OPPORTUNITIES AND LIMITATIONS IN HARDWOOD TREE IMPROVEMENT RESEARCH AND DEVELOPMENT

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Abstract.--Since there is such a great number of hardwood species, representing many genera and families, needs and procedures will vary greatly depending upon biological and economic factors and information already available. Prior to establishment of procedures it is essential to determine the importance of the species in question and how urgent it is to improve it.

Breeding programs with southern pines were initiated when forest managers determined an immediate need for increased production to supply their mills. Silvicultural practices, such as intensive site preparation, fertilization and increased stocking combined with shorter rotations would probably not result in sufficient production increases to account for the increasing demand for wood and the decreasing land base available for pine production. Under such circumstances, the possibility of increasing yield through breeding appeared very attractive even though gains from initial mass selection were expected to be modest. This urgent need for increased yields was the basis for a large number of "crash" breeding programs developed for southern pines. These programs, although generally successful, may be characterized as relatively expensive since development usually forged ahead of research and adjustments had to be made as research data became available.

When hardwood breeding programs were started a few years ago there was a strong temptation to copy procedures used in the successful pine programs. For many hardwoods there are, however, serious questions with regard to the urgency of the breeding programs. Since the degree of urgency may strongly influence breeding and research procedures it may be appropriate to evaluate each species as to the need for research and development programs. Such evaluations will, of course, to a large degree depend on the criteria used and the relative weight given each criterion (Farmer 1973). For the purpose of this paper it may be helpful to classify the native hardwoods into four "urgency groups":

1. Real urgency which is recognized
2. Real urgency which is not recognized
3. No real urgency but has been recognized as urgent.
4. No real urgency and has not been recognized as urgent.

Group 4 contains a large number of hardwood species, most of them of little or no commercial value. Since they are of no immediate concern to tree breeders they will be omitted from further discussion. In addition, there are some potentially important exotics; however, due to space limitations these hardwoods have also been omitted from this paper.

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"The author is grateful to King Features Syndicate Inc, for permission to reproduce Hagar comic strips in this paper."

REAL AND RECOGNIZED URGENCY

My friend and former country man, Hagar the Horrible, has agreed to illustrate a condition of real and recognized urgency (Figure 1). Some tree improvers can sympathize with Hagar in his predicament, but rather than waiting for some ladders they are looking for good research data to help them develop a breeding program.

Figure 1. -- The urgency is real and recognized.

Due to the large capital investment in the pulp and paper industry, needs related to wood procurement are readily recognized and seasonal shortages of suitable hardwoods have resulted in plantations of species such as cottonwood (*Populus deltoides* Bartr.), sweetgum (*Liquidambar styraciflua* L.), and sycamore (*Platanus occidentalis* L.). Improvement programs have been started with all three species.

Rapid growth rate and ease of vegetative regeneration promoted early selection work within the genus *Populus*. Our American cottonwood was introduced to Europe where it hybridized naturally with the European black poplar; selections of these hybrids were propagated vegetatively more than two hundred years ago. Artificial Euro-american hybrids created a number of different types which have entirely replaced native poplars in many countries. Such hybrids have not however, been successful in the southern United States where selections of native cottonwood consistently outgrow all hybrids tested. In addition, native cottonwoods have better stem form and are more resistant to pests (Maisenhelder 1970). To take advantage of the high broad sense heritability in native cottonwood, selection in natural stands or plantations were followed by clonal tests. Such programs have resulted in the release of several clones for commercial plantations. The short rotations used in pulpwood plantations should permit relatively rapid clonal evaluation, particularly since there appears to be good genotypic correlations between measurements made in the third and sixth year (Mohn and Randall 1971).

In developing cottonwood clones with greater yields than those presently used, it will be necessary to maintain a large amount of genetic variation in the breeding population. Diallel crossing schemes can be used to develop new populations of known parental background. These populations may then be used for selection followed by clonal testing. Some parental types may be of exotic provenances; additional gains can be expected from the use of more southern material (Randall 1973) and inter-provenance crosses should be evaluated.

Although sweetgum and American sycamore are also recognized as belonging to the "real urgency" group, their brief silvicultural history is less glamorous than the saga recorded for cottonwood. There are two obvious reasons for this: Sycamore and sweetgum do not belong to genera with a large number of species and thus they are unlikely to produce valuable interspecific hybrids. Also, because they are much more difficult to propagate vegetatively it is not possible to utilize such a large proportion of the variation present. Research and development procedures reflect these differences.

Sufficient seed to provide-for planting stock of the two species can easily be obtained from grafted orchards. Even though gains from phenotype selection in natural stands probably will be small, the cost of orchard establishment should also be modest due to the great number of seed produced per tree and the early age for flowering. However, to obtain significant genetic gains in these two species it is imperative to determine the variation among provenances and families within provenances.

The large geographic ranges of both species suggest that much seed source variation may be present. However, no range-wide studies have been established to determine variation patterns. Several studies, established by WGFTIP, the NC-Coop and the USFS Southern Forest Experiment Station, cover smaller parts of the southern range. The trees are still very young and offer only hints of geographic variation. Until more substantial information on provenance variation becomes available, breeders run the risk of selecting trees from inferior populations.

In most of the studies referred to above the identity of the open-pollinated progeny from individual mother trees has been maintained. In sweetgum the variation among families appears to be large (Wilcox 1970) indicating that selection based on progeny tests may result in significant gains. However, phenotype selection in natural stands did not result in genetic gains (Cooper 1974). These observations suggest that little emphasis should be placed on initial phenotype selection and that greater efforts should be made to establish open-pollinated progeny tests with a large number of more or less random selections from a substantial part of the species range. Better methods of vegetative propagation must be developed to take advantage of superior genotypes identified by this process.

REAL BUT NOT RECOGNIZED URGENCY

Figure 2. -- The urgency is real but is not recognized.

Hagar's wife illustrates a situation where there is a real urgency, but typically the matter has been ignored for years (Figure 2). Species belonging in this group will not be used by the pulp and paper industry at the present time and are not considered to be of great economic value. However, the overall national socio-economic values of these trees may be so high that the species deserve recognition by tree breeders.

Two species belonging to this group need special recognition: American chestnut (Castanea dentata (Marsh) Borkl.) and black locust (Robinia iseudoacacia L.). Chestnut is included because of its former great value as a timber and wildlife species and the fact that this genetic material is in danger of becoming extinct. Black locust deserves recognition since it is more widely planted than all other hardwoods.

Breeding work with the American chestnut was initiated by the US Forest Service, but when it became apparent that no quick solution to the problem could be anticipated the project was discontinued. As a result, it became a project of a few individual state organizations to solve what obviously is a national problem. The oldest projects are carried out at the Connecticut Agricultural Experiment Station (Jaynes 1976) and at The University of Tennessee (Samman and Thor 1976). Recently, breeding programs have been initiated at West Virginia University and Virginia Polytechnic Institute and State University. Several procedures have been followed since introduction of resistant exotics and interspecific hybridization failed to produce good forest trees. Attempts to produce resistant mutants by radiation are still being made, but so far with no success. Today,'mlost of the work on chestnut blight (Endothia parasitica (Murr.) And. and And.) is concentrated in three fields: basic work on host-pathogen relationships, selection of apparently resistant phenotypes of American chestnut and progeny production, and development of a hypovirulent variety of E. parasitica.

There is considerable evidence that some chemicals in the inner bark of chestnut trees may either promote growth of the fungus or retard it (Samman and Barnett 1973). Work is in progress to determine the specific formula of these compounds. When determined, this information may be used to develop early selection criteria in progeny tests. Another project at The University of Tennessee attempts to determine the mechanism by which the fungus kills chestnut tissue; oxalic acid produced by the fungus is a prime suspect.

Although chestnuts continue to sprout from stumps, the number of live trees is declining. Such surviving trees are scattered miles apart through our eastern forests and since they require cross pollination there is no production of viable seed. To preserve this germ plasm and make it possible to produce new and possibly better recombinations, a program with phenotype selection (criteria: to be alive and greater than 10 inches DBH) and grafting in a clonal bank was initiated several years ago. This bank yields thousands of nuts used for establishment of half-sib progeny tests.

The difficulty in finding resistance within C. dentata has encouraged work with hypovirulence in E. parasitica The hypovirulent strain discovered in Europe has been mated with a virulent American strain of the to produce a hypovirulent American fungus which will, when introduced on cankered American chestnut trees, slow down the growth of the fungus and actually start recovery (Van Alfen et al. 1975). If it becomes possible to establish this "sick strain" in our forests, trees with a relatively low degree of resistance to the virulent strains may be re-established.

Black locust does not generate nostalgia like the American chestnut; as a matter of a fact in some locations it is considered a weed species. However, the ability of this tree to fix nitrogen and become established on severely disturbed sites has made it a favorite among foresters engaged in strip mine reclamation. Thousands of acres of strip-mined land are planted annually with black locust making this species the most widely planted hardwood in the United States. Why then is there no recognized urgency for work with this species?

The answer is probably that people naturally tend to respond to economic needs that effect them directly. Strip mine operators usually do not have an interest in timber production and tree planting is only carried out to meet minimum requirements for release of compliance bonds and make the companies eligible for new mining permits. Timber production on such land is, however, of importance to the national economy and should be of public concern.

Foresters in Tennessee have observed that black locust planted on strip-mined land tends to grow with multiple stems and form brush thickets rather than forest stands. Even though site conditions may favor this development there is evidence that genetic factors may be important. It has been determined that the state nursery in Tennessee purchases black locust seed produced in western Europe. There is a good reason to believe that these stands originated from seed collected within the northern range of the species in New York. No attempt has been made to collect or test seed from native or other southern sources. The lack of information on genetic variation in the southern part of the species range indicates the need for a regional study of geographic and among-family variation.

Such a study, involving cooperation among the state forestry organizations in Kentucky and Tennessee, TVA, and The University of Tennessee, is now in the planning stage. Seed will be collected from at least a dozen natural stands in east Kentucky and Tennessee and north Alabama. Apparent clonal variation in growth form and borer resistance (Santamour 1970) indicates that some phenotype selection should be made. Test plantations will be established In strip-mined sites in Kentucky and Tennessee; in addition, a seedling seed orchard with half-sib families will be planted on a more conventional site. Following evaluation on the test sites for growth rate, stem form and resistance to insects, such as the locust borer and laaf miner, the orchard will be rogued by family and mass selection. Variation in rooting ability must also be evaluated. Since black locust flowers at an early age and early evaluation of many characteristics is possible,a clonal orchard can be established after about ten years. To take full advantage of the gains obtained it will be necessary to improve techniques for mass production of rooted cuttings (Stoutemyer et al. 1940). Since a relatively high plantation establishment cost is acceptable for successful reclamation of strip mines there are opportunities for development of new techniques such as production of containerized propagules.

NOT REAL BUT RECOGNIZED URGENCY

The third case of urgency, and the last one to be discussed, is the case when no real urgency exists but some people, due to hasty or maybe poor judgement, get carried away. In Figure 3 Hagar first deplores such rash actions, but then he gets involved in the general excitement and rushes off for what, at the moment, appears to be an important and urgent event.

Figure 3. -- There is no real urgency but it is recognized

There are some hardwood programs in the South which, I think, will fall into the third urgency group. To avoid straining some valuable friendships I will use as a prime example my own program with yellow -poplar (*Liriodendron tulipifera* L.). This program was started 17 years ago and has made some contributions to our knowledge of yellow-poplar (Thor 1975). The breeding program initiated was very similar to the crash programs developed for southern pines,but there was no similar economic justification for this approach. Even though a reasonable number of yellow-poplar seedlings were planted each year the demand for wood did not exceed production. As a matter of fact, Boyce and McClure (1975) concluded that "unless huge increases in demands occur, the present annual growth of 500 million cubic feet should be sufficient for many years to come." The rapid increase in net annual growth over the last 20 years has only been matched by a modest increase in removals resulting in a doubling of the growing stock volume. Such a situation should not call for urgent measures by tree breeders.

The lack of urgency due to large inventories of growing stock, high annual growth rates, modest harvests and long sawtimber rotations indicates that for yellow-poplar the emphasis should be on research in genetics rather than development of tree improvement programs. Such a research program, designed to determine the variation patterns within the species, has been developed by the S-23 Regional Technical Committee. This project, "Breeding strategies for genetic improvement of commercial forest trees in the South", includes basic studies in three hardwood species: yellow-poplar, sweetgum and American sycamore.

The S-23 yellow-poplar study may serve as an example for how forest genetics research can be carried out in a cooperative regional manner just as the three industry coops have served as models for developmental programs in tree improvement. The objective is to characterize genetic variation in natural populations and to determine optimal procedures for utilizing such variation in first-generation breeding strategies. Two provenance-progeny studies will be established, one based on regional collections and another based on altitudinal collections, to identify optimal sources and obtain narrow-sense heritability estimates by half-sib analysis of families within sources. Several cooperators will establish plantations so that by combined analysis it will be possible to determine family location interactions and stability of families evaluated. Based on this information we can determine probable success of different breeding methods.

Seed for the altitudinal study was collected at 1000-foot intervals from two transects across the Smokey Mountains. Seedlings will be distributed to cooperators in early 1978. Four transects (two N-S and two E-W) were used for regional collections; seedlings from two regional transects will be distributed in early 1978 while additional collections must be made for the two other regional transects. Tree breeders interested in participating in this program should contact Dr. Paul E. Barnett, Forestry, Fisheries and Wildlife, TVA, Norris, Tennessee 37828.

Another species which, in my opinion, qualifies for a "group three classification" is black walnut (*Juglans nigra* L.). The very high price paid for some individual trees and the propaganda by some hardwood manufacturers may suggest that an improvement program is urgently needed. However, our forests have been able to supply the industry with needed logs in addition to large volumes for export. Also, users of black walnut timber have not engaged in large planting programs to protect themselves, against a future shortage. These facts indicate that an urgent need for an improvement program may not be present.

Breeding black walnut will in all probability require much effort. Trees are normally found as scattered individuals making phenotype selection in natural forests difficult and little progress shoull be expected from this approach. Selection in plantations is more promising, but can only be meaningful when good provenance test data are available. In many locations selection in plantations of known local source may be counter productive when trees of local source are inferior to those of exotic origin. Trees from as far as 200 miles south of plantations generally grow as large or larger than trees from local sources (Bey 1973).

Most provenance tests are designed primarily to show geographic variation patterns and are usually not well suited for carrying out individual tree selection. When a general geographic optimum area has been determined it is more efficient to make additional and much larger single-tree collections from this area to determine both ecotypic and among family variation. It is probably desirable to combine such progeny tests with seedling seed orchards (Funk 1969). However, roguing of inferior families and inferior individuals within the better families should probably not start before plantations are about 20 years old, when the trees are half way through the rotation and ready for heavy nut production. At this time it may be justified to establish clonal orchards from selections made in the progeny test plantation; this decision will to a large degree depend upon how strongly economically important characteristics are inherited, if suitable methods of vegetative propagation have been developed, and if there is a strong demand for genetically improved seedlings. By including nut quality as a selection criterion the economics of grafted orchards may be greatly enhanced.

Several species of oaks *(Quercus* spp.) may be placed in the same urgency group as black walnut and the arguments for this classification as well as suggestions for breeding procedures will be similar. As a matter of fact, the large inventory of most oak species makes it even less urgent to develop clonal seed orchards. For large-seeded trees such as walnut and oak the cost per improved seedling tends to be excessive, particularly when vegetative propagation is difficult.

CONCLUSIONS

For a few hardwood species there is a real and urgent demand for improved seed. Phenotype selection in natural stands and establishment of clonal orchards are deemed appropriate for these hardwoods, especially when large amounts of seed can be obtained from relatively small orchards. Research aimed at the development of better methods of vegetative production, particularly mass production of rooted cuttings, should have high priority for these species.

For several other hardwoods of great economic importance there in no urgent need for improved seed. We will in most situations continue to rely on natural regeneration of these species. Until the economic conditions warrant large-scale plantings the development of clonal orchards should have low priority, especially for species yielding a relatively small number of seeds per tree. Research priority should be given to studies of variation within these species; future breeding efforts will depend on good estimates of both geographic variation and variation among families. These test plantations should include a large number of sources, families, and individual progenies so that they can be used for selection in future seed orchard development programs.

LITERATURE CITED

Bey, C. F. 1973. Growth of black walnut trees in eight midwestern States -- a provenance test. USDA For. Serv. Res. Pap. NC-91.

Boyce, S. G. and McClure, J. P. 1975. Capture of the biological potential for yellow-poplar timber. Proc. Third Annual Hardwood Symposium. p. 134-144.

Cooper, D. T. 1974. Performance of open-pollinated sweetgum progenies on contrasting sites in the Mississippi delta. Proc. of IURFO, Working Party on Progeny Testing S2-04.3. p.5.

Farmer, R. E. 1973. Decision making for development and use of genetically improved hardwoods. Jour. Forestry 71: 75-78.

Funk, T. 1969. Genetics of black walnut *(Juglans nigra).* USDA For. Serv. Res. Pap. WO-10.

Jaynes, R. A. 1976. New developments in chestnut research, Proc. 23rd Northwestern Forest Tree Impr. Conf. p. 36-41.

Maisenhelder, L. C. 1970. Eastern cottonwood selections outgrow hybrids on southern sites. Jour. Forestry 68: 300-301.

Mohn, C. A., and Randall, W. K. 1971. Inheritance and correlation of growth characters in _Populus deltoides._ Silvae Genetica 20: 182-184

Randall, W. K. 1973. Mississippi cottonwoods outperform local clones near Cairo, Illinois. USDA For. Serv. Res. Note SO-164.

Samman, S. N., and Barnett, P. E. 1973. Breeding for resistance to chestnut blight at The University of Tennessee. Proc. 23rd Northeastern Forest Tree Impr. Conf. p. 24-28.

Samman, S. and Thor, E. 1976. Breeding for resistance to chestnut blight at The University of Tennessee. Proc. 23rd Northeastern Forest Tree Impr. Conf. p. 24-28.

Santamour, F. S., Jr. 1970. Creating a seed orchard for superior black locust. Am. Hort. Mag. 49: 64-66.

Stoutemyer, V. T., Jester, J. R., and O'Rourke, F. L. 1940. Propagation of black locust clones by treating hardwood cuttings with growth substances. Jour. Forestry 38: 558-563.

Thor, E. 1975. Improvement of yellow-poplar planting stock. Proc. Third Annual Hardwood Symposium. p. 158-164.

Van Alf en, N. K., Jaynes, R. A., Anagnostakis, S. L., and Day, P. R. 1975. Chestnut blight: biological control by transmissible hypovirulence in _Endothia parasitica._ Science 189: 890-891.

Wilcox, R. 1970. Inherent variation in South Mississippi sweetgum. Silvae Genetica 19: 91-94.