# HARDWOOD TREE IMPROVEMENT IN THE SOUTHEAST

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Some of the earliest tree improvement work in the United States was done within the genus Populus in 1929 by Dr. Ernst Schreiner, working for the Oxford Paper Company in Maine. That work was the forerunner of the Populus hybridization program, which has received wide acclaim in the Northeast and, to a lesser extent, in other geographic regions of the United States.

Despite that auspicious start, tree improvement activities in indigenous hardwoods have been slow to develop. In the interim, genetic improvement of the conifers, especially those in the South and on the West Coast, has progressed rapidly. Among the reasons for the slow development of hardwood genetics and the rapid development of conifer genetics are these:

1. The market for products manufactured from coniferous species has developed much more rapidly than that from hardwoods.

2. Many of the hardwoods are climax species; as a result they succeed the conifers whenever there is a demise, planned or unplanned, of the latter group. In the South, for example, it is reported that 50% of the pine stands harvested during the past decade have regenerated to hardwoods. This type of succession presently assures an adequate supply of hardwoods coupled with an impending shortage of conifers.

3. Except for localized needs of planting stock for high value timber, such as black walnut (Juglans nigra), there has been until recently a lack of commitment to establish hardwood plantations. Development of an expensive tree improvement program is not justifiable until there is a demand for genetically improved seeds for artificial regeneration.

4. Progress made for the effort expended in a tree improvement program of hardwoods is considerably less than that for conifers. From a single controlled cross of oak (Quercus spp.) and hickory (Carya spp.) one fruit is obtained, whereas 100 or more viable seeds can be obtained from a single cross of the southern pines.

In recent years a commitment has been made by several wood-using industries in the southern United States to manage hardwoods in plantations because those organizations need hardwood fiber for the product they are manufacturing. They foresee the demand continuing into the future and they are concerned that a captive supply of the desired resource will be unavailable when needed unless positive steps are taken to assure the supply. Those positive steps are so expensive that those organizations not specifically needing hardwood fiber, and especially the small nonindustrial landowner, will find prohibitive the production costs for hardwood plantation management.

Considerable demand is being experienced by those involved in hardwood plantation management for seed. Water oak (Q. nigra) and willow oak (Q. phellos) acorns of undetermined source have sold for $85/bushel, and even then insufficient

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quantities of seeds are being obtained. Similar problems are encountered in obtaining desired seed of other species. With the high plantation establishment costs sometimes exceeding $250 per acre, it is crucial that genetically improved seeds in the quantities desired be available. Considerable effort is in progress in the Southeast and elsewhere to meet that goal. The remainder of this paper will be devoted to reporting the results of pertinent hardwood tree improvement accomplishments in the Southeast and to outlining breeding plans for the broadleaved species.

## Species Evaluation

Except for the hardwood species grown for high-value wood or nut production, there is limited information on the species to be favored and where they should be grown. Presence of a species in mixture with other species on a site is no assurance that it will perform well on that site when grown in a single-species plantation. The apparent reason for this inconsistency is that the commercially important indigenous hardwoods have extremely poor adaptability to site as compared to the adaptability of the southern pines. To evaluate the worthiness of species and site for growing plantation hardwoods, the N. C. State Cooperative Hardwood Research Program (the Hardwood Research Program consisting of 17 industrial organizations and one state forest service owning land in the area east of the Mississippi River and south of the Mason-Dixon Line) has coordinated establishment of species-site studies throughout the Southeast. Major conclusions from those studies are:

1. The most site-sensitive species are eastern cottonwood (P. deltoides) and black walnut, followed closely by American sycamore (Platanus occidentalis) and yellow-poplar. Sweetgum (Liquidambar styraciflua) is the most adaptable of the many species evaluated, but even it requires specific conditions for acceptable performance. The remainder of the commercially important species have an adaptability rating between that of yellow-poplar and sweetgum.

2. Among the species best suited for plantation management are:

a. Sycamore. Performs best on medium-textured, alluvial soils. Acceptable performance is obtained for about three years even on soils to which the species is poorly adapted, such as those containing high organic matter and high clay content in the surface layer.

b. Sweetgum. Performs well over a wide range of soil conditions but is being planted most extensively on finer-textured soils than those suited for optimum growth of sycamore. The species also does well on soils containing up to 20% organic matter such as those found in the pocosins of the lower Coastal Plain. Sweetgum is particularly susceptible to beavers. In some areas such as the upper Tombigbee and Sipsey River Basins in Mississippi and Alabama, the beaver problem is so bad that the planting of sweetgum is a significant risk.

c. Water-willow oak. Will generally perform well under the same site conditions suited for sweetgum but will tolerate a finer-textured soil than will sweetgum. The oaks and sweetgum have similar growth habits;

both groups are slow to initiate height growth even on the best sites. Incorrect conclusions are likely to be drawn about the relative performance of these species if evaluation is completed before the elapse of about five growing seasons.

d. Green ash (Fraxinus pennsylvanica). Suited for plantation establishment on imperfectly drained soils. The species is particularly susceptible to foraging by deer. Large seedlings are needed to assure that the tree crowns are above the deer browse line at the end of the first growing season.

It is to be noted that the species favored in our species-site trials are the ones most favored for fiber production. A different set of species would likely be selected if solid wood products were the objective. It is also to be noted that cottonwood has been omitted from consideration because of the limited area suited for growing this species in the Southeast.

3. Results from the species-site studies show that we can expect success from planting hardwoods only when attention is paid to strict silvicultural practices. Among the essential practices are:

a. Matching species to site. Failure can almost be assured by planting sycamore on a fine-textured soil or by planting green ash on a well-drained soil.

b. Complete site preparation. Hardwood seedlings are much more susceptible to woody and herbaceous competition than are the southern pines.

c. Large physiologically balanced planting stock of the correct source. Tests have shown that seedlings of sycamore should have a minimum root collar diameter of 1/2" and those of sweetgum, green ash and the oaks should exceed 3/8 inches root collar diameter if acceptable survival and growth are to be obtained.

d. Planting care and stand management. The entire plantation effort will fail unless care is used in planting and in nurturing the plantation to maturity. Control of insects and diseases will become an increasingly important consideration as pure-stand plantations become more extensive.

## Source Evaluation

Geographic variation studies have been conducted for a number of the southern hardwoods, including those for sweetgum (Roberds, 1965), yellow-poplar (Kellison, 1967), and sycamore (Schmidt and Webb, 1971); other studies are known to be in progress for willow oak, green ash, sycamore and northern red oak (Q. rubra). Results from many of these studies show the component of variation among stands to be larger and that among trees within stands to be smaller than has been reported for the southern pines (Sprague and Weir, 1973). This type of variation probably results because of restricted dispersal of the seeds and the coppicing nature of hardwoods. Nevertheless, sufficient variation among trees and among stands is present to allow good genetic gains to be made in a tree improvement program.

Seed source is extremely important in successful plantation management of hardwoods. In the Southwide sweetgum provenance study conducted by the Hardwood Research Program it was shown that height and diameter growth of trees from sources representing the range from North Carolina to Texas was comparable at 6.5 years from planting in the Piedmont of South Carolina. However, cold damage was significantly greater to the sources from the southern latitudes and to those from the Coastal Plain than it was to the Piedmont sources (Table 1)

Table 1. Cold damage of sweetgum by seed source at 6.5 years from planting in the Piedmont of South Carolina[1/]

| Seed Source | Cold Damage | |
|---|---|---|
| | Damage Score 2/ | % Affected |
| Granville Co., N.C. (Piedmont) | .24 | 2.4 |
| Bladen Co., N.C. (Coastal) | .50 | 4.8 |
| Newberry Co., S.C. (Piedmont) | .22 | 2.2 |
| Georgetown Co., S.C. (Coastal) | .69 | 6.7 |
| Barbour & Monroe Counties, Ala. (Coastal) | 1.00 | 14.0 |
| Coosa & Clay Counties, Ala. (Piedmont) | .60 | 6.0 |
| Warren Co., Miss. (Coastal) | 1.00 | 14.0 |
| Bienville & Winn Parishes, La. (Coastal) | 2.00 | 30.0 |

1/ Adapted from Zobel, B.J. (1975)

2/ Cold damage was scored by the following code:

None = 0
Light = Less than 1/4 top kill = 1
Moderate = 1/4 to 1/2 top kill = 2
Heavy = More than 1/2 top kill = 3

In a study of yellow-poplar in North Carolina, Kellison (1970) found that lower Coastal Plain sources planted in the Piedmont were fast-growing but highly susceptible to cold damage while Piedmont sources planted in the lower Coastal Plain had poorer survival and growth than the local sources. The use of the proper seed source when planting yellow-poplar in those regions was strongly urged.

Observations from the current plantation programs have further strengthened the conviction that use of the correct seed source is extremely important for the southern hardwoods. In one instance, sweetgum seedlings in a nursery in North Carolina were consistently superior when grown from seed collected from a local Red River Bottom stand as opposed to a Black River Bottom stand in the same general locality (personal communication with Mr. Jim Deines, Nursery and Seed Orchard Supervisor, Federal Paper Board Co., Inc., Lumberton, N.C.). Some nurserymen are relating this experience with their inability to consistently produce acceptable planting stock of the commercially important hardwood seedlings from year to year.

## Differences Among Trees

Early geographic variation studies such as those conducted by Critchfield, 1957, on lodgepole pine (P. contorta) and by Thorbjornsen, 1960, on loblolly pine showed variation among trees to be sufficiently great to warrant the initiation of selection breeding programs. Although not verified for hardwoods until some years later (e.g., Roberds, 1965; Kellison, 1967), the results were almost immediately extrapolated to the deciduous species for the establishment of clonal seed orchards. Orchards of sweetgum and yellow-poplar have existed since 1964 in North Carolina and Tennessee, and others of sycamore, green ash and water-willow oak have come into being since then (Table 2).

Selection of all commercially important hardwood species is urged regardless of plans to artificially regenerate the species. The emphasis for this endeavor is to preserve those genotypes that would otherwise be lost from planned harvesting or from pests and catastrophic events. These selections are grafted into clone banks where they are held in reserve while being progeny tested until there is need for initiation or expansion of a production orchard for the species.

Table 2. Hardwood seed orchards by species, clones and acreage in the N. C. State Cooperative Hardwood Research Program

| Species | Orchards Established | Acres | Clones Grafted Number | Orchards Being Established |
|---|---|---|---|---|
| Sycamore | 7 | 14 | 130 | - |
| Sweetgum 1/ | 4 | 29 | 57 | 1 |
| Yellow-poplar | 1 | 6 | 22 | - |
| Green Ash | 1 | 2 | 10 | - |
| Water-willow Oak | 1 | 2 | 14 | 2 |
| Eucalyptus 2/ | 1 | 1 | - | - |

1/ Seedling seed orchard of two acres included in total

2/ Seedling seed orchard of one acre included in total

In the N. C. State Hardwood Research Cooperative, 572 selections have been made consisting of 24 species (Table 3).

Table 3. Hardwood trees graded within the N. C. State Cooperative Hardwood Research Program for use in seed orchards and clone banks

| Species | # Graded | Species | # Graded |
|---|---|---|---|
| Sycamore | 149 | Chestnut Oak | 8 |
| Sweetgum | 129 | Black Oak | 8 |
| Yellow-Poplar | 65 | White Oak | 8 |
| Green Ash | 35 | Scarlet Oak | 7 |
| Red Maple | 27 | Swamp Black Gum | 6 |
| Willow Oak | 21 | Sugar Maple | 5 |
| Water Oak | 20 | Southern Red Oak | 5 |
| Northern Red Oak | 18 | White Ash | 3 |
| Black Cherry | 17 | Basswood | 2 |
| Black Walnut | 12 | Cucumber Magnolia | 2 |
| Cherrybark Oak | 12 | Swamp Chestnut Oak | 1 |
| Tupelo Gum | 11 | Shumard Oak | 1 |
| | | Hickory | 1 |

Selections of superior phenotypes have also been made by a number of other forestry organizations in the South, including, among others, the Western Gulf Hardwood Research Cooperative, the U. S. Forest Service, Tennessee Valley Authority, and the state forest service and educational organizations of Tennessee, Alabama, Mississippi and Georgia. 3/

Propagation of the southern hardwoods is usually accomplished by grafting or budding. However, the difficulty encountered in successfully grafting some species, especially the oaks, and the problems associated with graft incompatibility, have caused some organizations to propagate selected clones by cuttings. Some effort is also being made to propagate the southern hardwoods by tissue culture

3/ A number of states such as North Carolina belong to either the N. C. State or Western Gulf Hardwood Research Program and are not credited with hardwood selections when in fact they have made selections.

Hardwood clonal seed orchards have been shown to respond positively to cultural practices in much the same way as do the southern pine seed orchards. Seed production in a sweetgum seed orchard was found to increase significantly with the addition of 200 lbs./acre of $NH_4NO_3$ (Jett and Finger, 1973). However, a limitation to the treatment was greater susceptibility of the flowers to late frosts than was encountered in untreated plots. This and other problems would have to be resolved if hardwood seed orchards are to be managed for optimum seed production.

Seedling seed orchards have been advocated for the southern hardwoods because of some of the problems associated with vegetative propagation, especially grafting. I cannot generally champion that cause because of the limitations encountered in obtaining the needed distribution of the desired genotypes. It has been shown for sweetgum that the genetic gain to be expected from a seedling seed orchard is less by about 10% for height growth, 20% for diameter growth, and 45% for volume growth than that obtainable from a clonal seed orchard of the same material (unpublished report by Dr. R. J. Weir, N. C. State University, Raleigh). These differences result because some good genotypes have to be removed when they occur in clumps and some poor ones have to be retained in areas where large openings would be created by their removal.

An alternative to clonal seed orchards established from superior phenotypes from natural stands is clonal or seedling seed orchards established from open-pollinated progeny tests of parent trees selected in natural stands. Commonly referred to as mother-tree or one-parent progeny tests, this alternative has the advantage that greater genetic gain will be realized from the ensuing seed orchard than is generally obtainable from a first-generation clonal orchard. It has practicality because the demand for genetically improved hardwood seeds has not been so urgent as that for southern pine seeds, allowing development of a more orderly tree improvement program for hardwoods than for pines. More than 1300 open-pollinated progeny lots are under test in the N. C. State Hardwood Research Program (Table 4) and an equal number is probably under test elsewhere in the region.

Table 4. Open-pollinated progeny tests of southern hardwoods in the N. C. State Hardwood Research Program

| Species | Lots Being Tested Number |
|---|---|
| Sycamore | 589 |
| Sweetgum | 324 |
| Green Ash | 163 |
| Water-willow Oak | 48 |
| Hackberry (*Celtis occidentalis* L.) | 15 |
| Black Walnut | 38 |
| European Alder (*Alnus glutinosa*) | 89 |
| *Eucalyptus* spp. | 84 |

Results from these and other tests show that genetic gains from hardwood tree improvement programs will likely be greater than those obtained from southern pine improvement programs. An indication of the gain was obtained from a five-year-old open-pollinated test of sycamore growing in the Coastal Plain of South Carolina. Note the significant gains shown for both growth and quality improvements.

Table 5. Heritabilities and predicted gains for growth and quality improvement in a 5-year-old open-pollinated progeny test of sycamore growing in the lower Coastal Plain of South Carolina on lands of Westvaco Corporation 1/

| | Mean | Heritability | Gain(%) 2/ | Unit Gain |
|---|---|---|---|---|
| Height (ft.) | 16.7 | 0.27 | 14.2 | 2.36 |
| DBH (in.) | 1.59 | 0.30 | 26.3 | 0.42 |
| Vol. ($ft.^3$/tree) | 0.14 | 0.27 | 55.1 | 0.08 |
| Crown Score 3/ | 4.37 | 0.22 | 14.2 | 0.62 (units) |
| Straightness Score 3/ | 4.55 | 0.28 | 19.1 | 0.86 (units) |

1/ From Zobel, 1975

2/ Percent gain predicted for the next generation over the current one when 1 in 100 trees is selected as a parent

3/ Based on a score of 1 to 6 where the lower score denotes the most desired feature

Some organizations feel the need to develop hardwood tree improvement programs at a time when there is no demand for the seed. The N. C. Forest Service is one of those organizations. They have initiated a selection program for eight species having greatest commercial importance to the state. A minimum of 25 trees will be selected for each species. These will be preserved in clone banks while being progeny tested by a controlled-cross breeding scheme. The resultant progeny test will serve as the source of genetic material for second-generation seed orchards if and when such orchards are needed. This procedure also allows the organization the option of establishing a first-generation or a 1.5-generation orchard on the way to the second-generation orchard. We commend N. C. Forest Service and other organizations like them for their conviction that southern hardwoods will attain their rightful position.

## Summary and Conclusion

It is concluded that much is to be gained in a hardwood plantation program by using the best species for the site and by assuring that the correct source of seed is used. In addition, significant gains can be realized by adhering to a tree improvement program where selected trees from the wild are propagated in clonal seed orchards or where clonal or seedling seed orchards are established from progeny tests of those trees selected from natural stands.

All of the above potentialities will probably be for naught until there is a commitment to manage hardwood in plantations. Even then, only those organizations having specific need for the resource will probably be interested in investing in such a program because of the high costs associated with plantation establishment and management.

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