GENETIC IMPROVEMENT OF SOUTHERN HARDWOODS: THE CURRENT STATUS OF RESEARCH

By

Robert E. Farmer, Jr.
Plant Geneticist
U. S. Forest Service, Southern Hardwoods Laboratory
Southern Forest Experiment Station
Stoneville, Mississippi

Genetics research in southern hardwoods has moved, during the past decade, from a minor position in a few organizations to major status in most of the South's forest research establishments. This new interest in hardwood tree improvement has stemmed largely from (1) the increasing use of hardwoods for pulp and (2) a decreasing supply of high-quality hardwood sawtimber. These two aspects of the southern hardwood situation have stimulated broad programs of investigations in which genetics research is essential.

It is generally conceded that southern hardwood forestry of the future will be intensive; in many places foresters will be competing with farmers for use of land. Success will depend upon full site utilization via complete control of species and stocking, high levels of cultural practice and pest control (4). In some instances, radically new silvicultural concepts such as "sycamore silage" (3) may be the key to economic success. To realize the full potential of these costly silvicultural techniques, the best stock available must be used. On some sites and with some techniques, genetically improved stock may be essential, not simply advantageous.

It is with this prospect of intensive management in mind that I wish to review the goals of hardwood genetics research, the status of knowledge, and prospects for its application in the not-too-distant future. A number of review publications (1, 2, 5, 6, 7, 8) have appeared recently, and my summary is based partly upon them.

Species and Goals

Approximately 30 percent of the South's current tree improvement research is with hardwoods. While some research is being done with species in 12 genera, most attention is being given to sweetgum, yellow-poplar, cottonwood, sycamore, and the oaks. My comments will deal mainly with these major species. Sweetgum improvement projects are the most numerous; this tree is widely distributed in the South and is important to both paper and lumber manufacturers. Research on yellow-poplar is concentrated mostly in the Southern Appalachians and Southeast, where the species has high value for lumber. Cottonwood, an especially important pulp and lumber species in the floodplain of the lower Mississippi River, is the subject of intensive research there. Work is just beginning with some of the more valuable oaks (cherrybark, northern red, white), and with sycamore, which may be on the verge of new-found economic significance. All of these species have at least three characteristics in common; they are crucially important to one or more major segments of forest industry, they are currently being planted, and they are rapid growers on suitable sites. In other words, they are adaptable to intensive management.

The ultimate goal of tree improvement research with all hardwoods is planting stock having genetic potential for superior growth, good form, pest resistance, and desirable wood properties. However, because of dissimilarities in species, utilization and silviculture, hardwood breeding objectives probably vary more among species than in the pines; and the nature of hardwood utilization requires special emphasis on characters related to quality. Improved growth rate is a major objective in all the species. But to reach the level of quality needed by the hardwood lumber industry, the rapidly grown wood must also be free of defects caused by bad form, epicormic sprouts, poor pruning, and insect and disease attack.

Pulpmills buying hardwood, while having less stringent defect standards than sawmills and veneer plants, want wood that will give high yields of top-quality paper. Data on the relationship between wood properties and paper quality are much skimpier than for pine, but indications are that it will be desirable to develop trees with relatively dense wood and uniformly strong fibers.

Some hardwoods have well-known insect and disease problems. In cottonwood, for example, we know that troubles with twig borer and Cytospora canker are to be expected in plantations, especially on marginal sites. Melampsora leaf rust is a frequent late-summer pest that may reduce growth. Clones that are especially susceptible to these pests will be eliminated from breeding populations. In most species, however, we know little about plantation pests, simply because there are not many extensive plantations. Specific goals in breeding for pest resistance will develop as we learn more about the pests and are able to assess the possibilities of incorporating resistance into our material. In fact, breeding for pest resistance may be eventually one of the most important aspects of genetics research. At present, with the exception of the work on chestnut blight, there are no projects devoted solely to breeding against specific pests.

Organizations

Southern hardwood improvement programs are being conducted by the U. S. Forest Service, the Tennessee Valley Authority, several States, forest industries, and universities.

Forest Service research ranges from work in genetic theory to breeding projects and supporting work in physiology. Four laboratories in the Southern and Southeastern Forest Experiment Stations handle the bulk of these studies.

The objective of Forest Service investigation is to learn basic principles and methods for producing improved varieties. When breeding methods have been developed and foundation stocks developed, mass production of improved material will be the job of other organizations. The Forest Service research organization is thus not in the seed orchard business, although it plans to develop stock suitable for orchard use.

The TVA program consists of applied breeding and related research with six species of special importance in the Southern Appalachians.

University research varies from fundamental work in cytogenetics to long-term breeding programs. Dorman (1) lists thirty projects at eight southern universities. Some reflect the personal interests of faculty members; others are broad attacks on the range of hardwood breeding problems.

State and industrial hardwood improvement programs are on the increase. At least four Southern States now have staff foresters assigned to development and production of superior stock. Industrial efforts are budding; several cottonwood clonal tests are in the ground or being planned, some attention is being given to sweetgum seed production areas, and the beginnings of seed orchards in a number of species have been reported.

Most State and industrial work is aimed at producing the best material possible with current knowledge and techniques. However, these programs are necessarily research efforts; no standard procedures have yet been developed for breeding superior stock of any species.

Some of the best programs now operating are cooperative efforts between universities, Federal agencies, and State and private organizations. Furthermore, there exists a free, informal exchange of information among these groups. In short, I think hardwood improvement research is being conducted in a healthy, productive atmosphere.

Current Knowledge

At least two bodies of knowledge are essential to the design of a breeding program for any species: First, the breeder must know how much his species vary in important characters and how this variation is genetically controlled. Breeding is fundamentally a matter of selecting genetically superior material from a variable population. Second, in order to take advantage of variation through selection, he must have silvical information essential to successfully crossing, propagating and growing his breeding stock.

Variation

One of the first steps in assessing genetic variation is to determine the range in tree-to-tree variation in natural stands. This knowledge makes it possible to establish standards for choosing breeding material, an early job in any improvement project. In evaluating growth or form, the breeder may simply do a lot of walking and looking, then set realistic, yet high, selection criteria. Variation in wood properties will necessarily require more formal study, with a sampling design and statistical analysis. Variation in most of our important hardwoods has been or is being studied by sampling natural stands, and we have some useful information.

For example, we know that wood properties vary considerably in sweetgum, cottonwood, yellow-poplar, and tupelo gum, and that most of the variation is due to tree-to-tree differences within stands; smaller differences have been found between stands and geographical areas. Current studies of wood property variation in sycamore and some of the oaks should be reported soon.

While surveys of variation in natural stands are useful preliminaries, they give little direct information on the genetic control of variation. Estimates of genetic variation are obtained from provenance, progeny, and clonal tests.

Provenance, or racial, tests are designed to determine how a species varies genetically from region to region. Their results also indicate the degree to which trees can be successfully planted outside their "old home place." In brief, a provenance study consists of collecting samples from over a species' range, or part of it, and growing them together for comparison purposes at one or more locations in the range.

In the South today there are racial tests under way in cottonwood, sweetgum, sycamore, yellow-poplar, southern red oak, and water tupelo. Studies of northern red oak, black cherry, yellow birch, sugar maple, and walnut, now being conducted within the commercial ranges of these species, are also of interest to southern hardwood improvers.

The only published results from southern tests to date are for sycamore and yellow-poplar. Small provenance differences in heights of 2-year sycamore have been observed in a Louisiana planting. Yellow-poplar from 16 sources was planted in the Southern Appalachians; no significant source differences in height at 5 years were noted. Early, and as yet unpublished, results with other species indicate the presence of considerable geographic variation. In a Stoneville, Mississippi, test of sweetgum from various Midsouth sources, coastal material has made better early growth than local or Tennessee trees. In central Illinois, cottonwood from southern Illinois has performed better than local material. These data and evidence from other studies suggest the exciting possibility of improving growth rate simply by using material from a few hundred miles south of the planting site. However, much more testing will be required before this speculation can be transformed into recommendation.

Progeny tests are the breeder's main tools in most tree species. In these tests, performance of seedlings from selected parents is studied in plantings designed to allow an evaluation of genetic variation. Progeny from both open-pollinated parents and controlled crosses between parents may be used. Briefly, the progeny test is a method of determining a tree's value as a parent, i.e., the degree to which it endows its progeny with genetic potential for superior performance.

Southern research currently includes progeny tests in cottonwood, sweetgum, yellow-poplar, and sycamore. There are plans to begin cherrybark oak tests within the next two years. Most of these tests were established with progeny from open-pollinated trees; methods for making controlled crosses have either been perfected only recently or, as with the oak, have yet to be developed.

Observations to date are only for juvenile characteristics, but may be indicative of future results: In cottonwood and sweetgum, variation between progenies has been noted for height and diameter growth, branch characteristics, and spring foliation dates. Juvenile wood properties and disease resistance in cottonwood have also been shown to be under considerable genetic control. Progeny differences in yellow-poplar growth have been reported. When more data are obtained from these tests, we will be able to predict genetic improvement to be gained by selecting parents on the basis of their progenies' performance.

Some species, such as cottonwood and sycamore, may be easily propagated by cuttings. Plants thus propagated from an individual tree are genetically identical, and are referred to collectively as a clone. Final choice of genetically superior clones is based upon results from clonal tests. To date, such tests have been established only in cottonwood, a species for which we have considerable data on juvenile variation. For example, we know that clonal variation in growth, phenology, specific gravity, and Melampsora rust resistance is under moderate to strong genetic control and that effective selection can be made for these characters in clonal tests.

In brief, we are studying variation in hardwoods through direct sampling in natural stands, racial tests, progeny tests, and clonal tests. Information from all of these sources will be used to determine how we can most effectively select and use the best genetic material from a variable population. At present, we are still at the establishment stage in this work.

Silvical Characteristics

In the early phases of tree improvement research some of the most important work is not genetic, but silvical and physiological. Frequently a species' silvical characteristics dictate the nature of its breeding system.

Information on a tree's flowering characteristics is essential to developing crossing techniques. It is amazing how little foresters have known about the sex life of their trees, perhaps because it all takes place inconspicuously 50 to 100 feet above their heads. The hardwoods have an array of procreative devices. Yellow-poplar has large, perfect flowers which are pollinated by insects. Crossing techniques have been developed and are being standardly used. Low yield of seed due to ineffective natural pollination is the main problem with this species. Sweetgum is monoecious (male and female flowers occur on the same tree).

Studies of its reproductive characteristics have recently been published and a number of successful controlled crosses have been made.

Cottonwood, which has male and female flowers on separate trees, poses no major problems in crossing, although techniques need further refinement for large-scale use.

One of the physical problems with these species is making crosses at the tips of brittle branches in tall trees. This difficulty has been overcome in yellow-poplar and cottonwood by shooting down flower-bearing branches, grafting them to potted stock, and making crosses in the greenhouse. The technique also has potential for sweetgum.

As noted above, controlled crosses in the oaks are very difficult, and the literature contains little more than a botanical description of oak flowering characteristics. A major research effort will probably be required to develop techniques for these species. Sycamore, on the other hand, is similar to sweetgum with respect to flowering and should be comparatively easy to cross; studies are currently under way.

Vegetative propagation, necessary to establishing breeding arboretums or clonal seed orchards of selected trees, is not as difficult with hardwoods as with pines. During the past 10 years, cuttings from mature trees of cottonwood, sweetgum, and yellow-poplar have been grafted and rooted successfully. Stem cuttings from young sycamore root well, and we will probably encounter few difficulties with mature sycamore. The major propagation problem is with the oaks, which are moderately difficult to graft and very difficult to root. Several laboratories are working on oak propagation, and we should have suitable techniques by the time major breeding projects are started with these species.

With a few exceptions, procedures for establishing hardwood plantations have not been standardized. Hence, some planting research is necessarily being done within improvement programs. Here again the oaks are problem species, with their slow recovery from planting shock. With the other species we know that successful establishment depends upon attention to site and cultivation. One important phase of research in the near future will deal with relationships between cultural techniques and the performance of improved stock. This work should provide us with a silviculture designed to fully utilize improved genetic potential on good sites.

Breeding Systems

As one might suppose from what I have said so far, breeding systems for individual hardwood species are as variable as their silvical and genetic characteristics. Perhaps the only characteristic common to all systems is that they begin with selection of high-quality trees from natural stands. In cottonwood breeding, for example, there may be little place for the progeny-tested seed orchard so familiar to pine improvers. Instead, the goal will be development of vegetatively propagated clones with highly predictable superior attributes. Controlled crosses of superior parents will provide populations from which superior clones may be selected, rather than seed for commercial use. This sort of program is more similar to breeding sugarcane or rubber than pine.

Sweetgum, yellow-poplar, and oak programs, in contrast, will be basically similar to pine breeding systems in that seed orchard establishment will be a central feature. There will, however, be many species differences in breeding procedure within this group. Sweetgum is a self-sterile species which has abundant seed crops; it is conceivable that we may ultimately have some two-clone orchards producing sweetgum seed from single, thoroughly tested crosses. For yellow-poplar, with its pollination difficulties, the orchards may have to include many compatible, properly spaced clones. One author has suggested hiving bees in yellow-poplar orchards and coating them with compatible pollen as they leave the hive.

The exact nature of oak programs will be largely unknown until we have more genetic information on the species. It is certain, however, that open-pollinated progeny tests will be important, since both controlled crossing and vegetative propagation are difficult. At the moment we plan to select good trees, graft them into orchards, and test their progeny in rather extensive plantings. Improved seed may come from either the grafted parents or some of their progeny.

Application

Now, what can you, as consumers, expect from hardwood tree improvement research in the next decade? As has been the case in southern pine breeding, most of the information acquired early in the work will necessarily be of interest chiefly to breeders. Some data on variation and inheritance, flowering characteristics, and grafting procedures are essential to breeding, but have little direct application in management. On the other hand, information on racial variation will be immediately valuable in planting programs. For example, within a decade we should be able to tell you how far up or down the Mississippi River you can move cottonwood successfully and whether a growth advantage can be obtained by planting trees slightly north of their origin.

Data on the relationship between wood properties and paper quality, which I hope will become increasingly available, will not only guide breeders but will provide goals for silvicultural manipulation of wood properties. Silvicultural information obtained from progeny and clonal plantings should also be of considerable use soon. It will include some detailed growth and yield data from intensively managed experimental plantations on a range of sites.

Results in terms of genetically improved stock will vary a lot with species. Some improved cottonwood clones should be available for pilot plantings within 5 years. Yellow-poplar orchards now being established should be producing some seed for commercial use in 10 years. But I won't make a public guess as to when we will have acorns with guaranteed genetic potential for high-quality veneer.

In short, hardwood tree improvement research is advancing knowledge on a number of fronts. Application of this knowledge will not only lead to genetically superior planting stock, it will also help develop an intensive silviculture under which genetic potential can be fully realized in profit terms.

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Reprinted from **PROCEEDINGS, AREA I SPRING MEETING OF SOUTHERN PULPWOOD CONSERVATION ASSOCIATION, 8 pp. 1967.**