HARDWOOD TREE IMPROVEMENT - WHERE DO WE STAND

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The problems associated with hardwood tree improvement are many and complex. In many ways, they are limiting at the present time and should be fully considered before the initiation of an action program. The research effort to provide the answers is inadequate both from the standpoint of scope and financing. Hardwood research is not now as extensive as pine research when tree improvement was initiated for the softwoods. This is understandable when you consider that Timber Trends in the United States Forest Research Report No. 17, U. S. Department of Agriculture, dated February 1965 states that 69% of the growing stock in American forests is softwood and 31% hardwoods. Research is complicated by the greater numbers of commercial forest hardwood species and multiplicity of individual species problems.

One of the major problems confronting these desiring to initiate a hardwood tree improvement program is the establishment of forest stands with the new material. The already presently established stand will have vigorous root systems capable of sprouting as soon as light, moisture, and nutrients become more abundant following cutting of the trees. In addition, the advanced reproduction already present prior to cutting will be stimulated by the release from overstory removal into tremendous growth. All of this rapid vegetative growth overwhelms any new material introduced into the area, particularly species with the characteristic of slow juvenile height growth. Many hardwood species, especially the oaks, have juvenile height growth dormancy, and dieback.

Some studies are now underway to overcome juvenile height growth dormancy by intensive site preparation or the use of planting stock grown under special nursery conditions.

Another important problem is the determination of geographic races. Information on this subject is sadly lacking. How far can you move a clone without adverse effect on vigor and form? The present attempts to set limits for most species are really educated guesses. Hardwood species grow under a great variety of environmental conditions. For example, yellow poplar is found from the coastal areas to the tops of comparatively dry ridge tops. Altitudinal effects of seed source are evident in cold damage when lower altitude sources are used at higher elevations. Growth rates of trees from different geographic areas has also been noted in early

studies. Until more precise information is developed, a cautious, conservative approach to hardwood tree improvement is indicated. In the absence of more detailed research results, it behooves the tree improvement worker to use rather restricted local sources of seed or tree selections.

Propagation of clonal material is another area requiring more development. Preservation of the tree selections in a clone bank or seed orchard require successful methods of grafting, budding, rooting, layering, or seedling establishment. Many hardwood species are difficult to propagate both vegetatively or sexually.

Vegetative propagation for seed orchards or clone holding banks is desirable for preservation of the clonal material without changing its characteristics. Multiplication of the clone by layering or rooting minimizes the possibility of changing the gentic genetic characteristics of the original selection. In some species, this is extremely difficult. Generally speaking, more juvenile material is more easily propagated. Attempts have been made to induce root, stem, or limb sprouts on tree selections as a source of juvenile material. Sometimes this is well nigh impossible because the standards for selection stressed the absence of sprouts or their indicators. Some of the material used to induce sprouts has been cutting of limbs, girdling, and root and stem injury. Age of the tree and time of year for treatment appear to be important factors.

Breeding or controlled pollination is a difficult problem with many hardwood species. The work required to control pollinate does not produce the results obtained in softwoods. The oaks, for example, produce only one or two acorns per flower. The red oaks require 2 years for acorn maturity. Black walnut is another species difficult to control pollinate. A species such as yellow poplar produces seed of low germination. All of these difficulties restrict the scope of meaningful breeding work in many hardwoods.

The quality standards for hardwood products have long been established. The forest land manager knows in detail what he desires in tree characteristics to produce a quality product. Therefore, the standards for hardwood tree selection can be based upon these qualities. However, the unknown factors in developing tree selection standards are the heritabilities of the desired qualities. With our present knowledge of heritabilities, selections must be made upon faith that most of the desired characteristics will prove to be inherited in succeeding generations.

Other factors to consider in the initiation of a hardwood tree selection program are species and purity of clonal lines. Species included in a tree improvement program will be selected by the landowner upon the basis of species suitability on the available land, type of product desired, economics, silviculture, and frequency of natural occurrence. All of these considerations can be meaningful guides. Choice of species can be based on more positive reasons than many of the other activities in a hardwood tree improvement program. Most of the factors underlying species desirability were evolved by actual sale of timber products or observations of species habitat.

One of the characteristics of hardwoods is the ease with which natural cross-pollination occurs. This accounts for the many forms of a single species. For the tree improvement worker, it raises doubts as to just what kind of tree he will have in the progeny of the original hardwood selections even when made under the most exacting standards. The parent selections may be high quality trees of fast growth, but the progeny may not necessarily exhibit those characteristics. In order to avoid this problem, one approach proposed for hardwood tree selection is the establishment of plantations from outstanding tree selections. From these progenies the outstanding individuals with the desired characteristics would be selected for seed orchard establishment.

Another problem associated with seed orchard or clone bank establishment is animal damage. In most hardwood areas, the deer population is a definite problem. Browsing on young hardwood trees is common and very damaging. A proposed solution is the erection of an enclosure around each tree or the area occupied by the hardwoods. Another solution might be the growing of clonal material in a protected site until sufficiently high to preclude browsing after transplanting. Transplanting of this size of tree into the selected orchard area would be possible with the use of a mechanized tree spade.

Although a limited acreage of seed orchards have already been established, the majority of tree improvement programs concerned with tree selection have set limited goals for orchard established, the majority of tree improvement programs concerned with tree selection have set limited goals for orchard establishment in the immediate future. The search for outstanding individuals is continuing, and as soon as possible, these trees are placed in a clone holding bank. This is to preserve the clone until some of the problems already enumerated can be solved. The establishment of the clone holding bank is by grafting, rooting, or the use of open pollinated seed. Beyond the clone holding establishment phase, definite plans are usually lacking.

Now that some of the problems associated with hardwood tree improvement have been considered, the question arises, where will we obtain the solutions? In an attempt to answer this question, a survey of hardwood tree improvement activities in the eastern United States was made. The response by most organizations to the questionnaire about hardwood tree improvement activities was very good. The following listing of activities may not be entirely complete but includes most of the tree improvement projects in the eastern United States. A summary of activities by species is presented in Table 1. A very brief outline of each individual project by organization follows Table 1.

TABLE 1 - SUMMARY OF HARDWOOD TREE IMPROVEMENT PROJECTS - EASTERN UNITED STATES

	Yellow Poplar	Populus	Oaks	Ash	Sugar Maple	Birch	Black Walnut	American Chestnut	Chinese Chestnut	Black Cherry	Sycamore	Sweet Gum	Willow	Black Locust	Red Maple	Others
1. Clonal Tests		3	1				1			2						
2. Hybrid Tests	1	4				1	1	1								
3. Provenance tests	2	1	4	3	5	2	1	1		2	3	4		1		
4. Adaptability	1	1	1	2	1	1	1				1	1				1
5. Hybrid Tests																
6. Taxonomy		1			1		1									
7. Wood Characteristics		2		1	1											
8. Reproductive Process		1			1					1	1					1
9. Morphology		1	1		2											
10. Pollination	3				2	2					1					1
11. Controlled Crosses	1					1										
12. Seed Germination & Storage	1		1	1	4	1	1			1						4
13. Nursery Practices					3		2									
14. Seedling Survival			1	1	2	1	1			1	1	1				
15. Direct Seeding versus Planting					1											
16. Regeneration & Conversion	1		2	1		1	1		1	2	1	1		1	1	1
17. Soils & Nutrients		2			1											
18. Bark Analysis & Characteristics					1			1								
19. Growth & Form		1		1	1	1	5						1			
20. Disease & Insects																
21. Irradiation	1	1						1								
22. Vegetative Propagation	3	1	2		3		1			2	1	3				
23. Seed Orchards or Clone Banks	7		3		1		3	1	1	4	1	1				1
24. Progeny Testing	5	1	2			1	4	1	1	1	2	1				2
25. Arboretum						2	1			1						1
26. Heritabilities	1	2				1	2			1	2	1				
27. Stand Management	2		1							1	1					1
28. Sugar Content					4											
29. Disease & Insects		1		1				2	1			1	1		1	1
30. Tree Selection	8	2	5		1	1	4			4	2	2			1	2
31. Drouth Resistance							1									
TOTAL	37	25	24	11	35	16	31	8	4	23	17	16	2	2	3	16

U. S. Forest Service, Southeastern Forest Experiment Station, Asheville, N.C.

Black Cherry

1. Heritability of stem form.

Yellow Poplar

1. Heritability of epicormic branching.
2. Tree selection on poor sites.
3. Provenance study.

Northern Red Oak

1. Altitudinal effect on time of bud break.
2. Planting trials.

U. S. Forest Service, Southeastern Forest Experiment Station, Athens, Georgia

Sweet Gum

1. Relation of morphological seedling grade and field survival and growth.
2. Effect of ortet and time of collection on rooting of cuttings.
3. Effect of etiolation on rooting of sprouts.
4. Inheritance of interlocked grain, fiber length, and ray characteristics.
5. Rooting of forced epicormic branches.

Sycamore

1. Tree selection.
2. Management and yields of short rotations.
3. Variations in traits of veneer-type logs.
4. Development of tree selection standards for veneer products.
5. Rooting of forced epicormic branches.

Yellow Poplar

1. Vegetative propagation.

U. S. Forest Service, Resion 8, Atlanta, Georgia

Oaks

1. Tree selection in 5 recognized geographic zones.
2. Vegetative propagation.
3. Conversion of oak stands with oak species and selected clones.
4. Induction of sprouting.

Yellow Poplar

1. Tree selection in 3 recognized geographic zones.
2. Induction of sprouting.
3. Vegetative propagation.
4. Plantation establishment and management.
5. Establishment of clonal banks.

Black Cherry

1. Tree selection in 2 geographic zones.
2. Vegetative propagation.
3. Conversion of present hardwood stands to stands of improved clones.
4. Establishment of clone banks.

Northeastern Forest Experiment Station, Durham, New Hampshire

Poplar

1. Clonal test of 250 hybrid clones in northeastern United States.
2. Nation-wide hybrid clonal test.
3. Taxonomic study of American cottonwoods.
4. Field trials of hybrids from controlled breeding.

Oaks

1. Provenance study of 44 species and 9 varieties.

Ash

1. Provenance study of 4 species.
2. Wood characteristics of white ash.

Exotics

1. Tests in Northeast of various species of ash, birch, maple, ginko, and yellow poplar.

Northeastern Forest Experiment Station, Burlington, Vermont

Sugar Maple

1. Reproductive behavior, self-compatibility, and cross-compatibility.
2. Morphology and evolution of flowering.
3. Stratification of seed.
4. Fall versus spring sowing in nursery.
5. Effect of collection date on rooting of cuttings.
6. Distinguish between black and sugar maple.
7. Initiation and development of flower primordia.
8. Variation in sugar content of sap and selection for high yielding phenotypes.
9. Provenance study.
10. Chemically induced break of dormancy and greenhouse maintenance of cuttings.
11. Effect of pollen treatment on fertilization.
12. Storage of seed.
13. Effect of date of collection on seed germination.
14. Effect of soil moisture and nutrients on seedling growth.
15. Over-wintering survival of rooted cuttings.
16. Effect of cultural practices and protective measures on seedling survival.
17. Direct seeding versus planting in old fields.
18. Grafting and budding.
19. Long-term storage of pollen.
20. Shade requirements for nursery stock.

Ohio Department of Forestry, Wooster, Ohio

Sugar Maple

1. Selection for sap sugar content.
2. Geographic variation.

Pennsylvania Department of Forests and Waters, Harrisburg, Pennsylvania

Black Cherry

1. Establishment of a clonal seed orchard.

General

1. Study of seed production for 7 hardwood species in Northwestern Pennsylvania.

Univesity of Tennessee, Knoxville, Tennessee

Yellow Poplar

1. 100 selections used in establishing seed orchards with 3 physiographic regions recognized.
2. Controlled crosses made and progeny tests established.
3. Evaluation of crosses between physiographic regions.
4. Study of attempts to improve pollination and seed germination with use of honeybees.

Black Walnut

1. Seed orchard established with 40 selections, Open pollinated progeny tests started.

American Chestnut

1. Evaluation of trees produced from irradiated nuts.
2. Propagation of apparently blight-resistent trees.
3. Chemical analysis of bark.

New York State College of Forestry, Syracuse University,
Syracuse, New York

Black Cherry

1. Investigation of reproductive cytology.
2. Self-compatibility and reproduction.

Yellow Poplar

1. Hybridization between northern and southern populations.
2. Effect of gamma radiation on pollen used in controlled crosses.

Elm

1. Reproductive cytology.

Aspen

1. Rooting ability of juvenile and mature tissues.
2. Effects of labeling pollen with phosphorus 32 on controlled crosses.
3. Constancy of genetic control (repeatability) of wood characteristics and pulping properties in certain hybrids.
4. Heritability of leaf morphology and wood characteristics.

Yellow Birch

1. Provenance study.

Sugar Maple

1. Provenance study.
2. Selection for high sugar content.

Michigan State University, East Lansing Michigan

Yellow Birch

1. Provenance test.

Black Walnut

1. Variation among black walnut hybrids.

Michigan Technological University, Houghton, Michigan

Sugar Maple

1. Variation in bark characteristics.
2. Variation in wood quality.
3. Provenance study.

University of Minnesota, St. Paul, Minnesota

Poplar

1. Hybridization studies.

Paper Birch

1. Genetic variance.

New York Conservation Department, Ballston Spa, New York

Sugar Maple

1. Provenance study.

Institute of Paper Chemistry, Appleton, Wisconsin

Aspen

1. Early growth and wood properties of triploid aspen and aspen hybrids.
2. Geographic variation.
3. Heritabilities of form, rate of growth, and wood properties.
4. Nutrient requirements.
5. Physiology and cytology of tree growth and differentiations.
6. Cytology of fertilization and embryo initiation.

Connecticut Agricultural Experiment Station, New Haven, Connecticut

Chinese Chestnut

1. Natural regeneration studies in 40-year old stand.
2. Host-parasite relationships.

Chestnut

1. Hybridization and testing for blight resistance.

U. S. Forest Service, Region 9, Milwaukee, Wisconsin (Continued)

2. Planned -

- Open pollinated seed collections
- Establish clonal breeding arboretum
- Progeny tests in 12 areas
- Controlled pollination in breeding arboretum

Black Walnut

1. 59 selections made in Tennessee, Kentucky, Illinois, Missouri, Kansas, West Virginia, and Ohio.
2. Planned -
   - 4 progeny test areas - to be used as seedling seed orchards
   - additional 125 selections.

Tennessee Valley Authority, Norris, Tennessee

Yellow Poplar

1. Cooperating with University and State of Tennessee combine selections of all three organizations. 80 selections to-date.
2. 4 clonal seed orchards.

   4 geographic sources recognized -

   - West Tennessee
   - Cumberland Mountains - Highland Rim
   - East Tennessee
   - North Carolina

3. Progeny tests within and among sources.
4. Comparison of open, controlled, and self-pollinated progeny.
5. Effect of various cultural methods on orchard production and harvest.
6. Altitudinal variation in Smokies and Cumberland.

Black Walnut

1. Cooperating with University and State of Tennessee combine selections of all three. 75 selections to-date.
2. 4 clonal seed orchards. Establishment difficult because of grafting problems.
3. Open pollinated progeny test with U. S. Plywood-Champion and seedling seed orchard. 30 acres in North Alabama.

   Little breeding work planned because of lack of success in controlled pollination.

Black Cherry

1. 34 selections in Pennsylvania, Tennessee, North Carolina, and Virginia.
2. 4 seed orchards.
3. Geographic variation study -
   - 8 sources from North Carolian, Tennessee, Virginia, Pennsylvania, and Michigan.
   - 4 plantings in Tennessee, Alabama, West Virginia, and Michigan.

The Oaks

1. Selections throughout Tennessee Valley -
   - 33 NRO
   - 33 WO
   - 22 CO
2. Seed orchards - 4; to be progeny tested with open-pollinated seed.
3. Plantation tests -
   - 50 Northern red oak families for determining family differences and fertilizer response.
   - 25 white oak families for same reasons.
   - 11 chestnut oak families plus 3 CO-WO hybrids for same reasons.
   - 225 northern red oak and 35 white oak families for progeny testing to make second generation selections.

North Carolina State University, Raleigh, North Carolina

Southern Hardwoods

Research in regeneration, management, and harvesting.

Selection and preservation in clone bank of 20 species.

A few acres of seed orchards - sweetgum, yellow poplar, and sycamore.

Open pollinated program testing of each of the selections in the 20 species.

North Central Forest Experiment Station, Rhinelander, Wisconsin

Yellow and White Birch

1. Genetic variation
2. Breeding methods.
3. Compatibility with genus Betula and interspecific crossing to test hybridity.

North Central Forest Experiment Station, Carbondale, Illinois

Black Walnut

1. Breeding value of 40 selections outplanted in Indiana and Kentucky.
2. Seed source study

   Outplanting of 20 sources in 14 States representing 480 families.
3. Relation of seed source and growth in Southern Illinois.
4. Relation of growth to seasonal variation in precipitation, soil moisture, air temperature, day length, and climatic factors.
5. Variation in apical dominance.
6. Variation in growth, branching habit, and stem straightness among sources, families, and clones.
7. Selection for drought resistance

   Seed from 50 trees at 8 locations planted on 2 sites in western Missouri and Illinois.
8. Establish breeding collection of 24 Juglans species and hybrids.
9. Heritability of anthracnose resistance. Progeny test of 73 parent trees.

10. Selection for late flushing, cold hardiness, and rapid growth in 87 families.
11. Variation in rootability by layering in 48 families.
12. Environmental and genetic factors in production of nursery stock.
13. Taxonomic and genetic analysis of various Juglans species and hybrids.
14. Effect of irrigation on growth of 5 seed sources.
15. Genotypic variation in first year growth under 4 environmental conditions of 18 parents.

Texas Forest Service, College Station, Texas

Species - Site Trials in East Texas

1. Sycamore, green ash, sweetgum, water oak, cherrybark oak, white oak.
2. Double disked land prior to planting.
3. disked twice during first growing season.

Western Gulf Forest Tree Improvement Program (Hardwoods)

1. 6 organizations owning land in Arkansas, Louisiana, Texas, Oklahoma, and Mississippi - tree selection guidance by Texas Forest Service in experimental design, data interpretation, analysis, and developing new techniques.

   Individual companies assign own species priorities, rate of progress on own land, and silvicultural problems associated with species.

2. Geographic seed source studies within Texas - sycamore, sweetgum, green ash - just starting.

3. Cottonwood selection - spacing studies - irrigation.

Southern Forest Experiment Station, Gulfport, Mississippi

Sycamore

1. Anatomical and cylotogical development of reproductive process.
2. Reproductive process from selfing, crossing, and sweet gum pollination.
3. Variation in open pollinated progeny from 5 stands along the Chattahoochee River in Georgia.

White Oak Group

1. Premature acorn abscission.

Sweet Gum

1. Selection in Formosan sweetgum for fall coloration.
2. Geographic variation in 650 families in Mississippi, Louisiana, and Alabama.

Sweet Gum, Sycamore, Green Ash, and Cherrybark Oak

1. Provenance tests of open pollinated seed collected along transect in the Mississippi Valley from Southern Illinois to Southern Louisiana and along transect on the Atlantic Coast from Southeastern Virginia to Northern Florida.

Southern Forest Experiment Station, Stoneville, Mississippi

Cottonwood

1. Open pollinated progeny test of selections from Minnesota to Louisiana for study of survival, growth, branching form, specific gravity, fiber length, and resistance to insects and diseases - one plantation at Stoneville, Mississippi, and one in Illinois.

2. Adaptability of clones to different geographic areas. Fifteen testing sites from South Carolina to Missouri and Louisiana with 14 clones recently released for commercial production.

3. Screening of clones for commercial release - 14 already released and 2,000 being evaluated.

Sweet Gum

1. Geographic variation among sources from Mississippi, Alabama, and Tennessee.
2. Progeny test of Tennessee and Arkansas sources.
3. Cause of top die-back in plantations.

Willow

1. Comparison of growth and insect resistance of black and sandbar willow, three hybrids, and weeping and white willow.

Sycamore

1. Geographic variation in 100 families.
2. Progeny tests in Tennessee and Arkansas.

University of Vermont, Burlington, Vermont

Sugar Maple

1. Variability and effect of environment on sugar content of sap.

Sugar Maple, White Ash, White Birch, and Yellow Birch

1. Site evaluation.
2. Effect of environment on survival and growth.

University of West Virginia, Morgantown, West Virginia

Black Cherry

1. Vegetative propagation.
2. Provenance study.
3. Individual tree variation.

Northern Red Oak

1. Individual tree variation.

Black Locust

1. Effect of environment on genotypes.

Northeastern Forest Experiment Station, New Haven, Connecticut

Chestnut

1. Examination of hybrid and Asiatic chestnut

Red Maple, Aspen, and Ash

1. Feeding preferences of gypsy moth.

General Hardwoods

1. Factors affecting gypsy moth populations.

Northeastern Forest Experiment Station, Warren, Pennsylvania

Black Cherry

1. Establishment of breeding arboretum.
2. Fertilization response in clones.

Clemson University, Clemson, South Carolina

Southern Red Oak

1. Provenance study.

Chestnut

1. Progeny test of hybrids, chinese and American chestnut.
2. Clonal seed orchard.

Yellow Poplar

1. Selections and seed orchard establishment.

General

1. Arboretum composed of 380 hardwood trees and shrubs.

U. S. Forest Service, Southeastern Forest Experiment Station, Olustee, Florida

Eucalyptus

1. Tree selection (fiber production main criteria).
2. Progeny testing.
3. Coppice development
4. Seed orchards.

Tennessee State Forest Service, Knoxville, Tennessee

Yellow Poplar

1. Tree selection.
2. Progeny tests.
3. Seed orchards.

Black Walnut

1. Tree selection.
2. Seed orchards.

Cherrybark Oak

1. Tree selection.
2. Seed orchards.

North Carolina Forest Service, Raleigh North Carolina

Tree selection in following species:

Black cherry, basswood, northern red oak, scarlet oak, black walnut, southern red oak, sycamore, black oak, yellow poplar, red maple, white oak, sweet gum.

Copp icing:

Yellow poplar, oaks, black cherry.

Stemless planting:

Black walnut, sycamore, and black cherry.

Seed storage and germination:

Oaks, black cherry, black walnut, basswood, cucumber, ash, hickory, sugar maple, birch, tupelo gum.

Regeneration and conversion:

Sycamore, yellow poplar, black walnut, chestnut, oak, tupelo gum, black cherry, black locust, black oak, cherrybark oak, ash, northern red oak, red maple, birch, sweet gum, white oak.