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PNW Pacific Northwest Research Station

Science FINDINGS

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INSIDE

"Science affects the way we think together."

Lewis Thomas

The 1912 Douglas-fir Heredity Study: Lessons From a Century of Experience

Brad St. Clair

Wind River Experimental Forest, Washington. One of five plantations planted as part of the 1912 Douglas-fir Heredity Study. The study continues to provide valuable insights about Douglas-fir and how different populations of the species are likely to fare in different locales as the climate changes.

IN SUMMARY

One of the first forest genetics studies in the United States launched in 1912 in the Pacific Northwest. Researchers at that time gathered Douglas-fir seeds from various locations in Oregon and Washington, raised the seedlings in a nursery, then transplanted them to places other than where the seeds originated.

The results had wide-ranging impact, revealing a link between seed origin and where the resulting seedlings were likely to thrive. These results led to the delineation of "seed zones," an essential set of guidelines used for decades in reforestation projects to ensure that newly planted seedlings are suited to local conditions. However, as climates change, these guidelines may no longer be as effective.

Brad St. Clair with the USDA Forest Service, Pacific Northwest Research Station, and colleagues revisited the 1912 study in search of clues to help guide tree planting into the future.

Applying new statistical tools to old data, the scientists found that temperature affected the survival of trees planted in the 1912 study. Douglas-fir planted in areas where the temperature was about 4 ºF (2 ºC) warmer or colder than where their seed originated did not survive as well as ones planted within that temperature range. Results lead researchers to project that warmer temperatures will have a negative effect on Douglas-fir, while planting seedlings in areas cooler than their native zone may help forests thrive into the next century.

"The vast possibilities of our great future will become realities only if we make ourselves responsible for that future."

—Gifford Pinchot

A big shift in the way the United States viewed its forests began to take shape in the late 19th century. Before then, the vast ocean of trees in the Pacific Northwest was perceived as a nearly unlimited source of timber that could be harvested at will, with little reason to worry about the future. But as human competition for natural resources of all kinds grew, so did concern for the future of these forests. A new emphasis on scientific research began to emerge—along with the founding of the Forest Service—as a way to protect this precious resource.

Amidst this backdrop, a 1912 Forest Service study in the Pacific Northwest broke new ground—literally and figuratively—on the study of forest genetics. Scientists gathered Douglas-fir seeds from various locations in the Pacific Northwest, grew them in nurseries, and transplanted the seedlings to various locations

KEY FINDINGS

- Douglas-fir can withstand a change in climate, warmer or colder, of about 4 ºF (2 ºC) and continue to survive and grow well, regardless if the change comes from seed transfers—growing trees at a location different than their seed source—or from changes in climate at a site.
- Climates are expected to warm more than 4 ºF over the next few decades, leading to lower survival and productivity of Douglas-fir stands.
- Moving populations from more continental climates, such as in parts of the Cascade Range, to more maritime climates, such as in the Coast Range, may increase the probability of needle diseases.
- Maladaptation may take time to develop. Differences in survival among studied populations of Douglas-fir were not evident until more than two decades after planting.

in Oregon and Washington to see how well the trees fared when they were moved away from their original habitat.

The results, published more than two decades later, showed that the trees were remarkably well-adapted within a certain geographic range. The study provided information for the establishment of "seed zones," which have since guided forest managers in the selection of stock for reforestation projects for decades. Seed zones delineated geographic boundaries and elevational limits, which corresponded to differences in temperature and moisture, drawing distinctions between the growing habitats of, say, the Coast Range and the Cascade Range.

Seed zones tend to be fairly conservative and have worked well over the decades. However, these seed zones may soon be outdated.

"The problem is that's the past. The climate is changing," says Brad St. Clair, a research geneticist with the U.S. Department of Agriculture, Forest Service, Pacific Northwest (PNW) Research Station. "We need to pay attention to what's happening so future generations can have productive, healthy forests."

Indeed, the climate in the Northwest—which follows the global average—has warmed about 1.8 ºF over the past 30 years, and it's projected to rise as much as 9 ºF by the end of the 21st century. Trees thriving in a certain location today could suffer the effects of drought and heat stress by mid-century. One method for mitigating this is through assisted migration, a process in which seedlings from a seed source that has adapted to a warmer location are planted in an area that's currently cooler but expected to warm as trees grow.

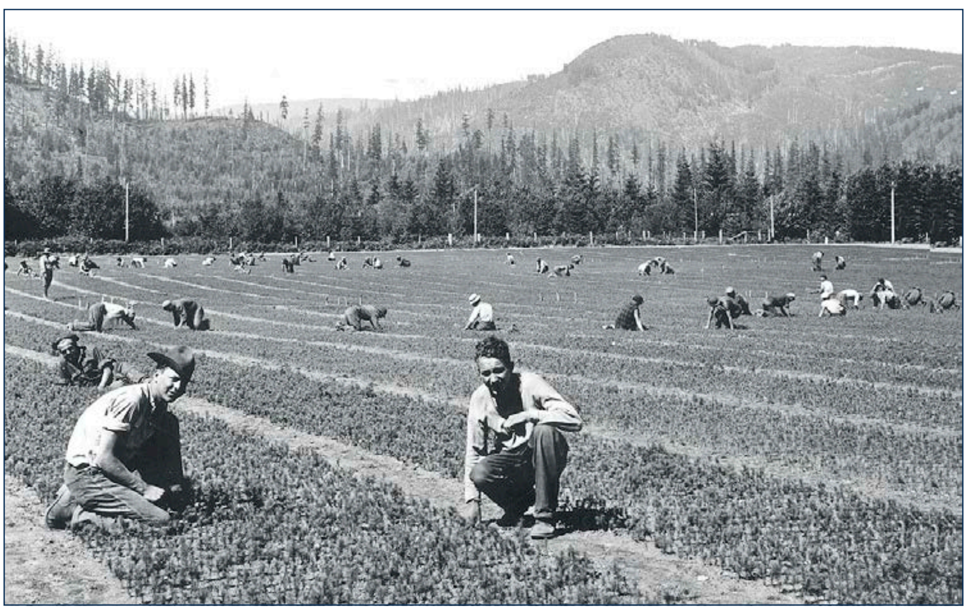
But how far north or how far up a mountain should the seedling be migrated? How far is too far?

By looking at the 1912 study and using some statistical tools that weren't available at the time, St. Clair and his colleagues were able to form some strategies for the future.

Looking to the Past

The 1912 study was intended to help silviculture in the Pacific Northwest. Devastating forest fires had occurred earlier, and natural regeneration was deemed inadequate for restoring the forests in a timely enough manner to feed the nation's demand for timber and protect watersheds. In 1909, the Forest Service established the Wind River Nursery on the Washington side of the Columbia River Gorge to supply replanting stock.

These were the early days of forest science, St. Clair explains. Scientists throughout the 1800s had been working out theories of "inheritance" (the word "gene" wasn't coined until 1909), most of which centered around the idea that the traits of parents were blended in their offspring. Gregor Mendel in 1865 posited the theory that some inherited traits were more dominant than others. Mendel's work was not recognized at first, but in 1900, other biologists confirmed his results. The rediscovery of Mendel's Laws of Inheritance became the predominant theory and generated much excitement in the science of genetics. As a result, forest scientists began taking a closer look at the genetics of trees and their habitats.



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A historical photo from Wind River Nursery, Washington. Tree seeds from different provenances were planted here and later transplanted as seedlings to study sites.

Purpose of PNW Science Findings

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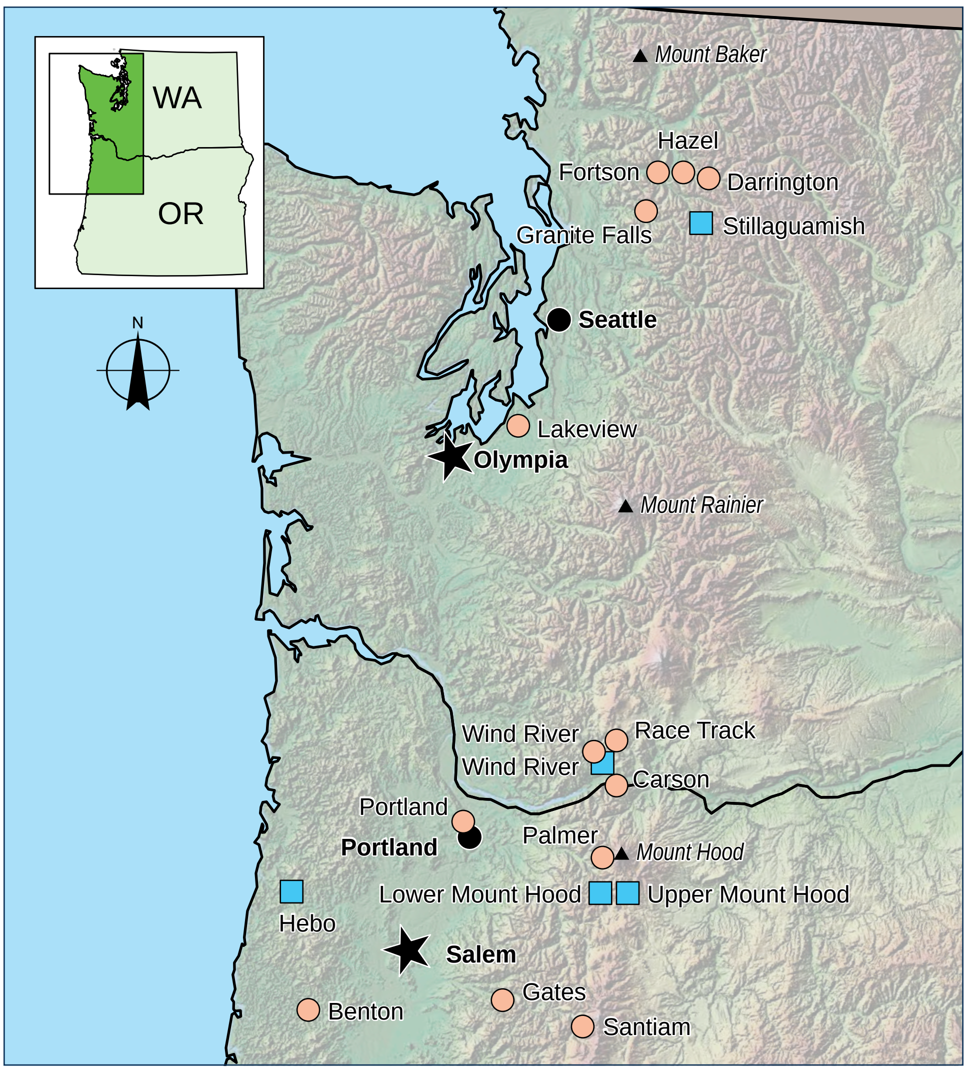
Differences in seed sources already were being recognized in Europe in the early 20th century, and by North American scientists soon after.

In 1912, Thornton Munger, who would become the first director of the Pacific Northwest Forest Experiment Station, known today as the Pacific Northwest Research Station, initiated two studies on the suitability of species and seed sources in the Pacific Northwest. The first, at the Wind River Arboretum, tested the survivability of more than 150 native and exotic hardwood and conifer species from a broad geographic scope. It demonstrated that native Pacific Northwest species performed better in Northwest growing conditions than species brought in from outside the area. That may seem like simple logic, but it was not at all certain before the study was conducted.

The second study was the Douglas-fir Heredity Study, one of the earliest forest genetics studies in North America.

In the fall of 1912, Munger had a crew collect cones from 13 locations in the Coast and Cascade Ranges that differed in latitude, elevation, and soil type. At some sites, parent trees were selected to reflect differences in stand age, stand density, and disease infection. They grew the seeds from the 120 parent trees at the Wind River Nursery, and then planted them in 1915 and 1916 at six locations in western Oregon and Washington. One site was destroyed by fire in 1917. Of the five that remained, four are in the Cascades, and one is near Mount Hebo in the Oregon Coast Range. The original objectives were to determine the best parents to use as seed trees after logging and as seed sources for artificial reforestation.

"Munger was particularly interested in knowing whether the offspring of parents from different sites or classes of trees inherited different characteristics—hence the name of the study," St. Clair says.



The Douglas-Fir Heredity Study. Seeds from 120 parent trees were sown at the Wind River Nursery in the springs of 1913 and 1914, grown for two growing seasons, and then planted at five test sites (blue squares) in the springs of 1915 and 1916. The orange circles indicate the 13 original seed locations, or provenances, of the parent trees.

Munger and his research partner W.G. Morris published the first results of the study in 1936. They showed that most seed sources—regardless of origin—were well-adapted at the various locations, with one important detail: the high-elevation sources grew best at the high-elevation test site, and the coastal seed source grew best at the milder coast site.

Results of the study spurred the development of the first seed collection guidelines and seed zones for the Douglas-fir region. In 1939, the USDA established the Forest Seed Policy, which required that seeds used for reforestation be identified by their origin. The policy also recommended that seeds be planted within 100 miles, and within 1,000 feet in elevation, of their site of origin.

Beginning in the 1950s, forest researchers, particularly Roy Silen of the Pacific Northwest Research Station, continued to measure the trees in the study for the next half century. Silen's work strongly influenced ideas of fine-scaled local adaptation in the region. By 1962, a system to certify forest tree seeds was established for Oregon and Washington, and in 1966, seed zone maps were developed that are still widely used to this day.

Little had been published about the Douglas-fir Heredity Study, aside from its original findings in 1936 and reports by Silen in the 1960s. St. Clair saw an opportunity. The long-term nature of the study made it particularly valuable, and concerns over climate change made it an opportune time to see if further information could be gleaned to help guide future reforestation efforts.

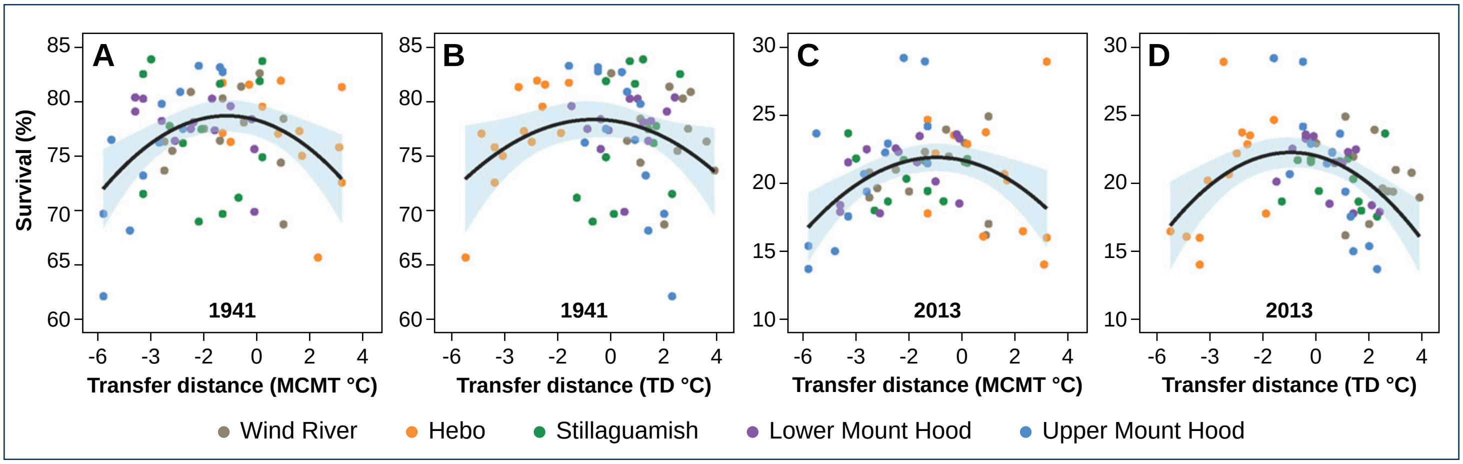
The Analysis a Century Later

Researchers in the 1912 study measured survival and growth of the trees every 10 years from 1923 to 1993, and then again in 2013. Recognizing the unique value of this long-term dataset, and the importance of time to understanding adaptation in long-lived species such as Douglas-fir, St. Clair worked with Glenn Howe and Jennifer Kling at Oregon State University to consider adaptation as related to climate and climatic events. They hypothesized that the trees' performance was related to the climatic difference between where the seeds originated and where the seedlings were later planted.

Their analysis was made easier by the fact that the 1912 study had two climactically distinct test sites: one at a cooler climate at a higher elevation site near Mount Hood, and the other at the more maritime climate near Mount Hebo in the Oregon Coast Range.

They used statistical tools that weren't available when the study was originally designed.

"It was challenging," Howe says. "Some of the basics of experimental design just didn't exist



Survival rate from 13 populations of trees grown at five test sites in the Douglas-fir Heredity Study. Change in mean cold month temperature (MCMT) and continentality (TD)--moving from an inland to maritime climate, for example—from the seed source to the test site had the greatest effect on survival. From St. Clair et al. 2019.

back then. If you were to do this experiment today, you would have introduced randomization—basically, planting in more locations on the test site so you could average out environmental variability. They didn't do that."

St. Clair and his team found that trees grown from seed sources in warmer climates did not survive well when moved to the colder, high-elevation site near Mount Hood. The likelihood of survival decreased as the change in temperature from the seed source site increased. A change of more than 4 ºF resulted in undesirable declines in growth or survival. Furthermore, seedlings from the more continental climates of the Cascades did not fare well when planted in the more maritime climate of the Coast Range. The lower survival of some Cascade sources at the Coast Range site was thought to be a consequence of Rhabdocline needle disease—a note from one of the earlier researches indicated that Rhabdocline was present at the Mount Hebo site, and other research by St. Clair and others found a relationship between continentality and Rhabdocline infection.

Brad St. Clair

The Hebo, Oregon, site in the Douglas-Fir Heredity Study. Land managers are using new findings from the study that was initiated in 1912 to determine where to find Douglas-fir populations that will be best adapted to future climates at their planting sites.

In terms of application, these findings indicate that a seed or seedling planted today will likely be able to withstand temperatures that are upward of 4 ºF warmer than its current environment. Pushing the boundaries of the original seed zones by planting in currently cooler zones will likely give those seedlings a better chance of survival in a world that may test their heat tolerance in a few decades.

According to St. Clair, climate change in North America has not exceed 4 ºF over the past 100 years. "However," he comments, "the climate is expected to be strikingly warmer by midcentury." Current projections show average temperatures in 2050 could be as much as 6 ºF warmer than they were in 1990.

New Insights, New Tools

The new insights from the 1912 study contributed to the Douglas-fir Seed-Source Movement Trial, another study designed by St. Clair and Connie Harrington, an emeritus research forester with PNW Research Station research forester. Established in 2009, the Douglas-fir Seed-Source Movement Trial is a large, long-term experiment to study the effects of the growing environment and genetics on coastal Douglas-fir in Washington, Oregon, and California. It is producing new information on the adaptive potential of Douglas-fir populations in different environments, including the effects of heat and cold on drought resistance, cold hardiness, and needle diseases, as well as growth and survivability.

With climate change in mind, St. Clair and Howe also developed the Seedlot Selection Tool (https://seedlotselectiontool.org/sst/), a web-based GIS mapping program designed to help forest managers match seedlots with planting sites based on climatic information. The climates of the planting sites can be chosen to represent current climates or future climates based on different scenarios.

With this tool, St. Clair says users can aim for planting sites where conditions in mid-century would still be suitable for seedlings established today.

St. Clair is working with Forest Service geneticists at national forests to train silviculturists and decisionmakers on how to use the Seedlot Selection Tool, and, generally, how to plan future tree planting projects with climate change in mind.

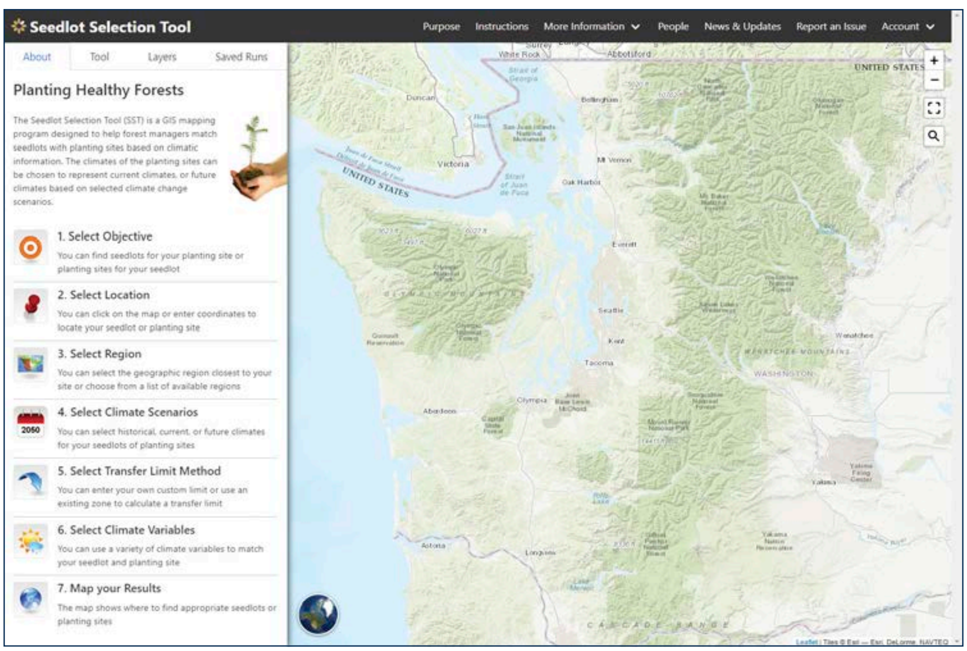
"People are already thinking about climate change when they're sourcing seeds," says Vicky Erickson, the regional geneticist with the Forest Service based in Pendleton, Oregon. "Each district tends to manage its own seed inventory, but in the future, they may need to acquire their seeds from other districts or forests, or even other landowners."

Andy Bower, a Forest Service geneticist based in Olympia, Washington, is working with St. Clair to design a demonstration project in the Gifford Pinchot and Okanogan-Wenatchee National Forests. The work will involve Douglas-fir and ponderosa pine and will use the Seedlot Selection Tool to determine where to source seeds and where to plant them in 2021 and 2022.

"It may be that by the end of the century, we'll be planting trees in the Gifford Pinchot that come from seeds as far south as southwest Oregon," Bower says.

LAND MANAGEMENT IMPLICATIONS

- As climates change, local Douglas-fir populations may no longer be the best fit for reforesting or restoring a site.
- Using seedlings from source locations that are warmer than the planting site—assisted migration—has been suggested to help future forest stands be adapted to increasing temperatures and changes in moisture availability. Limiting the move to areas that are not more than 4 to 5 ºF cooler than the current climate of the seed source avoids cold damage and ensures good survival of the seedling in the near term.
- Results from this study are being used by land managers to determine where to find tree populations that will be adapted to the future climates of their planting sites. For example, U.S. Forest Service geneticists in Oregon and Washington are developing a process to prioritize seedlots for adaptation to planting sites based on climatic distances in temperature, aridity, and continentality.



The Seedlot Selection Tool is a web-based mapping application designed to help natural resource managers match seedlots with planting sites based on climatic information. Access it at: https://seedlotselectiontool.org/sst/.

Reexamining the 1912 study showed St. Clair the value in monitoring results over many decades. Although climate change likely didn't cross the minds of the study's originators, the test results could have a huge bearing today, not only in planning future reforestation, but also in understanding carbon sequestration—a major factor in climate change.

"As seen from this research, which originated more than 100 years ago, there is value in long-term field studies," St. Clair says. "Changing objectives and technology over time can lead to new insights from old studies."

"Old trees just grow stronger."

—John Prine

Writer's Profile

John Kirkland has been writing about science, higher education, and business for more than 20 years. He lives in Portland, Oregon.

For Further Reading

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Scientist Profile

BRAD ST. CLAIR, Ph.D., is a research geneticist with the Pacific Northwest Research Station. His research focuses on exploring and understanding how plants are adapted to their environments, and the resulting implications for management. Those implications include reforestation, restoration, tree improvement, gene conservation, and responding to climate change. He also studies geographic genetic variation in several grass species and the implications for restoration after disturbances.

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