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Forest Tree Improvement at Michigan State University: Past, Present, and Future

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Abstract: The Department of Forestry at Michigan State University has engaged in forest tree improvement for more than 50 years. This paper presents a brief historical perspective on past research, the status of current projects, and outlines plans for the future.

Keywords: provenance tests, genetics, progeny tests, seed orchards, resistant genotypes

Introduction

Forest tree improvement in the United States began in earnest in the 1950s. At Michigan State University (MSU), the first tree improvement planting (a hybrid chestnut blight resistance trial) was established in 1947. Although only a handful of outplantings were accomplished throughout the 1950s, the program expanded dramatically in the early 1960s. More than 500 outplantings have been established since 1947. These plantations contain(ed) over 5,000+ accessions of 59 hardwood species, and over 10,000+ accessions of 58 conifer species. The preponderance of conifer accessions reflects the fact that conifers are much more widely planted than hardwoods on forest land in Michigan.

The Tree Research Center (TRC) located on the south end of the MSU campus (East Lansing, MI) serves as a base of operations, and the TRC greenhouses and nursery produce virtually all of the planting stock for our forest genetics plantations. Many of our tests are located on several off-campus experimental forests, and the crews at Kellogg Forest (Augusta, MI), the Upper Peninsula Tree Improvement Center (Escanaba, MI), and the TRC provide invaluable help in outplanting, maintaining, and collecting data from these outplantings.

During its long history, the Michigan State Forest Genetics (MSFG) program has worked nearly continuously on a few widely-planted species, such as jack pine (*Pinus banksiana*), red pine (*P. resinosa*), and white spruce (*Picea glauca*). There have, however, been periodic shifts in species emphasis that correspond to changing market demands for planting stock and funding opportunities. These shifts are roughly associated with the tenure of the three successive directors of MSFG research: Jonathan Wright, James Hanover, and Daniel Keathley. To briefly sketch the history of MSFG research, I plan to highlight the accomplishments and primary species of interest to each of these directors. The paper will conclude with a description of plans for future tree improvement work.

Jonathan Wright: 1957 to 1974

Jonathan Wright was one of the proverbial forefathers of tree improvement in the United States. Wright advocated a relatively low cost, less intensive approach to tree improvement that relied heavily on provenance and half-sib progeny testing. This approach contrasted sharply with the more intensive programs in the Southeastern and Northwestern US that placed more emphasis on costlier full-sib progeny testing and grafted seed orchards. The two approaches essentially reflected the forestry markets in which they operated. Operational forestry is much more intense, and the increased cost of more intensive tree improvement programs can quickly be recouped in these large markets. In contrast, Lake States timber and pulp markets are substantially smaller, with fewer acres planted annually, and the resources available for tree improvement are greatly reduced.

During his tenure, Wright was responsible for establishing 140 provenance test plantations. Species tested ranged from regional staples like white spruce, and jack and red pine, to relatively minor native species such as balsam fir (*Abies balsamea*), black cherry (*Prunus serotina*), and black walnut (*Juglans nigra*), to exotics including Scotch pine (*Pinus sylvestris*), Japanese larch (*Larix leptolepsis*), and Norway spruce (*Picea abies*). Many of these provenance tests were cooperative efforts with other universities and the USDA Forest Service (USFS). For many years the USFS organized and partially funded a loose regional cooperative of land grant universities and state agencies in the North Central region. One institution would initiate a test and cooperating institutions would aid in the collection of seeds, plantation establishment, and collection of data. Nearly all of Wright's provenance tests were implemented under this cooperative agreement.

Compared to provenance tests, Wright established markedly fewer half-sib progeny tests (approximately 40). Many of them, however, were very intensive and formed the foundation of future MSFG work with a handful of native species. Notable among these are progeny tests of red, jack, and

eastern white pine (*Pinus strobus*). Each of these tests contained from 150 to 300 half-sib families collected from Michigan and Ontario, and provided selections for second generation tree improvement.

Although Wright worked to varying extents with several exotic species, he certainly devoted more effort to Scotch pine than any other exotic. Wright was responsible for establishing over 40 Scotch pine provenance and progeny tests. Wright and his cooperators (establishing 31 test locations spread over eight North Central states) delineated geographic varieties based on growth, foliage color, needle length, and susceptibility to four insect pests. This information aided Christmas tree growers in selecting appropriate seed sources, and made Scotch pine the premier Christmas tree in Michigan for more than two decades.

James Hanover: 1974 to 1992

James Hanover joined the MSU faculty in 1966, 15 years prior to Wright's retirement in 1981. During the mid-1970s, Hanover gradually assumed the reins of the MSFG program. In 1974, Hanover founded the Michigan Cooperative Tree Improvement Program (MICHCOTIP). At its inception, MICHCOTIP had nearly 20 cooperators, including several Michigan nurseries, pulp and paper companies, and the Michigan Department of Natural Resources (MDNR). MICHCOTIP strove to optimize available resources and advance tree improvement in Michigan by drawing a broad group of private and public interests under one organizational umbrella.

MICHCOTIP continued Wright's work on species essential to the state's pulp and timber industry, particularly jack, red, and eastern white pine, and white spruce. Data collected from 1960s progeny tests of all four species were used to thin several plantations for the production of genetically improved seeds. Hanover also began to work more intensively with Douglas-fir (*Pseudotsuga menziesii*) in order to provide seed source recommendations to Michigan Christmas tree growers.

In 1988 and 1989, controlled pollinations were made among selections in a Great Lakes half-sib progeny test of jack pine. In 1994, seedlings from those crosses were planted in a second generation full-sib progeny test and a 9-ha (23-ac) seedling seed orchard at the MDNR State Tree Improvement Center near Brighton, MI.

While he continued work on pulp and timber species, Hanover also began screening a wide variety of species for biomass production. Interest in alternative forms of energy was extremely high during, and immediately following, the gasoline crisis of the 1970s. The US Department of Energy (DOE) was charged with evaluating and developing the potential of various alternative energy sources; one of these sources was woody biomass. At this point in time, potential species were evaluated primarily on the basis of BTU production (a simple function of biomass production, wood density, and moisture content), because all woody fuels were expected to be burned in power plants. Ethanol production, gasification, torrefaction, and other conversion processes under consideration today did not figure prominently in immediate plans to convert wood to energy. In species trials, black locust (*Robinia pseudoacacia*) produced the most BTU/ac in southern Michigan, while poplar and aspen hybrids (*Populus* spp.) performed best in northern Michigan and the Upper Peninsula.

The species trials led to the establishment of an extensive black locust half-sib progeny test containing more than 400 families collected throughout the natural range of the species east of the Mississippi. Field tests of clones selected from the progeny test were also established. Work also continued on hybrid poplar and aspen hybrids with establishment of clonal trials and full-sib progeny tests respectively.

Daniel Keathley: 1992 to Present

By 1990, only the USFS, MDNR, and Christmas tree growers were planting significant acreages in Michigan. Membership in MICHOTIP had dwindled below financially and operationally sustainable levels, and the DOE had virtually ended all of its woody biomass genetics research. In 1992, James Hanover's untimely death led to Daniel Keathley assuming the directorship of MSFG research. Faced with diminished resources, Keathley focused tree improvement research on the needs of its two most prominent constituents: the MDNR and Christmas tree growers.

Work for the MDNR still focused primarily on the same pulp and timber species that the MSFG program had worked with continually for more than 40 years. In 2004 and 2008, two progeny test plantings of white spruce were thinned to produce genetically improved seeds. Progeny test data was used to modify a systematic thinning of the MDNR jack pine seed orchard at Brighton, MI. More than 2600 trees were removed to create growing space for residual trees and increase the level of genetic gain. An aerial view of the one of the thinned blocks is provided in Figure 1. The topping of residual trees is currently underway in order to keep live crowns within reach of cone harvesting equipment.

In 2007, the MDNR requested that the MSFG program cooperate with them and the USFS in evaluating American beech (*Fagus grandifolia*) selections for potential resistance to beech bark disease (BBD). BBD has devastated beech in New England for decades, and was discovered in Michigan in 2000. Uninfected trees have been identified in killing fronts (areas of heavy BBD-induced mortality) in Michigan. The project is managed by Jennifer Koch of the USDA Forest Service Northeastern Forest Experiment Station. MSFG has been producing rootstock and assisting in the propagation of resistant selections via grafting. The goals of the project include quantifying the degree of genetic control over BBD resistance, archiving resistant genotypes via grafting, and creating seed orchards that produce known percentages of resistant progeny.

Other than the USFS and MDNR, no commodity group or agency in Michigan plants more acres of trees annually than Christmas tree growers. By 1992, the national Christmas tree market was becoming increasingly competitive as demand decreased and new states (particularly North Carolina) entered the market. For more than two decades, Scotch pine was the mainstay of the Michigan Christmas tree market. As cultural practices intensified to produce higher quality trees, growers had difficulty finding consistent sources of quality Scotch pine seeds. In cooperation with the Michigan Christmas Tree Association, we made more than 50 phenotypic selections after surveying growers' fields across Lower Michigan. Ramets of these selections were established in two grafted seed orchards in 1995 and 1997. A half-sib progeny test of the orchards established in 2009 will empirically quantify the actual genetic value of the phenotypic selections and guide any future roguings of the orchards.

During the past two decades, Fraser fir (*Abies fraseri*) has gained prominence in Michigan's Christmas tree market, and commands a premium price. Fraser fir, however, is susceptible to root disease caused by *Phytophthora* spp. on wet sites and suffers poor growth and survival on even moderately dry sites. MSFG is grafting Fraser fir scion on various *Abies* spp. rootstock to determine if the rootstock can confer resistance to *Phytophthora* spp. and/or drought to Fraser fir scion growth. This work was spurred by field tests at North Carolina State University that found Fraser fir grafted on to Momi and Nordmann fir (*A. firma* and *A. nordmanniana*) rootstock survived and grew dramatically better than standard Fraser fir planting stock on sites infested with *Phytophthora* spp. Similar success in Michigan could expand the range of sites capable of producing Fraser fir. If the biology of conferring resistance to *Phytophthora* spp. and/or drought is effective, further work will need to be done to determine if the added cost of using grafted planting stock is financially feasible.

Figure 1. Aerial view of a block in the Michigan Department of Natural Resources jack pine (*Pinus banksiana*) seed orchard after thinning.

Current Plans for Future Work

Work will surely continue with the staples of the pulp and timber industry, particularly jack pine, red pine, and white spruce. Trees in the MDNR jack pine orchard at Brighton are currently being topped, and the orchard should remain in production for many years. Selections will eventually be made from the full-sib progeny test that complements the orchard, and a third generation seed orchard and progeny test will be established. Red pine selections have been made in a 44-year old progeny test. Past grafting efforts with red pine have met with limited success, and we may attempt to establish a seedling orchard when we get a decent cone crop.

We will continue our cooperative work with the USFS and MDNR on developing BBD-resistant beech. In 2010, MSFG will design and help establish an orchard of resistant genotypes at the MDNR State Tree Improvement Center. It is expected to take several years of testing and grafting selections to complete the orchard.

Future work for Michigan Christmas tree growers will include roguing the Scotch pine orchards based on data from the progeny test established this year. The progeny test will also provide selections for the eventual establishment of a second generation orchard.

In spring 2010, we plan to start field testing grafts of Fraser fir on various *Abies* spp. rootstocks on dry sites and sites infested with *Phytophthora* spp. The field tests will determine if the rootstock species can confer resistance to *Phytophthora* spp. and/or drought to the Fraser fir scion, and produce a high quality Christmas tree within an acceptable rotation length.

Following a decade long lull, our work with biofuels species will increase as Michigan and the country seek to develop alternative energy sources. Currently, a general consensus on which systems are most efficient and practicable in converting cellulosic feedstocks into energy is lacking. Therefore it is difficult to determine what the ideal characteristics of feedstocks will ultimately be. Recent biofuels field tests in the Lake States are emphasizing poplar and willow (*Salix* spp.) feedstocks. The TRC is providing planting stock for large plot clonal trials in the Upper Peninsula organized by Ray Miller (Upper Peninsula Tree Improvement Center manager). In southern Michigan, our previous work with black locust puts us in a position to develop improved planting stock if black locust proves to be a suitable feedstock. We have already coppiced one replication of a clonal trial to get basic information on coppice yield and management. A wider array of species that have been field tested for their suitability in Michigan biofuels plantings would also be useful. MSFG plans to collect silver maple (*Acer saccharinum*) seeds from Ontario and the Northeastern US in spring 2010. These seeds will provide planting stock for a combined provenance/progeny test to be planted in spring 2011. If growth and wood characteristics of silver maple are suitable for operational biofuels outplantings in Michigan, this test will provide the first step in developing genetically improved planting stock.

MSFG will continue to maintain older genetic plantings, particularly at MSU-owned properties with on-site personnel. Although many of these plantings are now of little use for operational tree improvement, forestry researchers from many different fields have found it extremely useful to have mature trees of known geographic origin in common garden field trials. Researchers working on forest entomology, pathology, basic population genetics, physical wood properties, and climate change models have all made use of MSFG plantings, data, and records. MSFG plantation records, accession information, and nearly 50 years of data are maintained by the author. Anyone wishing information on MSFG plantings should contact the author.