differences, and one improvement problem will be the isolation of genotypes that will perform consistently well throughout plantations.

Cottonwood shows a high potential for improvement in growth rate and wood quality characteristics. Its rapid growth on good sites combined with the relatively short rotation age will mean that progenies can be evaluated for economically important characteristics sooner than most other hardwood species. Hence improvement should be more rapid than with other hardwoods.

Oaks

As with the species already discussed, much of the data on variation is from reports of juvenile characteristics manifested in seed-source studies. Genetic differences among seedlings of four seed collections of Shumard oak have been reported (Gabriel 1958). Seed sources ranged from Illinois to Florida. In plantations in Pennsylvania, seedlings of northern origin suffered less dieback and grew more rapidly during the early part of the growing season than seedlings of southern origin.

Two-year data on seed-source studies with Shumard oak, bur oak, and water oak indicated that these species should be classed as geographically variable (Wright 1957). All three species exhibited variation in growth rate and autumn coloring associated with seed sources.

Single-tree progenies of five white oak and five red oak species from several locations were evaluated for earliness of germination, 1-year and 3-year height, and survival (Santamour and Schreiner 1961; Schreiner and Santamour 1961). From these studies the authors concluded that individual-tree selection appears to offer more promise for genetic improvement than ecotypic or racial selection in these species.

Variation in wood properties within and among trees of southern red oak have been reported (Hamilton 1961). Specific gravity, percentage of latewood, and toughness were inversely related to both height in the bole and age from the center. Fiber length was directly related to height and age. Some among-tree variation existed, but in most instances more variation was observed within individual trees.

A statistical comparison of the distribution of forkedness and straightness among the two largest stems of 132 sprout oak clumps indicated that the tendency to fork may be hereditary (Downs 1949).

An improvement program with any species of oak will have to overcome a number of technical problems. Especially needed are techniques for making controlled pollinations. The oaks are notoriously difficult to control-pollinate, and the most informative genetic studies as well as the accumulation of favorable genes into a superior genotype are dependent upon such pollinations.

The limited data cited indicate that early improvement should be possible in tree form as well as growth rate. Bringing together superior individuals within broad geographic areas would be the initial step. Wind pollinations among these individuals should result in progeny with good seedling vigor and good tree form.

Green Ash

Wright (1959) has summarized much of the information on the genetic variation of green ash. He differentiated (1944) a northern ecotype and a Coastal Plain ecotype on the basis of growth rate, petiole color, and winter hardiness. Meuli and Shirley (1937) distinguished three ecotypes on the Great Plans on the basis of drought-resistance.

Information on individual-tree variation is very limited. Wright (1959) demonstrated clonal differences in hardiness of leaves to growing-season frosts among the open-pollinated offspring of a single female parent. He surmised that randomly distributed variation in pubescence and samara shape is under genetic control.

The extremely limited information on this species does not permit an estimate of progress to be made in tree improvement.

Summary

Beyond these few species, or genera, data on variation and patterns of inheritance in important southern hardwoods are either extremely limited or completely lacking. For example, there is no information on the extent of variation or on patterns of inheritance for important characteristics of sycamore, willow, black cherry, and the tupelos.

In summary, then, just what answers do we have to the questions, "What do we know about inheritance patterns of southern hardwoods and how can we get improvement through genetics?"

We actually have very little information about inheritance patterns of southern hardwoods. We have good evidence from seed-source studies that several juvenile characteristics, including survival and early growth, are under genetic control. The information at this stage is limited, but the studies will yield more data as they mature. Research on wood quality of yellow-poplar, cottonwood, and oak indicates that enough of the variability is under genetic control to make selection profitable in these species.

In spite of the limited information on inheritance patterns, we know we can get improvement through genetics. The genetic principles that apply to other plant and animal species apply to southern hardwoods as well. Selection of individuals with desirable characteristics and their propagation, clonally or from seed, should result in timber stands that are better than the average forest of today. As results of current and future research become known, optimum ways of combining germ plasm from selected individuals will bring further benefits. The genetic potential is available to us. The development and application of breeding techniques can improve southern hardwoods to their full potential.