North Carolina's Christmas Tree Genetics Program

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ABSTRACT

The Christmas Tree Genetics Program at N.C. State University started July 1, 1996 with the charge to improve Christmas tree species important to the state. Emphasis of the program is on Fraser fir (*Abies fraseri* [Pursh] Poir.) in the western N.C. mountains, but genetic improvement programs have also been initiated for Virginia pine (*Pinus virginiana* Mill.), eastern white pine (*Pinus strobus* L.) and eastern redcedar (*Juniperus virginiana* L.), which are important Christmas tree species in the coastal plain and piedmont regions of the state. Additionally, fir species that might demonstrate heat tolerance and/or disease resistance are being evaluated. Efforts to date have concentrated on the establishment, maintenance and assessment of 25 genetic field tests containing over 51,000 trees. In the near future, selections from these tests will be made, breeding programs initiated and seed or hedge orchards established to provide improved planting stock for the state's Christmas tree growers.

Keywords: forest tree improvement, Fraser fir, Virginia pine, eastern white pine, eastern redcedar

North Carolina's Christmas Tree Industry

Nationwide, approximately 35% of all U.S. households use Christmas trees resulting in over 35 million trees sold each year. In North Carolina, 5.5 to 6.0 million Christmas trees are harvested annually (2nd in nation) (McKinley 1996) with estimates of annual revenue from the state's Christmas tree industry ranging from $74 million to more than $100 million (1st in nation) (Aruna et al. 1998, McKinley 1996, NCDA&CS 1998). This economically significant industry has developed over the last 25 years primarily in the mountainous western portion of the state based on the production of Fraser fir and is critical to the people of western North Carolina because it provides an important source of income to rural areas.

Fraser fir has been widely accepted as the premier Christmas tree species in much of the United States due to a combination of attributes including pleasing aroma, dark blue-green foliage, natural Christmas tree shape, strong branches for holding ornaments and excellent post-harvest foliage retention (Arnold et al. 1994). The later characteristic allows Fraser fir to be harvested early and shipped to markets primarily along the Atlantic seaboard but, also, to the nation's interior and west coast as well as to Caribbean and Latin American markets.

Fraser fir is largely adapted to a cool season climate, so that its production in North Carolina is restricted to elevations at or above 3,000 feet (Thor et al. 1962, Torbert and Nichols 1991). Fraser fir's extreme susceptibility to phytophthora root rot (caused by the water mold fungus, *Phytophthora cinnamomi* Rands) also limits production on infested sites in the

mountains but, even more so, in piedmont and coastal plain areas where warmer temperatures provide more favorable conditions for disease development.

Currently, Christmas tree production east of the mountains in North Carolina is small and accounts for less than 2% of the state's production revenue. Christmas tree production in this region is limited to "choose and cut" operations since the species grown rapidly lose their needles after harvest, precluding shipment to non-local markets. The primary Christmas tree species in this region include Virginia pine, eastern white pine, eastern redcedar and Leyland cypress (x *Cupressocyparis leylandii* 'Leighton Green')'. In addition to poor post-harvest needle retention, these species are also quite variable in quality (except Leyland cypress, which is a clone) and difficult to culture.

Christmas Trees versus Traditional Forest Products

Growing forest tree species for Christmas tree production is different in many ways from growing them for traditional pulp, paper and solid-wood products. McKinley and McKeand (1995) pointed out that Christmas trees generally have a 1) higher value ($15-25/tree wholesale), 2) shorter rotations (4-12 years), 3) more intensive management (frequent pest and weed control, fertilization, shearing, baling and for some species, colorant applications) and 4) more consumer dependence than forest trees grown for timber production. Additionally, Christmas tree production is usually a family business as opposed to the large corporations and government agencies that dominate the forest products industry. When comparing genetic improvement efforts between Christmas tree and timber species, one must keep in mind that for Christmas trees there is 1) a shorter and inconsistent research history (i.e., a smaller knowledge base), 2) fewer funding sources with lower levels and 3) a poorer understanding of the value of research by Christmas tree growers. Thus, Christmas tree genetic improvement efforts have lagged, and will likely continue to lag, those in forestry.

Genetic Improvement Programs

In July 1996, the Department of Forestry at N.C. State University established the Christmas Tree Genetics Program although a considerable amount of Christmas tree research with Fraser fir preceded this date. This program was initiated largely as a response to appeals by the growers of the state and is charged with the genetic improvement of Christmas tree species important to North Carolina. Since its inception, genetic improvement efforts have begun for Fraser fir, Virginia pine, eastern white pine and eastern redcedar. Each of these programs is uniquely tailored to the individual species according to their biologic constraints and importance to the state's industry.

Fraser Fir

Due to its importance as a Christmas tree species, genetic improvement efforts for Fraser fir have spanned a number of years although progress has been slower than for southern pine species. The North Carolina Division of Forest Resources (NCDFR) and the N.C. State University-Industry Cooperative Tree Improvement Program carried out early work. When the Christmas Tree Genetics Program began in July 1996, it continued these and initiated new efforts. An overview of Fraser fir genetic improvement efforts is presented in the following sections.

N.C. Division of Forest Resources

In response to the growing Fraser fir Christmas tree industry and the increasing need for seedlings, the NCDFR established a Fraser fir seed orchard at the Gill State Nursery near

Crossnore, N.C., during 1967-1969. Trees in this orchard were selected from Christmas tree plantations, evaluated by the N.C. State University – Industry Cooperative Tree Improvement Program and then transplanted into the orchard site. A total of 312 trees occupying about 4.5 acres were originally transplanted. Significant seed production from this orchard began in the early 1980s after which time the orchard averaged about 265 pounds of seeds a year (about 55,000 seeds/lb) although year-to-year yields have been highly variable. Progeny tests of the orchard parents were established in 1983 through 2000 and performance evaluations are available for a portion of the parents. Second generation selections have also been made from these tests and grafted for future breeding efforts. Currently, this orchard is in a state of decline and will be phased out of production over the next several years. In 1984-1986, 38 phenotypic selections from the original seedling orchard were grafted into a clonal seed orchard for a total of 15 acres. Significant cone production for this orchard has commenced so that it will eventually replace the original orchard.

Annually, the NCDFR's Linville River Nursery sells 2-4 million Fraser fir 3-0 seedlings to North Carolina Christmas tree growers. Growers purchase and line out these seedlings into transplant beds for two years to produce 3-2 transplants for Christmas tree plantation regeneration. Seedlings derived from the seed orchards described above are sold as improved whereas; unimproved seedlings that originate from a planted seed production area are sold as wild seedlings. The NCDFR has begun collecting seeds by orchard parent tree and as soon as enough seeds are accrued, will begin separately sowing and marketing seedlings from the better open-pollinated families.

N.C. State University

The N.C. State University–Industry Cooperative Tree Improve- ment Program established a Fraser fir provenance-progeny test in 1983. Wind-pollinated seeds collected from each of 10 trees from nine Fraser fir seed sources (elevation class/population combinations) were planted at three sites: Bald Mountain, Crossnore and Purchase Knob. Eight-year (rotation age) data from this test series indicated high genetic control of traits important for Christmas tree production including height, crown diameter, crown density and wholesale value (open-pollinated family mean h^2 = 0.73, 0.81, 0.72 and 0.87, respectively) (Arnold et al. 1994). Height and wholesale value differences among seed sources were statistically significant. Generally, the southern sources that were tested (Richland Balsam and Clingman's Dome) and the lower elevation classes (5000 and 5500 feet) resulted in the tallest Christmas trees with the greatest wholesale value. This and other information generated from this study is being used to continue improvement of Fraser fir.

Prior to harvesting the trees at the three study sites, over 100 elite trees were selected and grafted into a clone bank in Macon County. These selections were from progeny of the best 18 of the original 90 trees included in the study. These selections will become part of the breeding population to further improve Fraser fir for Christmas tree production. Select progeny trees from the remaining 72 of the original 90 trees were also grafted into the clone bank for genetic conservation purposes. With the decreasing availability of mature Fraser fir and increasing restrictions on collecting cones from natural stands, this material has proven to be valuable and will continue to be even more so in the future.

In 1994, taking advantage of an exceptionally productive cone year, N.C. State University conducted a range-wide Fraser fir cone collection (McKeand et al. 1995). This resulted in the most extensive collection of Fraser fir seeds ever assembled including over 500 open-pollinated families from each of the six major Fraser fir populations. Using these seeds, the

Fraser Fir Progeny Test Series was established in 2000. Seedlots representing all six populations are being tested. Seedlots from the southern sources (Balsam and Great Smoky Mountains) and originating from the lowest elevations within each source have been given greater representation. The areas within each source tested will be considerably greater in the new test series than in the 1983 provenance-progeny test study. For example, only Clingman's Dome in the Great Smoky Mountains was tested in 1983, while about ten sources within the Smokies are currently being tested. Also, one source not previously tested, Grandfather Mountain, has been included in the new test series.

The Fraser fir seedlots were split into two groups of 100 each, including checklots common across both groups. Each group of seedlots has been established on each of four different test sites. Thirty-five blocks containing single-tree noncontiguous plots were established at each planting site along with ten 10-tree row plots for demonstration purposes. These studies have been established with cooperating growers and will be managed as commercial Christmas trees including shearing. These tests will be measured annually for at least four years. In 2005, selections will be made based on analyses of growth and Christmas tree quality data. Scions will be collected and grafted to preserve select material for future generations of genetic improvement and for seed orchard establishment.

Growers' Cooperative

The North Carolina Premium Fraser Fir Seed Cooperative (NCPFFS Coop) was organized and filed Articles of Incorporation and bylaws during the summer and fall of 2000. This organization will operate like a farmers' cooperative as outlined in Chapter 54 and amendments of the Public Laws of North Carolina with the primary purpose of producing and distributing genetically improved Fraser fir seeds. N.C. State University has entered a licensing agreement with the NCPFFS Coop to exclusively use the Fraser fir selections from the 1983 provenance-progeny test series (although the NCDFR will retain access rights to the material).

Currently, about 35 growers are NCPFFS Coop members with an ultimate cap of 60 members. Membership cost is $3,000, payable over a three-year period. A ten-acre site in Ashe County has been donated for the orchard. This past spring (2001), the site was planted with 3-3 Fraser fir transplants that will be grown on site with the orchard trees and sold as Christmas trees in 7-8 years to defray orchard costs. Positions for planting future orchard trees were left vacant. Also during this past spring, 55 or more scions from the best 30 Fraser fir selections from the 1983 provenance-progeny test series were grafted onto 3-3 transplants in an Ashe County nursery. These grafts will be transplanted into the orchard site next planting season. Significant cone production is anticipated to begin in 10-12 years.

Virginia Pine

Virginia pine is the second most commonly planted species for Christmas tree production in North Carolina. It is widely planted by North Carolina Christmas tree growers east of the Appalachian Mountains where Fraser cannot be successfully grown. Virginia pine is a deserving Christmas tree species because of its: 1) rapid growth (3 to 5 years to harvest), 2) short needles, 3) good branch structure for holding ornaments, 4) pleasant pine scent and 5) dark green color. However, Virginia pine also has several significant problems as a Christmas tree species. Chief among these problems are 1) poor stem form, 2) non-uniformity and 3) extreme susceptibility to damage by the Nantucket pine tip moth (*Rhyacionia frustrana* [Comstock]). In fact, due to the cumulative effect of these and other problems, growers typically only market about 50% or less

of Virginia pines planted. The future use of genetically improved planting stock will help substantially raise this yield.

Currently, Virginia pine planting stock of most North Carolina growers originates from the North Carolina Division of Forest Resources' seed orchard at the Morganton Forestry Research Center. This orchard contains 20 clones that were selected for forest production rather than for Christmas tree production. While this material is a good temporary source for growers, a comprehensive comparison of available Virginia pine material is needed.

The current tree improvement strategy includes establishment of a Virginia pine progeny test series using seeds from select trees of existing forest tree improvement programs. Seeds of 110 open-pollinated families were obtained from six organizations representing 1st and 2nd generation trees largely selected for fast growth and straight stem form. During the 1998-1999 planting season, four progeny tests were established at university field stations, two in the coastal plain and two in the piedmont. Each site is a completely randomized block design with single-tree noncontiguous plots except for a demonstration block that contains five-tree row-plots. Each single site contains about 4,000 study trees and at a 6 ft. x 10 ft. spacing occupies about seven acres. The progeny test series is being sheared and managed as Christmas trees and additional traits such as branching habit and tip moth resistance are being evaluated. During 2002, selections will be made from these tests and grafted to establish an open-pollinated seed orchard to provide growers with genetically improved seeds. It is anticipated that orchard production will meet demand by 2007.

Eastern White Pine

Eastern white pine is cultured as a Christmas tree across the state of North Carolina although its natural range is restricted to the mountains. Fast growth and high survival, heat tolerance and good color are desired traits for this species. Prior to the increase in Fraser fir production, white pine was widely grown in the mountains for Christmas trees. Currently, Christmas tree growers buy unimproved white pine 2-0 seedlings from the NCDFR.

In 1999, a three site eastern white pine progeny test series was established. One progeny test was established in the mountains, piedmont and coastal plain. Thirty-four seedlots including three checklots are represented. The open-pollinated families originate from the NCDFR and Virginia Division of Forestry seed orchards and have previously been selected for fast growth and stem straightness. These studies will also be managed as Christmas trees and in 2005, selections will be grafted for future breeding efforts and for seed orchard establishment.

Eastern Redcedar

Eastern redcedar is a traditional Christmas tree species commonly planted in North Carolina. This species makes an ideal candidate for clonal Christmas tree production. Unlike pine species, eastern redcedar roots readily at the ages of concern for Christmas tree production. Many cultivars (clones) of eastern redcedar exhibiting a wide variety of growth habits and colors have been propagated in the horticultural industry for years. Although eastern redcedar is an important Christmas tree species, the relatively small number of trees planted each year makes it difficult to justify a large-scale breeding program for this species. However, clonal selection within the currently used source will serve to provide growers with uniform and superior planting stock for the near future.

Christmas tree plantations of seven interested growers were searched for select trees early in 1997. Thirty-two individual tree selections were made. Measurements were taken for each selection and 5 surrounding check trees. Trees which were outstanding in any of the following

four categories were candidates for the clonal testing program: 1) growth and form, 2) color, 3) foliage softness, or 4) resistance to *Phomopsis* blight (caused by the fungus *Phomopsis juniperovora* Hahn).

Three clonal field trials were established in 2000; one in the piedmont, one in the upper coastal plain and one in the lower coastal plain. It is anticipated that selections can be made in 2004 and a hedge orchard established so that growers will have rooted cutting planting stock by 2006. No further genetic improvement efforts for eastern redcedar are planned due to its limited volume and values as a Christmas tree.

Alternative Fir Species

Two objectives have prompted investigation of the use of species other than Fraser fir from the genus *Abies*: the search for 1) resistance to phytophthora root rot and 2) a higher quality Christmas tree species for North Carolina's piedmont and coastal plain regions. Promising species include Turkish fir (*Abies bournmuelleriana* Mattf.), momi fir (*Abies firma* S. & Z.) and Nordmann fir (*Abies nordmanniana* (Stev.) Spach). Currently, these and a few other fir species are being assessed in field tests both as seedlings and as rootstock for Fraser fir scion. Additionally, a more comprehensive fir species evaluation containing 35 *Abies* species has been initiated and is currently in the greenhouse phase.

Additional Research

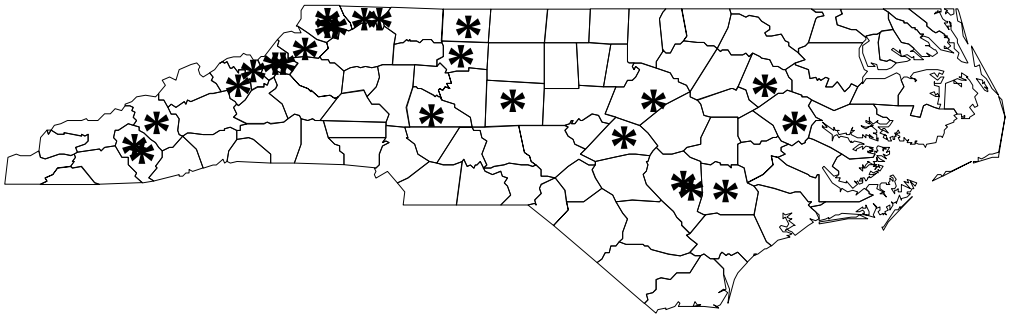
The Christmas Tree Genetics Program is conducting several avenues of research to support its genetic improvement efforts. Numerous other investigations are needed such as how to reduce the age of female and male strobilus production in Fraser fir. These research needs will be prioritized and addressed as time and resources permit.

One major effort currently under way is the vegetative propagation of Virginia pine, Fraser fir and other *Abies* species. Rooted cutting studies are under way to study 1) auxin type and concentration on rooting percent and root system quality, 2) the use of stumping to produce orthotropic and juvenile cuttings for rooting and 3) the potential for using outdoor beds for rooted cutting production. Tissue culture research with the same species is under way by collaborator, Ron Newton, in the Department of Biology at East Carolina University. Both micropropagation and somatic embryogenesis techniques are being investigated (Newton and Bivans 1999).

Another major research effort involves phytophthora root rot. Current investigations include 1) greenhouse resistance screening trials of Fraser fir families and other *Abies* species and 2) the use of amplified fragment length polymorphism (AFLP) techniques to better understand variation in the *P. cinnamomi* populations in western North Carolina.

SUMMARY

The North Carolina State University Christmas Tree Genetics Program is progressing toward producing genetically improved planting stock for Christmas tree growers throughout the state. Initial emphasis has been on the establishment of genetic tests for Fraser fir and several other important Christmas tree species. Twenty-five tests containing over 51,000 study trees have been established (Figure 1). According to the species, selections will be made in the near future, beginning with Virginia pine in 2002. Seed orchard establishment and advanced generation breeding programs for each species will follow. Additionally, vegetative propagation and disease resistance are being investigated to help further enhance Christmas tree production in North Carolina.



Species	# Tests	# Trees (approx.)
Eastern Redcedar	3	1,300
Eastern White Pine	3	3,500
Fraser Fir	8	28,800
Other Fir Species	7	2,300
Virginia Pine	4	16,000
Total	***25***	***51,900***

Figure 1. Research field trials established by the North Carolina State University Christmas Tree Genetics Program.

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