Building a Better Christmas Tree: Understanding Tree Improvement

Bert Cregg, Michigan State University, Department of Horticulture and Department of Forestry

Species trials are a critical first step in most tree improvement programs.


Fir species are screened for phytophthora resistance at Washington State University in controlled flood tests.

Christmas tree growers, like all crop producers, have two primary means to improve productivity and quality of their crop. First, they can modify the environment of their trees through cultural techniques such as irrigation, fertilization, or weed control. The other primary tool by which growers manage crops is through selection of improved genetics. While the term genetics may conjure up images of scientists in white lab coats splicing together strands of DNA, genetic improvement of Christmas trees includes a wide range of activities from traveling the world to find new exotic species to identifying genetic markers that may point to trees with better needle retention or disease resistance. Although Christmas tree improvement includes a diverse array of activities, some basic principles apply to all types of tree improvement.

Development or identification of new genotypes

The first step in a tree improvement program is to develop or identify new genotypes that we want to evaluate. At this point in the discussion we need to define what we mean by a genotype. Most simply, a genotype is the genetic make up of an individual. For Christmas trees and other forest trees, species selection is often the first level of genetic evaluation. Proper species selection is critical. If a species is not adapted to local climate and soils or doesn't have a sufficient growth rate and needle characteristics to make a desirable Christmas tree, than it is a non-starter. Species selection has been, and continues to be, one of the cornerstones of Christmas tree selection. In Michigan over a dozen species of conifers are grown as Christmas trees. Nevertheless many growers continue to explore new species and look for the exotics that will become the next big thing. At Michigan State University, Jill O'Donnell and Mel Koelling established an exotic fir demonstration trial at Kellogg Forest that includes over 30 Abies species. A subset of the trees was transplanted to MSU Horticulture stations across the state. Nordmann fir, Canaan fir and hybrid of Fraser X Nikko fir showed the best combination of form and growth rate at the field stations.

Populations of trees within species may also exhibit wide variation. For tree species that have large geographic ranges, populations within the species may evolve into distinct varieties. For example, Douglas-fir occurs as two varieties. Coastal Douglas-fir (Pseudotsuga menziesii var. menziesii) occurs mainly west of the Cascade crest in western North America and in the Sierras. Interior Douglas-fir (var. glauca) grows in the Intermountain West from southern British Columbia to northern Mexico. The interior variety is slower growing than the coastal form but is much more drought and cold hardy, enabling its use as a Christmas tree in the Upper Midwest and Northeast; climates that are too severe for the coastal form to survive. Grand fir (Abies grandis), Concolor fir (A. concolor) and subalpine fir (A. lasiocarpa) are other examples of Christmas trees species from western North America that exhibit significant varietal differences.

In addition to varieties, conifers may also vary at smaller geographic levels based on their seed origin or provenance. Identifying superior seed sources based on provenance testing has long been a major activity in many forest tree improvement programs. Michigan State University's Jonathan Wright was a leader among tree improvement scientists in the United States. Wright and his colleagues worked in regional cooperatives and established dozens of provenance tests, many of which were replicated in areas as diverse as Oklahoma and Saskatchewan. Wright made numerous contributions to the Christmas tree industry including

Fir species are screened for phytophthora resistance at Washington State University in controlled flood tests.

screening of Scots pine seed sources from throughout Europe and Asia. Identification of superior seed sources remains an important activity. In our current work with Turkish and Trojan fir in conjunction with the Collaborative Fir Germplasm Evaluation (CoFirGE), for example, we are evaluating trees produced from seed collected in Turkey by Dr. John Frampton (North Carolina State University), Dr. Gary Chastagner (Washington State University), and Chal Landgren (Oregon State University). The team collected cones from five different geographic areas (provenances) in the mountains of northern Turkey. The seeds were then sent to a nursery in Oregon where 30,000 seedlings were produced and then sent out to cooperators at five locations around the United States. Each cooperating institution installed two plantings in the spring of 2013, resulting in 10 test plots throughout the country.

Collecting seed from exotic species or from specific seed sources can lead to improvements in a variety of tree traits. To take the next step in tree improvement, however, requires identification of specific parent trees. If we collect cones from an individual tree, extract the seeds and plant them; all of the resulting seedlings have the same maternal parent. Collectively these seedlings are referred to as an open-pollinated family; we know the maternal parent (the tree from which we collected the cones) but we don't know the paternal parent since conifers are wind pollinated. Trees from an open-pollinated family may also be referred as half-sibs since they share only one parent. To get to an even greater level of relatedness breeders may develop full-sib families. To create a full-sib family a tree breeder isolates the female cones on a superior (or plus) tree and then deliberately introduces pollen collected from another plus tree.

By creating a series of crosses and using specific mating designs, breeders can estimate heritability (how much variation in a population is explained by genetics) and genetic gain (how much improvement can be expected by using selected families versus natural crosses). Some forestry tree improvement programs have progressed to advanced generation breeding. This means taking the best offspring from the first generation of families and then making crosses with them. Through a process of recurrent selection, breeders can repeatedly cross the best with the best for each generation to continually improve a species. The challenge with this process in conifers is that trees may

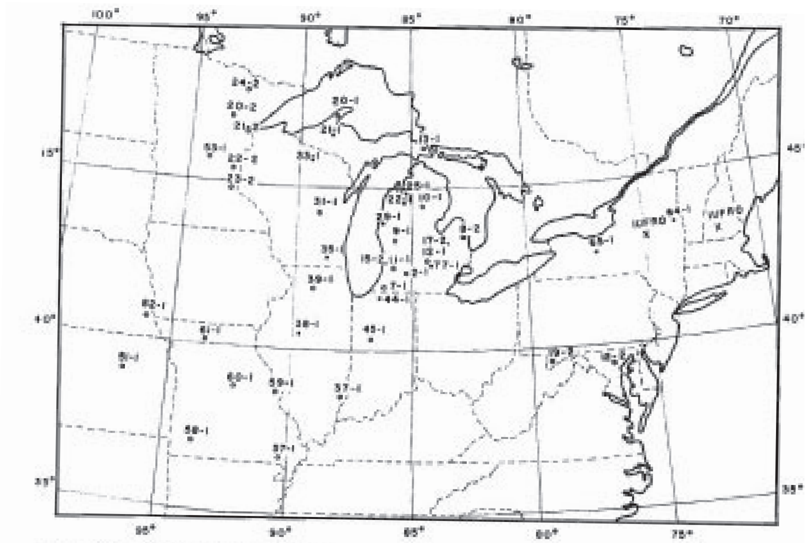


Figure 3. — Location of NC-51 and IUFRO test plantations of Scotch pine. The second number signifies date (1 = 1961, 2 = 1962).

Jonathan Wright (Michigan State University) and his colleagues installed provenance tests of Scots pine at over 30 locations across the central U.S.

Seed source selection remains an important means of incorporating genetic information into production systems.

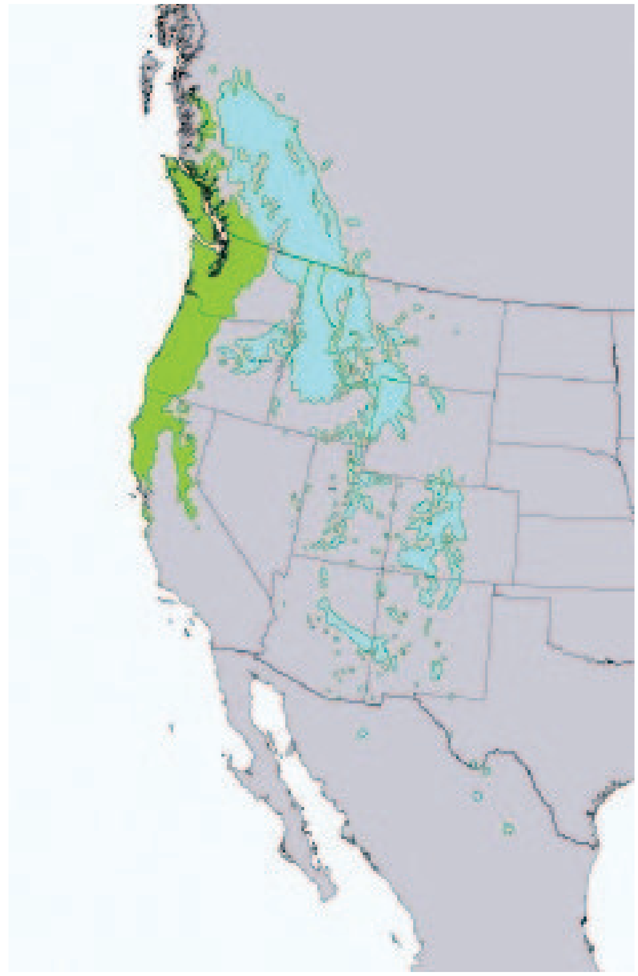
not reliably produce cones until age 15. For Christmas trees another 10 or 12 years may be required to evaluate the progeny.

Another application of controlled crossing is the development of interspecific hybrids by crossing trees from different species. Where the natural ranges of two species overlap they may form spontaneous hybrids. The area where species overlap and interbreed is called an introgression zone. Introgression zones occur in the western U.S. for concolor fir and grand fir in northern California and for noble fir and Shasta fir in southern Oregon. It is also possible to create deliberate interspecific crosses for distant species using controlled crosses. Korean fir has been crossed with subalpine fir to produce a hybrid that is a striking tree. We have also observed spontaneous crosses of concolor fir and Fraser fir in Michigan where the two species were planted nearby.

Evaluate and select superior genotypes

Once a group or population of trees of interest have been identified, the next step in the tree improvement process is evaluation. Evaluating genotypes usually involves planting trees in replicated plots and then tracking growth, form, disease resistance, needle retention and other key traits. A key consideration in establishing genetics trials is to ensure that genotypes are planted at different locations in order to evaluate their performance under varying soil and climatic conditions. In the current CoFirGE trial, plantations of 100 half-sib families of Turkish and Trojan fir have been established in Michigan, North Carolina, Pennsylvania, Connecticut and the Pacific Northwest (2 plantings per region). The design of the test will allow the research term to evaluate variation within seed sources as well as variation between seed sources. This type of analysis can provide critical information that can guide future selection. North Carolina State researchers examined variation within and between seed sources of Fraser fir. They found that trees varied more within provenances than between them This indicates that greatest gains can be achieve by selecting the proper families regardless of their geographic seed source. This has implications for growers in Michigan since it suggests we can potentially make gains by selecting plus trees from existing local plantings and using these as the basis for future improvement, regardless of their original seed sources. An example of this is our current efforts to identify and develop Fraser firs for delayed coning. Coning is a major concern for growers, however if we can select parent trees that will produce offspring that won't cone until age 12, growers could complete a harvest rotation without having to pick cones. To begin this process Paul Bloese and Pascal Nzokou

Parent trees in a Douglas-fir seed orchard in Washington state are girdled to induce stress and promote coning.



Douglas-fir is an example of species with a diverse geographic range that forms distinct varieties. Pseudotsuga menziesii var. menziesii (green) and P. menziesii var. glauca (blue).

This Fraser fir x concolor fir hybrid was produced when seed were collected from Fraser fir that had been pollinated by nearby concolor fir.

identified trees that did not cone in operational plantations where most trees had substantial coning. The trees have been transplanted to MSU and will form the starting point for genetic testing and evaluations. Determining the value of these as parents will require evaluating their off-spring (progeny testing). Trees that consistently produce offspring with delayed coning can be retained in the planting to form the beginning of a seed orchard. The remaining trees will be removed; a process known as roguing a seed orchard. We can multiply the number of the elite trees remaining in the seed orchard by grafting scions of those onto additional rootstocks.

This example illustrates the one of the bottlenecks in tree improvement; the lag between identifying trees of interest and evaluating their genetic value. One approach to eliminating this lag is the use of DNA fingerprinting using SNP's (single nucleotide polymorhpisms). By studying SNP arrays, investigators may be able to identify genetic markers for disease resistance or needle retention. Such work is currently underway as part of multi-institution USDA Specify Crops Research Initiative (SCRI) grant led by NC State.

A key step in making controlled crosses is keeping females isolated until desired pollen can be introduced.

Seedlings for the CoFirGE project are tagged and sorted.

30,000 seedlings are ready to be shipped to establish tests in five regions across the U.S.

Capture genetic gains in a production system

The ultimate success of a tree improvement program is capturing the genetic gains and producing improved plants for the market. For species and provenance selection this may simply mean the identification of superior seed zones for collection. In fact, this is the method we still rely on for most Christmas trees grown in the U.S. Gradually, however, seed produced from more sophisticated tree improvement efforts are becoming available. This is usually done by developing seed orchards of select trees. For example Michigan State University has developed an improved seed orchard for Scots pine. In North Carolina, the North Carolina Christmas Tree Association has established a seed orchard of Fraser fir based on selections from Dr. John Frampton's selection and breeding program. Even seed from seed orchards will retain some degree of random genetic variation. Clonal propagation enables the production of genetically identical individuals. In some conifers, such as arborvitae, ornamental nurseries routinely produce clonal stock from rooted cuttings. Unfortunately, most trees within the pine family, including firs, pines, spruces, and Douglas-fir, are difficult to root from cuttings or only root when trees are juvenile. Ornamental nurseries propagate desirable clones of high-value conifers such as dwarf types or weeping forms by grafting. The portion of the plant above the graft union (scion) retains the genetics of the plant from which it was collected, while the rootstock below the graft is usually produced from seed. Grafting adds significantly to the expense of producing planting stock and is rarely used to produce transplants for Christmas tree production. Therefore, identifying superior seed sources and developing seed orchards based on progeny tested parents remain the most common means of realizing gains from tree improvement for Christmas trees.