TREE IMPROVEMENT RESEARCH IN OAK SPECIES

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ABSTRACT. Early efforts at developing new forms of oak by interspecific hybridization have not been very successful, although spontaneous hybrids appear rather readily in nature. Preliminary reports on a few seed-source or provenance studies indicate that differences among sources are generally less than differences among trees within sources. This directs tree-improvement programs along the line of single tree selection. Selection methods followed in several programs are briefly outlined, and it is suggested that breeding programs to develop oak wilt resistant individuals be started immediately.

THE OAKS consist of a "typical genus of angiospermous trees of the North Temperate Region" *(Stebbins 1950)*. The genus includes 250 to 300 species, but many of these are probably subspecies of a smaller number of polytypic species. All the oaks studied cytologically have a chromosome number of 2n = 24 (the diploid state).

Although all the oaks have the same chromosome number, it is well recognized that there is a great deal of variation within the species. The oaks apparently hybridize quite readily in the field *(Stebbins 1950)*, although artificial hybridization in this country has, up to now, been very unrewarding *(Schreiner 1962, Taft 1966)*. Because of the great amount of inherent variability available, tree-improvement programs with oak species should progress at a rather rapid rate, using the standard selection techniques. There are few biosystematic studies to verify this fact, but any forester who has spent time looking at individual trees will acknowledge the fact that among oak trees one can find great variation in form, leaf shape, and growth rate.

At West Virginia University we have begun a biosystematic study of red oak. After measuring one plot of 50 trees in an even-aged stand, we noted that diameter breast height varied from 7.1 to 15.0 inches; total height, 49 to 77 feet; clear bole, 7 to 34 feet; height to first live branch, 8 to 34 feet; height to first fork, 12 feet, to trees that retained terminal dominance completely; number of epicormic branches, 0 to 25; bole straightness, excellent to poor; bark thickness, 0.28 to 0.45 inch; and crown radius (average of four measurements at cardinal directions), 5 to 14.5 feet. Specific gravity varied from 0.549 to 0.656. With this magnitude of variation, and assuming even medium heritabilities, a selection program should be very rewarding.

Active red oak selection programs are being carried out in Illinois *(Boyce 1963)*, Indiana *(Rambo 1966)*, Tennessee, Kentucky, North Carolina *(Taft 1966)*, Ohio *(Kriebel and Thielges 1969)*, and West Virginia. A few white oak selections have been made in West Virginia, and both white and chestnut oak selections have been made in the TVA program *(Taft 1966)*. Although the selection procedures vary, the goals of these programs are similar: to develop seed orchards that will produce trees with rapid diameter growth, straight boles with no spiral, good natural pruning, and few or no defects.

Emphasis in most selection programs is on the butt log, which gives the highest monetary return. Actually, even though the butt log grades No. 1, the second log will normally grade No. 2, and the third No. 3. According to Taft *(1966)* the No. 3 log will not produce enough income to pay for its processing.

SELECTION METHODS

Four selection techniques are in use:

Method 1

This method is generally used in the conifer selection program. The select tree is graded in comparison to several (usually five) crop trees growing as nearly as possible on the same site as the candidate tree. However, oaks normally grow in mixed stands, and often there are too few trees sufficiently close to the candidate tree for efficient comparison.

In the West Virginia program, we use any number of available comparison trees up to the desired five. The justification for this is simply that two trees give a better estimate of the site potential than does one.

In all the selection schemes, there are certain characteristics that disqualify a candidate tree. Primary among these is bole quality, which includes spiral grain (as evidenced by bark spiral or actual spiral of the bole) and lack of straightness. The candidate tree must be free of epicormic branches. A minimum number of "other defects" as defined in "A Guide to Hardwood Log Grading" *(Ostrander 1965)* may be tolerated.

Characteristics such as height, volume, branch diameter, and crown characteristics are graded on a comparative basis, using the best neighboring comparison trees as a base. Where an outstanding selection has no comparison trees, it is graded on its own merits; and the fact that there were no suitable comparison trees is noted on the grading form.

Method 2

The TVA system as used by Taft *(1966)* includes no comparison trees. Each candidate tree is graded on its own merit. Eight factors are considered. If the first two (straight grain and perfect bole straightness for two logs) are not satisfactory, the tree is discarded. The next two (defect and uniform, relatively fast growth rate) restrict selection to well-formed vigorous trees. The last four (high form class, desirable wood properties, total height, and crown characteristics) are given minor consideration.

Method 3

The selection for white oak seed parents in the tree-improvement program of the Central States Forest Experiment Station is based solely on log quality as evidenced by number of lateral branches and suppressed lateral buds. By pruning the select trees to a height of 17 feet and making a phloem block, suppressed bud development is encouraged. If, at the end of the next growing season, the number of new branches plus the number of old branches is 8 or fewer, the tree is included. Progeny testing follows to verify the selection *(Boyce 1963)*.

Method 4

By comparison, Kriebel and Thielges *(1970)* have selected a number of superior red oak stands in Ohio on the basis of phenotypic appearance, emphasizing growth rate and form. Original selection included 60 stands. The 20 best stands were then defined, and 10 superior trees were selected in each stand. Open-pollinated seed was collected from 3 of the best trees in each of the 20 stands for progeny testing.

If the better progenies come from certain stands, these stands will be developed for immediate seed production. If the better progenies are randomly distributed, the progeny test areas themselves may be converted to seedling seed orchards. If outstanding individuals are defined in the progenies, and if it is determined that vegetatively propagated orchards will produce seed at an earlier age, grafted seed orchards will be established. Before the seed orchards are bearing seed in commercial quantities, the seed production areas should provide genetically improved seed for interim planting *(Kriebel and Thielges 1969)*. Presumably this seed will be intermediate in genetic quality between field-run seed and that to be collected from the seed orchards.

Each of these methods has minor advantages and disadvantages. However, without progeny testing, any system is merely an exercise, as the validity of the selection method is proved by the performance of the progeny. Progeny tests, therefore, are an integral part of each method. Until the progeny test results are available, one can only speculate about which method will provide the greatest improvement.

PROVENANCE

Though the oaks have a considerable range, there are few provenance studies in this genus. Shreiner *(1970)* indicates that such testing is being carried on with white oak, cherry bark oak, northern red oak, and scarlet oak. To this list should be added the provenance test of southern red oak initiated at Clemson University under the S-23 cooperative program (Schoenike; personal communication, 1969), and chestnut oak in the TVA program *(Taft 1966)*. Although the Michaeux Quercetum at the Morris Arboretum has no formal seed-source studies, various species are represented by seed from several geographic locations.

Santamour and Schreiner *(1961)* reported on geographic variation in five white oak species in the Michaeux Quercetum. Data recorded were time of germination, 1- and 3-year height growth, and autumn coloration. For white oak, chestnut oak, post oak, bur oak and overcup oak, they concluded that individual tree selection would be more promising as an improvement technique than racial or ecotypic selection.

Schreiner and Santamour *(1961)* also studied the same four characteristics in seedlings of blackjack oak, northern red oak, black oak, scarlet oak, and southern red oak, and concluded that—with the possible exception of blackjack oak—individual tree variation was of greater importance than geographic seed source in the red oak group also.

Taft *(1966)* noted in the TVA study that although acorn size varied greatly, there was no correlation between acorn size and seedling size.

From an elevation study of northern red oak, including samples from 2,700, 3,300, and 5,000 feet, McGee *(1970)* found differences in both growth and frost damage. The test plantation was established at an elevation of 2,100 feet. The first-year growth advantage of the lower-elevation seedlings was not considered significant because the seeds were larger than those from the highest elevation. Bud break was earlier for the two lower elevation sources in both the second and third growing seasons, but frost damage, primarily to these two sources, nullified growth gain; and at the end of the third growing season there was no difference in height among sources. It may be that, where elevation is important, some sort of zoning will be necessary.

In 1960, the North Central Cooperative Regional Committee (NC-51), initiated a cooperative northern red oak provenance test, headed by Howard Kriebel of the Ohio Agricultural Experiment Station. Cooperating states are Ohio, Indiana, Illinois, Kansas, Nebraska, Iowa, Minnesota, Wisconsin, and Michigan. The studies include 29 sources on a region-wide basis, and two additional sources are represented in a few tests *(Kriebel 1965)*.

Early information on seed characteristics and seedling growth showed considerable variation among sources. The most northern sources had lighter, smaller, narrow acorns with deep cupules, while the southern sources had broader, heavier acorns with shallow cupules. In the 1961 planting, which included sources from throughout the natural range, there was a great deal of variation in seed size, most of the variance being due to seed source. However, in the 1963 planting, which included fewer sources and excluded the more northern sources, about one-fourth of the variance for seed size was due to source, while the other three-fourths was due to differences among mother trees. As in the TVA study, seed size was not correlated with seedling size except for two instances, which the author suggested could have been a chance relationship. Measurement of growth rate indicated a strong relationship with geographic origin when the planting with wider geographic coverage was considered. But when the second planting with restricted geographic range was analyzed, again there was a stronger within-source or mother-tree effect *(Kriebel 1965)*.

Presumably, at the termination of this study, each State included in the plantation distribution will have a strong indication of the best source of seed for their red oak planting stock. If the classical breeding procedure as outlined by Wright *(1962)* is followed, the next step would be to make superior tree selections in the indicated area for seed-orchard development. If seed from one area should perform best in most or all States, one or two seed orchards could be established to provide seed for nearly everyone. If different sources or the local source should prove best, individual seed orchards will have to be developed for each State.

In the event that the tree-to-tree differences in the seed-source study are greater than those among sources, single tree selection over the entire range might be most productive. The best phenotypes could then be used in a single large orchard without regard to the portion of the range from which they originate, and seed from such an orchard could be used range-wide.

Without the information derived from such a provenance or seed-source study, individual tree selections from a number of restricted locations will have to be used; and the seed from orchards so designed would be returned to the area covered by the selections.

HYBRIDIZATION

The selection phase of oak breeding has been implemented only very recently. Original genetic work in the genus *Quercus* centered on interspecific hybridization to produce better forms by combining species. Much of the early work was centered in Europe where, for example, some 200,000 hybridizations were made in 47 different interspecific combinations at the Ukranian Research Institute *(Piatnitsky 1960)*. Piatnitsky noted that 50 to 60 percent of the flowers pollinated set and produced acorns. He did not specify the number of seedlings that resulted from this seed, but stated that second-generation hybrids were being grown.

Breeding arboreta in the United States include the Michaeux Quercetum at the Morris Arboretum, the Arboretum at the Ohio Agriculture Experiment Station, Clemson University, and TVA *(Taft 1966)*. Schreiner *(1962)* summarized the crosses made by personnel of the Northeastern Forest Experiment Station from 1937 to 1941. Ten species were used as female parents and these were crossed with 8 species as the male parent. From 6,936 flower clusters pollinated, 242 germinable acorns resulted. Approximately 170 control-pollinated seedlings were actually outplanted, and 153 of these were from the white oak intraspecific cross. Results from 1947-48 breeding programs were no more encouraging.

Apparently both intra- and interspecific hybridization are difficult in the oaks. Schreiner attributes some of the difficulty to the lack of dependable hybridization techniques; but even with the best technique, production of hybrid seed in commercial quantities will probably be extremely difficult.

Vegetative propagation of mature oak is also difficult. Grafting can be accomplished with varying degrees of success. Cuttings cannot be rooted. All these difficulties make it abundantly clear that oak improvement will necessarily be accomplished through selection with some type of seed-orchard program.

Breeding for resistance to oak wilt is a feasible procedure, but techniques for seedling inoculation and methods of recognizing resistant specimens will be difficult to develop. The financing of such an ambitious project will also be difficult.

The author is informed that the one red oak that might have had inherent resistance has died, apparently from oversampling. The stump should be watched for possible sprouting. Scion wood was collected from this specimen for grafting, but none of the grafts was successful. Perhaps scions from sprouts would graft more readily. This tree would be a good starting point for genetic resistance.

Because we do not have an effective means of oak wilt control, and the upland oaks make up such a considerable portion of the Appalachian hardwoods, a comprehensive genetic program for developing genetically resistant stock should be started without delay. Without control of oak wilt, the oak breeding programs now in progress will be less effective. In the long run, well-formed fast-growing oak trees will be of no use if they cannot survive this disease.

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