PNW
Pacific Northwest
Research Station

Science FINDINGS

INSIDE

issue fifty-two / april 2003

"Science affects the way we think together."
Lewis Thomas

CONSERVING AND MANAGING THE TREES OF THE FUTURE: GENETIC RESOURCES FOR PACIFIC NORTHWEST FORESTS

Credit: USDA Forest Service

Existing protected areas are important in situ reserves for the conservation of genetic diversity.

"If you can look into the seeds of time, And say which grain will grow and which will not… "
Wm Shakespeare (Macbeth)

As the U.S. Forest Service geared up to meet the immense demand for wood in the building boom after World War II, forest geneticists in the Pacific Northwest were focused primarily on productivity. Can trees be improved in a manner similar to crop improvement in agriculture? Which genetic races of trees are most suited to a site? How far can seed be moved from its native site and still thrive?

So when the Forest Genetics Team was established at the Pacific Northwest (PNW) Research Station in 1954 to address such questions more coherently, the National Forest System was well on its way from a custodial to a production mode, and the focus was on optimization of harvest, seed production, and growth rate.

Today, however, the accrued knowledge of the region's forest genetics doesn't just provide more refined data on growth characteristics. Knowledge of different species' abilities to adapt to changing environmental factors is now equally crucial, as is concern for thoughtful management of the overall genetic

IN SUMMARY

Genetic resource management has historically called for altering the genetic structure of plant populations through selection for traits of interest such as rapid growth. Although this is still a principal component of tree breeding programs in the Pacific Northwest, managing genetic resources now also brings a clear focus on retaining a broad diversity within and among genetic populations.

Genetic diversity, after all, allows species to adapt to the ever-changing environmental and biological stresses they experience through time, and provides the material for new traits of interest. Wise genetic resource management thus involves the monitoring and management of multiple levels of genetic variation that operate at different scales of space and time.

Current challenges to genetic "manipulation" of any kind, even via old-fashioned breeding, are raising new questions about diversity that are now part of the expanding realm of tree breeding programs in the Northwest and elsewhere.

resource. The questions have changed. What are optimum disease screening procedures? To what extent are adaptive traits genetic, and therefore might be available in adapting to climate change? How can molecular gene markers be used most efficiently?

"We are not just concerned with how breeding populations are structured for short-term genetic gain, but how they are structured for the long term, for needs that we cannot yet envision," says Brad St. Clair, a research geneticist with the PNW Research Station. "Gene conservation is important because we do not have a complete understanding of what parts of a system are critical to current and future form and function."

Genetic diversity, in other words, is the basis for evolutionary change that allows species to adapt to future biotic and abiotic environments. Clearly, this is important for ecological and economic reasons. St. Clair adds intrinsic social values as a third rationale for gene conservation. "An aesthetic rationale states that people find beauty in a world that is diverse, and genetic diversity contributes to that biological diversity."

HONING A BREEDING PROGRAM

"Using the tools of genetics to select and breed for certain traits is not new science, and it's not rocket science," says Randy Johnson, another PNW research geneticist in Corvallis. "Humans have been selecting and breeding plants and animals for millennia, and most production questions can be answered pretty definitively."

But this modest description of his profession understates the work that has been carried on since Roy Silen, a retired PNW geneticist, established the Station's genetics research program 50 years ago. Most organizations today perform their tree breeding activities in conjunction with the Northwest Tree Improvement Cooperative, which was initiated in the 1960s by the strong leadership of Roy Silen working with agency and industrial partners.

Operational tree breeding programs in the Pacific Northwest at first focused primarily on Douglas-fir because of its importance to the timber industry. Cooperative tree improvement was jointly run by the PNW Station and Industrial Forestry Association until 1985, when the group became know as the Northwest Tree Improvement Cooperative (NWTIC). The cooperative is now under the auspices of Oregon State University.

"In all of these programs, breeding zones were kept small to ensure that all planting stock would be locally adapted," Johnson explains. Breeding zones generally refer to an area in which seed from parents in a breeding program can safely be used. "The complex environmental patterns of the Pacific Northwest region do not provide large areas of uniform climate like those breeding programs around most of the rest of the country."

First and second generation breeding zones for the Northwest Tree Improvement Cooperative Douglas-fir breeding program.

The result was that 125 separate breeding programs soon existed in western Oregon and Washington and British Columbia, testing over 30,000 selections. Subsequent research confirmed what is called local adaptation, or the presence of structured adaptive variation across the landscape; however, it turned out that breeding zones had been made overly conservative in defining what was local, and could safely be enlarged. As a result, 65 of the first-generation Douglas-fir breeding programs have been merged into 13.

"Because the decision to consolidate breeding programs was based on short-term tests, tree breeders have structured their breeding populations to maintain flexibility in order to adjust to future findings," St. Clair explains.

Purpose of PNW Science Findings

To provide scientific information to people who make and influence decisions about managing land.

PNW Science Findings is published monthly by:

Pacific Northwest Research Station
USDA Forest Service
P.O. Box 3890
Portland, Oregon 97208
(503) 808-2137

Sherri Richardson Dodge, Editor
srichardsondodge@fs.fed.us

Send new subscriptions and change of address information to
pnw_pnwpubs@fs.fed.us

Carlyn Mitas, Design & layout
mitasc@cascadeaccess.com

United States Department of Agriculture

Forest Service

Science Findings is online at:

http://www.fs.fed.us/pnw

The site includes our new *Science Update*—scientific knowledge of pressing decisions about controversial natural resource and environmental issues.

RETAINING THE OPTIMAL GENE RESOURCE

Although Johnson and St. Clair and their Forest Genetics Team still work closely with the cooperative, their work also involves far broader research into genetic conservation in general, not just for tree breeding.

"Our short-term work still focuses on growth, disease, wood quality, that sort of thing," says St. Clair. "But in the longer term now we think a lot about conserving the genetic resource and keeping as much variation within that as possible." The philosophy, familiar perhaps from *A Sand County Almanac*, is to not throw away any of the individual parts.

Genetic diversity, it is well understood, is essential for sustainable forest management. As Johnson points out, you need to look only to corn breeders in the agricultural world, desperately seeking new genetic material, to understand what happens if you narrow down your genetic base too far.

"Genetic diversity permits tree species to adapt to new stresses, such as disease and climate change, and allows tree breeders to continue achieving genetic improvement objectives," says St. Clair. "The conservation of genetic diversity is, therefore, an integral component of responsible forest stewardship."

Knowing this, a group of public and private organizations in western Oregon and Washington formed the Pacific Northwest Forest Tree Gene Conservation Group (GCG). Its principal mission is "to address gene conservation issues in the region by designing and promoting cooperative efforts to ensure that the adaptation and evolutionary potential of important tree species are maintained."

The first part of this project involved compiling data to evaluate the status of the genetic resource for eight conifer species both at their original location (called in situ), and at some other location (ex situ) such as genetic tests or seed stores. Both in situ and ex situ populations are crucial to the conservation of the overall resource.

"In situ conservation typically involves protecting trees in reserves where they can respond to natural evolutionary processes," St. Clair explains. "Ex situ genetic resources are the direct product of human intervention, and consequently their conservation value depends largely on how we develop and manage them." Ex situ resources include progeny and seed source tests, clone banks, and seed and pollen stores.

LAND MANAGEMENT IMPLICATIONS

- Current research allows managers to use the benefits of tree breeding without adversely affecting the genetic indicators important to long-term sustainability.
- Recent results have brought about a new breeding effort for Swiss needle cast tolerance in Douglas-fir in order to increase forest health in coastal regions.
- Seed collections for genecological studies cover multiple ownerships over relatively large scales. Opportunities for collaborative research are thus widely available.

GAP ANALYSIS TO ASSESS GENE RESOURCES

It is important to conserve both types of genetic resource because they are complementary and can serve different purposes, St. Clair explains. For example, in situ reserves are good because they allow for natural evolutionary processes. It's also easier to conserve large numbers of individuals, and several species at once, and they are low cost. On the other hand, it might be more difficult to find rare unique variants in in situ reserves compared to finding them within genetic tests. Once found, new genetic traits can be more easily incorporated into breeding populations.

"Thus, an inventory of in situ and ex situ genetic resources, and knowledge of management activities and species distribution and patterns of genetic variation are required to evaluate the adequacy and success of a gene conservation strategy," St. Clair points out. "Including both in situ and ex situ resources helps the GCG to not only identify genetic resource 'gaps' but also to provide a scientific foundation for policy and management decisions of landowners."

The gap analysis, directed by Sara Lipow, formerly with Oregon State University, summarized the resources for eight species found in the Northwest—noble fir, Sitka spruce, ponderosa pine, western white pine, sugar pine, western redcedar, western hemlock and coastal Douglas-fir. According to St. Clair, these are the species most subject to genetic manipulation, best understood in terms of their genetic structure, and of greatest ecological and economic importance.

In general, it was found that genetic resources for all species are in a healthy condition. "This includes the fact that the extent of ex situ genetic resources differs greatly among conifers in Oregon and Washington, largely reflecting changing historical and present priorities for reforestation and tree improvement."

Several specific conditions have initiated closer examination of genetic resources for those species: white pine resources in situ have been undermined by blister rust, and there are few noble fir in situ in Washington's Willapa Hills. "The gap analysis has drawn attention to these potential localized problem areas, and management can respond to them if necessary," St. Clair says.

CHALLENGES OF PUBLIC UNDERSTANDING

It is a common perception that using genetically improved seed will reduce the variation in our forests, Johnson says, and that seed orchard seed does not have enough rare genes (alleles) for use against rare diseases or overall genetic conservation.

"Plantations regenerated from seed orchard seed have essentially the same variation in tree size as plantations regenerated from field-collected seed," he explains. "In a trait like height, most of the tree-to-tree variation seen in a stand is due to environmental differences; usually only around 20 percent of the variation is influenced by the genetics of the trees." He notes that reducing 20 percent of the variation by only one-twentieth (an overly conservative estimate for a typical seed orchard) results in a loss of only 1 percent of the total variation.

As for rare genes, Johnson points out they are contained within the breeding population for the long-term. "Low-frequency neutral genes in the native population will automatically be at a low frequency also in the breeding population and therefore in the seed orchard, which selects the best from these populations." He adds that theoretical calculations have shown that a mix of 20 to 40 families provides essentially the same protection against catastrophic failure as extremely large numbers of families, and most seed orchards provide these numbers.

"The point is, there are usually only a few trees in any population that have these rare genes, and if the genes were really important, there'd be more of them, based on natural selection!" In addition, they are conserved in populations other than seed orchards, if they are needed.

Another common criticism of breeding programs is that breeding for fast growth will result in increased insect and disease susceptibility. Not so, according to the genetics team. "Results of most forest genetics research demonstrates just the opposite," says Johnson. "The fast-growing families tend to be the healthier families. Numerous studies bear this out, including the favorable associations in Douglas-fir between fast growth on sites without Swiss needle cast (SNC) and tolerance to Swiss needle cast."

Similarly, St. Clair has found that healthy trees that grow fast in ideal, high-light conditions, are usually capable of growing well when planted in shade conditions. Trees that grow well under one silvicultural regime generally perform well under others. Superior growth, in other words, appears to be an indicator of overall health and vigor.

TACKLING SWISS NEEDLE CAST

The specter of yet another disease among timber trees always casts a pall over economic projections for a particular region. Swiss needle cast has been no different. A fungus that attacks and yellows the needles of Douglas-fir, it appears to have direct impact on growth rate, although it rarely kills the tree.

"The thing to remember is that this is a disease that has always been present but has intensified in an area naturally given to growing mixed-conifer forests in the spruce-hemlock zone, and now has extensive areas of Douglas-fir plantations," Johnson says. "We shouldn't be surprised that any particular disease has increased under such circumstances."

Typical of many new genetics projects, the investigations into Swiss needle cast began with questions and concerns coming from managers to the genetics team. In turn the geneticists asked: What can we assess? What do we measure? How do we analyze foliage health?

"More importantly, we asked, is there a genetic difference between the diseased and healthy trees?" Johnson explains. "We can only do our work with existing variation. The progeny tests show this distinction, and from them we might also see some breeding possibilities."

Many first-generation progeny tests serve an important role in ex situ gene conservation.

Breeders have found families that grow 25 to 30 percent faster than average when experiencing moderate disease pressure. These families may be suitable in areas with moderate SNC infection (stands that

---

WRITER'S PROFILE

Sally Duncan is a science communications analyst and writer specializing in natural resource issues. She is currently a Ph.D. candidate in Environmental Sciences at Oregon State University in Corvallis.

hold at least 2 years of needles). In severely affected areas, Douglas-fir is best left out of the species mix.

Another aspect of the breeding approach to diseases in the Oregon Coast Range, he notes, is that disease pressure was not historically intense enough to develop a lot of resistance to SNC; it usually takes many generations of natural selection to develop "new" traits. This may tell us as much about how to view disease infestation as it does about how to select for it genetically.

GENES OF THE FUTURE

"We're still learning how we might use the tools of molecular biology, or biotechnology, in ways that will be both responsible and productive," Johnson says. "I remind the people who are singing the praises of the new molecular tools that there are limits to what can be done with these new tools."

Most of what breeders will do from here on will have to do with refining our selection procedures, but given that breeding programs are already at efficiency rates of 60 to 80 percent and above, we're not going to be doubling the rate of improvement any time soon, he says. "Tree breeding programs will continue to provide genetic gains in economic traits, and new species and traits will become increasingly important as pest problems and silvicultural practices continue to affect each other."

KEY FINDINGS

- Highly heterogeneous environments of the Pacific Northwest have resulted in relatively small tree breeding zones compared with other locations. Because of this factor, and long rotations, breeding in this region must be efficient to be profitable.
- Families that perform well under one management regime usually do well in other regimes. Studies have confirmed this by examining the robustness of family performance under different spacings, levels of shade, environments, and disease pressures.
- Responsible gene resource management requires managing and monitoring the genetic resource to ensure its ability to adapt to changing conditions through sufficient variation. A recent gap analysis has established that extensive genetic resources are conserved throughout the regional ranges of eight key species.
- Results indicate that increasing use of genetically improved seed is not a threat to maintaining the within-species diversity in the region: genetic resources in existing set-asides are sufficient for future sustainability.

Modeling improved stands and understanding how we can best adjust growth and yield models are two areas of improved knowledge that both researchers expect to continue strongly in the future.

Johnson sees broad and deep insurance in the populations that already exist, either in reserves, in breeding populations, or in seed repositories of various kinds. The focus on maintaining genetic resources is very wise, he says, but even in the face of new disease, he feels the resources currently available in the Northwest are ample for the purposes of research and new breeding, provided the natural variation exists out there already.

St. Clair concurs, noting that the close relations between genetic researchers and managers with endless new questions means that topics of interest can be addressed collaboratively and immediately.

FOR FURTHER READING

Lipow, S.R.; St. Clair, J.B.; Johnson, G.R. 2002. *Ex situ gene conservation for conifers in the Pacific Northwest.* Gen. Tech. Rep. PNW-GTR-528. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.56 p.

Johnson, G.R. 1988. *Breeding design considerations for coastal Douglas-fir.* Gen. Tech. Rep. PNW-GTR-411. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 34 p.

Johnson, G.R. 2002. *Genetic variation in tolerance of Douglas-fir to Swiss needle cast as assessed by symptom expression*. Silvae Genetica. 51: 80-86.

Johnson, G.R.; St. Clair, J.B.;Lipow, S.R. 2001. *Genetic conservation in applied tree breeding programs*. In: Proceedings, International conference on ex situ and in situ conservation of commercial tropical trees. Yogyakarta, Indonesia: Faculty of Forestry, Gadjah Mada University: 215-230.

St. Clair, J.B.; Sneizko, R.A. 1999. *Genetic variation in response to shade in coastal Douglas-fir.* Canadian Journal of Forest Research. 29:1751-1763.

Science
FINDINGS

U.S. Department of Agriculture
Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, OR 97208-3890

SCIENTIST PROFILES

BRAD ST. CLAIR is a research geneticist and team leader for the Forest Genetics Team in the Resource Management and Productivity Program of the PNW Research Station, USDA Forest Service. He has been involved with tree breeding and forest genetics for 25 years. His research interests include genecology, gene conservation, tree breeding, and the integration of genetics and silviculture.

St. Clair can be reached at:
Pacific Northwest Research Station/
USDA Forest Service
Forestry Sciences Laboratory
3200 SW Jefferson Way
Corvallis, OR 97331-4401
Phone: (541) 750-7294
E-mail: bstclair@fs.fed.us

RANDY JOHNSON, is a research geneticist in the Forest Genetics Team with the PNW Research Station, and has been involved with tree breeding and genetics research for 20 years. He has worked with breeding programs in Brazil, New Zealand, Australia, and the United States. His current research interests involve the genetics of disease resistance, wood properties, and genecological studies of trees and shrubs.

Johnson can be reached at:
Pacific Northwest Research Station/
USDA Forest Service
Forestry Sciences Laboratory
3200 SW Jefferson Way
Corvallis, OR 97331-4401
Phone: (541) 750-7290
E-mail: randyjohnson@fs.fed.us

COLLABORATORS

Sara Lipow, Oregon Department of Forestry

Northwest Tree Improvement Cooperative, Oregon State University

Swiss Needle Cast Cooperative, Oregon State University