# Cooperative Brings Life to Tree Breeding Tools and Approaches

BY GLENN HOWE

The Pacific Northwest Tree Improvement Research Cooperative (PNWTIRC; www.fsl.orst.edu/pnwtirc/) conducts forest genetics and tree breeding research that supports forest management by federal and state agencies and a multi-billion-dollar forest products industry. Over the years, our members have included private companies and governmental agencies in Oregon, Washington, and British Columbia. The focus of our research is on Pacific Northwest tree species and the development of new tree breeding tools and approaches. The knowledge and tools we develop are made available to breeders in reports, scientific publications, and through technology transfer meetings and workshops. Most of our research attention has been on Douglas-fir, but we also conduct research on other tree species such as western hemlock and western white pine. The PNWTIRC was formed in 1983 to address concerns that forest genetics research was not keeping pace with the rapid expansion of applied tree breeding programs. Today, the cooperative has 14 member organizations.

## Tree breeding research

The initial focus of the PNWTIRC was to understand the genetics of Douglas-fir growth and stem form traits. How can we efficiently and accurately measure these traits? Are they heritable? How much genetic gain is possible if these traits are included in breeding programs? What is their relative importance—genetically and economically? Results from these early studies and subsequent research highlighted the importance of stem defects, particularly the loss in value caused by ramicorn branches, which are large, steep-angled branches that are often associated with second flushing in the summer. These early, short-term studies provided quick results to breeders because they were conducted in existing genetic tests owned by PNWTIRC members.

The next phase of the PNWTIRC focused on newly designed experiments, such as the early testing study. In this experiment, we grew Douglas-fir seedlings in outdoor nursery beds and greenhouses, and then compared their performance to siblings that had already been growing in the field for 15 years. This retrospective approach demonstrated that we can predict longer-term field performance by measuring families in their first or second growing season—at least well enough to practice early culling. Early culling is the removal of the poorest performing families at the seedling stage, before they are planted in long-term and expensive field tests. Thus, we can use this approach to lower tree breeding costs and increase the quality of the field tests by allowing us to plant smaller test plantations that have less environmental variation.

In the 1990s, the PNWTIRC concentrated on the genetics and physiology of adaptive traits such as cold hardiness and drought hardiness. In keeping with the early testing theme, a main goal of this work was to develop early screening protocols for identifying cold hardy and drought hardy genotypes. We developed a cold hardiness testing protocol that involves collecting cuttings from progeny tests and then testing them using artificial freeze tests in programmable freezers. These artificial freeze tests are now widely used to improve fall cold hardiness in Douglas-fir breeding programs.

We also developed a seedling testing protocol for drought hardiness. This approach involves imposing drought stress in raised nursery beds and then assessing drought hardiness by measuring foliage damage, diameter growth, and the loss of water flow through the stem caused by embolisms. Because of climate change, our work on drought hardiness continues with recently established genetic tests on hot and dry sites in southern Oregon.

Research by the PNWTIRC and others led to the adoption of new acoustic tools for measuring and improving wood stiffness in Douglas-fir breeding programs. Between 2005 and 2013, we conducted two major studies of Douglas-fir wood properties. Douglas-fir is renowned for its strong and stiff wood, but breeders are concerned that wood quality could decline because faster-growing trees are being harvested at younger ages. Thus, the aim of this research was to develop effective and cost-efficient ways to identify genotypes with stiff wood. Tools that measure acoustic velocity had already been used to sort mill logs based on wood stiffness. To predict stiffness, one can strike the log with a hammer and then measure the speed of the resulting sound waves. We demonstrated that these same tools (e.g., Hitman or TreeSonic) can be used on standing trees or logs thinned from genetic tests to identify superior genotypes in breeding programs. A core element of this project was a study in which we harvested trees from 25-year-old genetic tests and then milled nearly 400 of them into 2x4s to test our wood stiffness predictions. Later, we extended this research to much younger trees and western hemlock.

## Seed orchard research & molecular genetic markers

In the Pacific Northwest, seed orchards are fundamentally important for capturing genetic gain and delivering it to the field. Improved genotypes from breeding programs are planted together in seed orchards where they can cross-pollinate to produce improved seed. Thus, seed orchard research has also been an important

part of our mission. For example, we studied seed orchard design and management, including tree spacing, crown management, early flowering, and the use of molecular genetic markers to understand mating patterns in seed orchards. We conducted a 15-year study of miniaturized seed orchards, which are alternatives to traditional seed orchards where trees are planted at a close spacing and maintained at a height of only 10 feet or less. Because of high per-hectare seed yields, miniaturized orchards are potentially desirable for capturing genetic gains at an early age. The small size of the trees also facilitates controlled crossing, supplemental mass pollination, overhead irrigation, and cone harvesting. The methods of early flower stimulation we developed as part of our miniaturized seed orchard program are widely used to increase the yields of genetically improved seed in Douglas-fir seed orchards.

PHOTO COURTESY OF GLENN HOWE

**The PNWTIRC conducts research on tree breeding methods and the production of genetically improved seed. This photo shows Jim Smith next to grafted trees that were part of a 15-year study on the establishment and management of Douglas-fir miniaturized seed orchards.**

In Douglas-fir, we developed genetic markers called SSRs that are being used by tree breeders to identify mislabeled trees in seed orchards, determine the parents of open-pollinated seedlots, and measure pollination contamination. Pollen contamination, which occurs when trees in nearby stands mate with the genetically superior orchard trees, reduces genetic gains and may lower adaptability. The Douglas-fir SSRs we developed are being used by seed orchard managers, breeders, and other forest geneticists, mostly through the genotyping services offered by the USFS National Forest Genetics Laboratory.

## Current focus & future research

Currently, the PNWTIRC is helping to bring the latest genomic approaches to tree breeding. New, large-scale genomic technologies and advanced statistical approaches have already transformed crop and livestock breeding, and are likely to do the same for tree breeding. For example, we used genomic approaches to identify hundreds of thousands of genetic markers called SNPs (single nucleotide polymorphisms) in Douglas-fir. SNP markers are now being used to test an approach called genomic selection to improve growth and wood quality in Douglas-fir, and to enhance blister rust resistance in western white pine. These topics are discussed in greater detail in the article on forest genomics and biotechnology.

The fundamental mission of the PNWTIRC has been the same since 1983—to advance tree breeding and our understanding of native tree populations in the Pacific Northwest. The prospects for using genomics to enhance tree breeding are great and will be a key area of research into the future. At the same time, climate change imposes challenges to tree breeders and forest managers. Thus, it is particularly important to understand how trees are genetically adapted to climate. Future research by the PNWTIRC will continue to address topics such as seed zones and breeding zones, assisted migration, and the genetics of adaptation to cold and drought. For example, we are collaborating with the US Forest Service and the Conservation Biology Institute to develop a suite of tools that can be used to implement forest management practices designed to help forests adapt to climate change. The first of these tools is a web application called the Seedlot Selection Tool (SST; https://seedlotselectiontool.org/sst/). The SST is a GIS mapping tool designed to help forest managers match seedlots with planting sites based on selected climate change scenarios.

As a research cooperative, collaboration, teamwork, and the sharing of knowledge and resources are fundamental to what we do. Members of the PNWTIRC not only provide funds needed to conduct PNWTIRC research, but also field sites, plant materials, and the expertise and energy needed to make the research possible and relevant. Additionally, we have many outside partners and funding organizations that have contributed to our success. ◆

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