# Building on a Century of Forest Genetics Research

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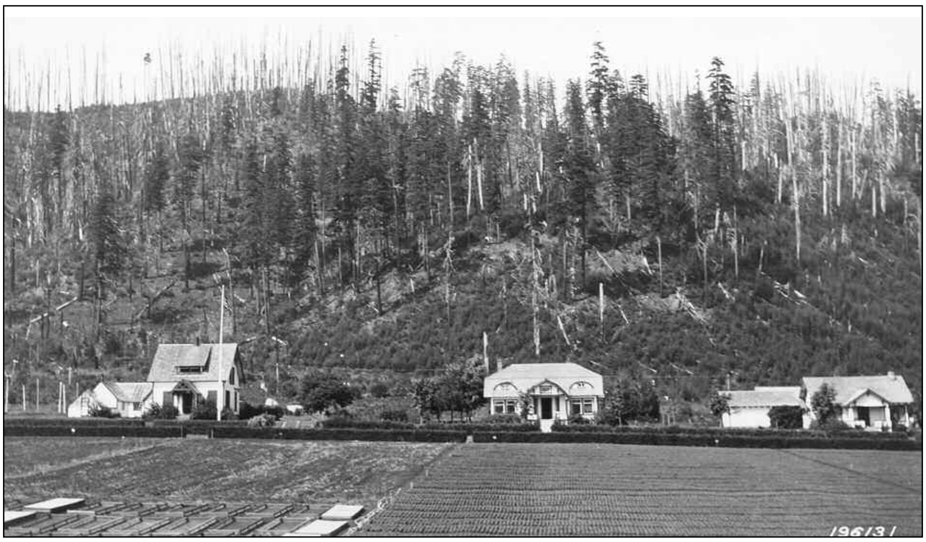
Forest genetics research in the Pacific Northwest goes back to the beginning of the 20th century. One of the first long-term studies undertaken by the US Forest Service, and one of the first forest genetics studies in North America, was a provenance study of geographical variation and trait inheritance of Douglas-fir. This study, called the Douglas-Fir Heredity Study, was established by Thornton T. Munger in 1915 at the Wind River Experiment Station and other sites in Oregon and Washington. It was recently remeasured, and is still providing insights more than 100 years later. Another important study was the Wind River Arboretum, a study looking at non-native species for use in the Pacific Northwest. Both studies would prove to be highly influential on subsequent thinking about appropriate species and seed sources for reforestation. Meanwhile, poor natural regeneration after large fires in the early 20th century led to an interest in tree planting and the establishment of the Wind River Nursery in 1910. Early foresters, however, did not pay particular attention to their choice of seed source, resulting in poor growth and survival of many stands. Experiences with plantation failures and the results from the species and provenance trials ensured the preference for native species, and led to the development of seed collection guidelines and the first delineation of seed zones in the 1940s. By the 1960s, a seed source certification system was adopted, and in 1966, seed zone maps for Oregon and Washington were published.

Interest in forest genetics and tree improvement took off in the 1950s. An increase in logging as a result of the post-war housing boom led to an increased interest in production forestry and a shift from largely natural regeneration to planting. Foresters became keenly interested in planting well-adapted seed sources and in possible improvements through applied genetics. The Douglas-Fir Heredity Study was often used to demonstrate the importance of genetics by pointing to the large differences in growth among family row plots. In 1954, the Industrial Forestry Association (IFA) hired Jack Duffield to begin a program of Douglas-fir tree improvement. Also in 1954, Roy Silen established a research program on forest genetics and tree improvement at the USFS Pacific Northwest Forest and Range Experiment Station (now the Pacific Northwest Research Station {PNWRS}). In the late 1950s, Alan Orr-Ewing began research on tree improvement and genetic variability of Douglas-fir for the British Columbia Forest Service (now the BC Ministry of Forests, Lands, and Natural Resource Operations {MFLNRO}). In Idaho, Richard Bingham began to breed for blister rust resistance in western white pine at the USFS Intermountain Forest and Range Experiment Station (now the Rocky Mountain Research Station {RMRS}). Meanwhile, the need for an organization to bring together researchers and practitioners to share information was recognized, and the Western Forest Genetics Association was established in 1955. It continues to be the primary forum for forest genetics in western North America.

Tree improvement programs grew over the next decades, particularly for Douglas-fir. A major obstacle for Douglas-fir, however, was the issue of graft incompatibility in clonal seed orchards. In 1966, Roy Silen proposed an alternative strategy to get around this issue by using seedling seed orchards created from full-sib crosses of parents in the field. The parents would be intensively selected from progeny tests of a large number of open-pollinated families from native stands. Under the leadership of Roy Silen and Joe Wheat of the IFA, this “progressive” tree improvement program brought together many public and private landowners to cooperate in selection and testing. This program later became the Northwest Tree Improvement Cooperative (NWTIC).

At about the same time, the British Columbia Forest Service expanded its work with a diallel crossing program of their Douglas-fir selections followed by field testing. The BC program later came under the auspices of the Forest Genetics Council. The Inland Empire Tree Improvement Cooperative (IETIC) was founded in 1968 to develop improved ponderosa pine in eastern Washington, northern Idaho, and western Montana, and expanded their program in 1974 to include several additional native conifer species. Weyerhaeuser initiated an independent research and tree breeding program. Other independent programs were begun that later came together

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**An early picture of the Wind River Nursery illustrates the story of reforesting the burns shown in the background.**

under the auspices of the NWTIC. Today, tree improvement programs exist for a wide variety of conifers, including Douglas-fir, western hemlock, ponderosa pine, interior spruce, western redcedar, lodgepole pine, western larch, Port-Orford-cedar, and five-needle pines. The University of Washington and Washington State University had large research programs aimed at developing hybrid poplars, and several industrial landowners planted extensive poplar plantations in Oregon and Washington. Research on disease resistance continues at the USFS Dorena Genetic Resources Center, RMRS, and BC MFLNRO.

For most species, genetically improved planting stock is produced in seed orchards. Thus, seed orchard research has been an important component of forest genetics research in the Pacific Northwest. The problem of graft incompatibility in Douglas-fir was mostly solved by Don Copes at the PNWRS through a research and breeding program that led to the development of graft-compatible rootstock. Because of his efforts, clonal seed orchards are the foundation of Douglas-fir tree improvement, and nearly all seed orchard clones are grafted onto "Copes'" rootstock.

Other important seed orchard research has been conducted by the PNWRS, Pacific Northwest Tree Improvement Research Cooperative (PNWTIRC), BC MFLNRO, and Weyerhaeuser Company. Improvements have been made in orchard design (spacing and arrangement of clones), flower stimulation, crown management, supplemental mass pollination, pest management, and bloom delay to control pollen contamination. Tom Adams at Oregon State University (OSU) pioneered the use of allozyme genetic markers to understand and manage mating systems and pollen contamination in seed orchards, and this work was extended to SSR genetic markers by the PNWTIRC. The PNWTIRC has also studied the genetics of important traits such as growth, stem form, wood quality, cold hardiness, and drought hardiness; developed breeding approaches such as early selection; and developed genetic markers that are now being used by breeders. Approaches for advanced generation breeding, field testing, and data analysis were developed by Bob Campbell and Randy Johnson at the PNWRS, and later by the NWTIC.

Other forest genetics research focused on population genetics and geographic variation in adaptive traits. The advent of allozyme genetic markers gave us a better understanding of gene flow, population structure, and phylogenetics of several species. Genecology research was conducted using short-term common garden studies to understand how seedling performance is related to the climatic environment of their parents. The pioneering work of Jerry Rehfeldt at the RMRS, and Bob Campbell and Frank Sorensen at the PNWRS, provided an understanding of the geographic distribution of adaptive traits that was important for refining seed zones and breeding zones. This genecology research will become increasingly important as we grapple with climate change and to help us understand how forests will respond and what we can do about it. Recently, the PNWRS established a provenance test using a reciprocal transplant design in which seed sources from a wide range of climates were planted at test sites of a wide range of climates. Results from this study, called the Seed Source Movement Trial, are being used to simulate the effects of climate change, and to evaluate options for "assisted migration"—a strategy that involves moving populations to areas where they are expected to be better adapted to future climates.

Finally, we've entered a new age—the age of genomics. As in the past, new knowledge, approaches, and tools will continue to make tree breeding and adaptation to climate change more effective, less costly, and faster. We now have complete genome sequences for several important forest trees, with more to come. Millions of genetic markers are now available to tree breeders—in contrast to the 20 or so allozyme markers available in decades past. We can now directly study the expression of the genes that are important to adaptation to climate, disease resistance, or increased growth. In the PNW, this work has been active at the University of British Columbia, OSU, PNWRS, and RMRS. New approaches for gene editing (using CRISPR) have grabbed the attention of the biological sciences and the public. Although genetically modified trees are unlikely to be widely used in the Pacific Northwest, these technologies and their potential benefits are being studied by the Tree Biosafety and Genomics Research Cooperative at OSU.

The past 100 years has seen enormous progress in our understanding of forest genetics and our ability to breed trees—but we cannot rest. The future will bring even greater challenges, including climate change, the introduction of new pests, and greater demand for natural resources. Thus, we must continue to develop new forest genetics knowledge, approaches, and tools to help sustain our forests and society. ◆

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