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# *Ex Situ* Gene Conservation for Conifers in the Pacific Northwest

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## Abstract

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Recently, a group of public and private organizations responsible for managing much of the timberland in western Oregon and Washington formed the Pacific Northwest forest tree Gene Conservation Group (GCG) to ensure that the evolutionary potential of important regional tree species is maintained. The group is first compiling data to evaluate the genetic resource status of several species of conifers both at their original location (*in situ*) and at some other location (*ex situ*). We summarize the *ex situ* genetic resources present in seed orchards, provenance and progeny tests, seed stores, and clone banks both in western Oregon and Washington and in other countries with germplasm that originated in western Oregon and Washington. Some species, such as ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), noble fir (*Abies procera* Rehd.), and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) are found to have extensive genetic resources in *ex situ* forms. The resources for western redcedar (*Thuja plicata* Donn ex D. Don), for example, are more limited. Disease greatly influenced the development of *ex situ* genetic resources for western white pine (*P. monticola* Dougl. ex D. Don), sugar pine (*P. lambertiana* Dougl.), and Sitka spruce *(Picea sitchensis* (Bong.). The summaries of genetic resources are, therefore, placed in the context of issues affecting each species. This provides land managers with the accurate information necessary for assessing the potential value of each resource for gene conservation and for prioritizing future actions.



Keywords: *Ex situ* gene conservation, seed orchard, progeny tests, seed storage, clone bank, breeding population, Pacific Northwest, gymnosperm.

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## Introduction

Genetic diversity is essential for sustainable forest management. It permits tree species to adapt to new stresses, such as disease and climate change, and allows tree breeders to continue achieving genetic improvement objectives. The conservation of genetic diversity is, therefore, an integral component of responsible forest stewardship. This understanding recently prompted a group of public and private organizations in western Oregon and Washington to form the Pacific Northwest Forest Tree Gene Conservation Group (GCG). The principal mission of GCG 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 group is first compiling data to evaluate the genetic resource status of eight conifer species in an area extending from the coast of Oregon and Washington to the eastern slopes of the Cascade Range and foothills.

The effort by the GCG is unique among conservation assessments. It includes both resources at their original location (*in situ*) and at some other location (*ex situ*). The GCG opted to include both *in situ* and *ex situ* genetic resources because it recognized that these resources have conservation value for different reasons. *In situ* conservation, for example, typically involves protecting trees in reserves where they can respond to natural evolutionary processes, whereas *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* genetic resources include many types of plantations such as progeny and provenance tests, seed orchards and clone banks, and seed and pollen stores.

The relative importance of conserving the genetic resources existing *in situ* and in various *ex situ* forms depends on the unique characteristics of the species, the extent of breeding and tree improvement activities, and the type and source of the resource. Monterey pine (*Pinus radiata* D. Don), for example, has an extremely restricted natural distribution. The *ex situ* gene resource populations associated with the worldwide breeding effort for Monterey pine comprise a highly significant component of its conserved genetic resources (Burdon 1997). Although fewer genetic resources are found worldwide for coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*), it is extremely well-protected *in situ* and in seed stores and progeny tests throughout its native range.[1] Thus, an inventory of *in situ* and *ex situ* genetic resources, and knowledge of management activities and species distribution and pattern of genetic variation are required to evaluate the adequacy and success of a gene conservation strategy. 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.

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[1] Lipow, S.R.; Johnson, G.R.; St. Clair, J.B. [n.d.]. *Ex situ* gene conservation of coastal Douglas-fir in the Pacific Northwest. Manuscript in preparation. On file with: S. Lipow, Department of Forest Science, Oregon State University, Corvallis, OR 97331-5752.

We summarize the *ex situ* genetic resources for seven tree species found in the Pacific Northwest: noble fir (*Abies procera* Rehd.), Sitka spruce (*Picea sitchensis* (Bong.) Carr.), ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), western white pine (*P. monticola* Dougl. ex D. Don), sugar pine (*P. lambertiana* Dougl.), western redcedar (*Thuja plicata* Donn ex D. Don), and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). These and coastal Douglas-fir, considered separately elsewhere (see footnote 1), are the regional species most subject to genetic manipulation, best understood in terms of their genetic structure, and of greatest ecological and economic importance. This summary emphasizes the genetic resources present in seed orchard and progeny tests in the Pacific Northwest, in provenance tests and other genetic tests outside the Pacific Northwest that use regional genetic material, and in seed stored by individual family. For a comprehensive analysis of the extent of populations of these species protected *in situ,* see footnote 1.

# *Ex situ* Gene Conservation

## Genetic Resources Included in Inventory

We focus on the *ex situ* genetic resources present throughout western Oregon and Washington from the coast to the eastern slopes and foothills of the Cascade Range (fig. 1). The area includes 14 national forests, five Bureau of Land Management (BLM) districts, and Washington Department of Natural Resources (DNR) and Oregon Department of Forestry (ODF) lands, as well as extensive industrial forests.

Most of the regional *ex situ* genetic resources reside in seed stores, seed orchards, progeny and provenance tests, and a few clone banks. Subsets of these selections typically comprise the dynamic breeding populations. For each of these resource types, we compiled the information we deemed most valuable for assessing the potential value of the resource for gene conservation. This information indicated the extent of the genetic base by listing the number of selections in genetic tests and seed orchards or the number of parent trees represented in seed stores. A selection may represent a clone, an open-pollinated family, or a family produced by a controlled cross. For progeny tests, we augmented this information with data on the number of test sites. For seed orchards, we added the hectares of each species. Additionally, a description of the geographic location and elevation range of the germplasm is provided. For U.S. Department of Agriculture Forest Service and BLM programs, the geographical information usually refers to breeding zones or units defined in internal documents available through the forest or district geneticist (see appendix). We included this detail to help land managers evaluate their resources and facilitate their discussion and sharing of them. For many nonfederal programs, the geographical information refers to seed zones. These are defined either in the older Tree Seed Zone Map (U.S. Department of Agriculture Western Forest Tree Seed Council 1973) or Randall's (1996) revised maps for Oregon or Randall and Berrang (in press) for Washington. Finally, for genetic tests and seed orchards, we included a date for when the resource was established to provide at least a cursory indication of longevity.

The information presented for individual programs is not entirely accurate. Some contacts said that numbers were approximate and not up to date. For example, although we tried to omit abandoned test sites, the number of selections for a progeny test may not take mortality into account. Establishment dates of seed orchards and progeny tests are also inexact, sometimes reflecting sowing dates and at other times planting or grafting dates; records often did not indicate when selections were added over the years. We do not expect such minor inaccuracies, however, to alter conclusions about the gene resource status of a species.

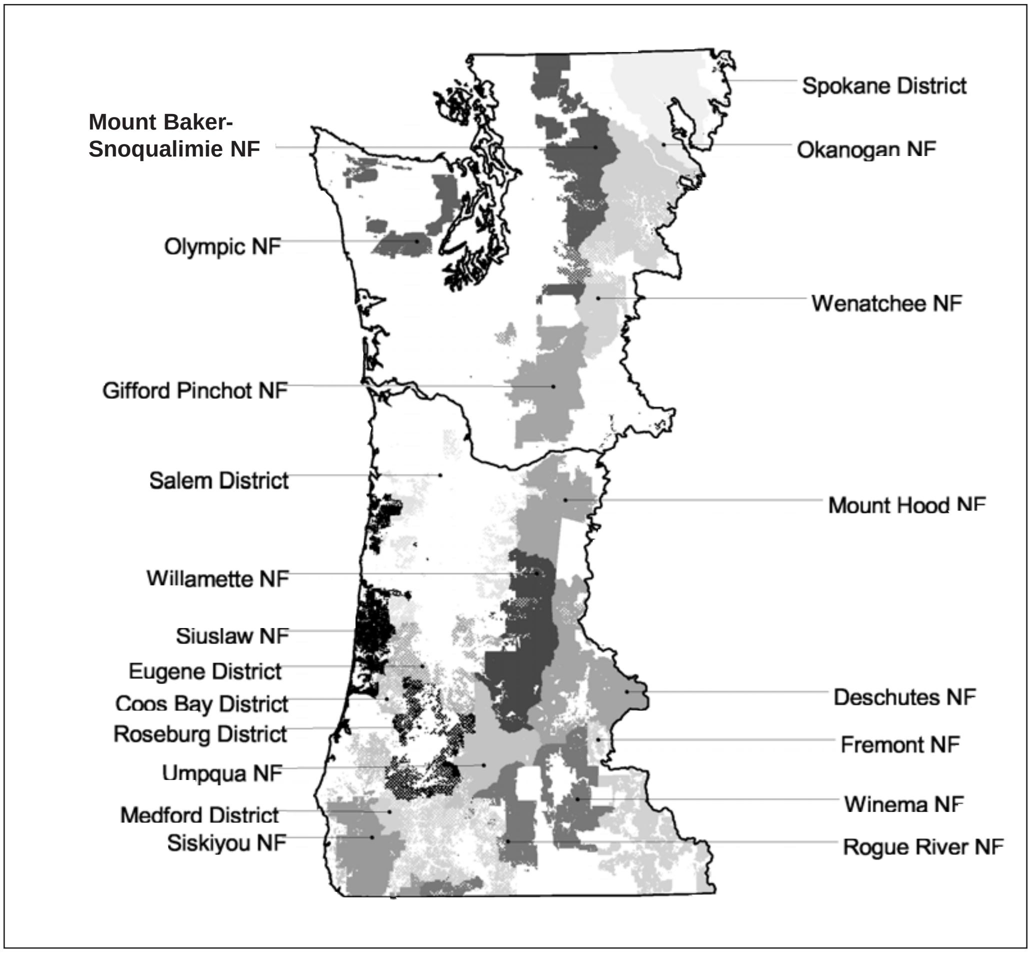


Figure 1—The study area includes 14 national forests and six Bureau of Land Management districts.

Our objective in summarizing this information on *ex situ* genetic resources was to help land managers compare the value of different resources. With a few notable exceptions, most resources included in this summary were not designed for gene conservation, and their expected permanence differs. Seed is often removed from seed stores for use in reforestation. Many progeny tests and seed orchards will be thinned or abandoned after they have served their primary purposes. Describing the resources that exist today, however, enables land managers to better prioritize future actions and investments.

We included all the main types of *ex situ* genetic resources in this summary with one exception, data were not compiled on commercial stands of known genetic material. Such stands are often stocked with germplasm produced in seed orchards; their genetic background, therefore, reflects the variation present in orchards. Moreover, finding useful variation in commercial stands is tricky as they are difficult to screen, especially when compared with genetic tests (see footnote 1). Many stands are also on private owned lands and records are proprietary. Other types of *ex situ* collections, including DNA libraries, tissue cultures, and pollen stores, are virtually absent in the region.

Most of our information was supplied by geneticists, seed orchard managers, or other foresters responsible for it. A primary contact for each of the major programs is listed in the appendix. Several sources were especially helpful in identifying these contacts. The organizations participating in the GCG manage most of the tree improvement programs in the region, and representatives referred us to genetic resources for these programs. Additional contacts were identified in a 1990 publication summarizing the seed orchards of western Oregon, western Washington, and northern California (Cress and Daniels 1990). We also consulted a database of tree improvement programs maintained by the Northwest Tree Improvement Cooperative, an organization that primarily oversees breeding of coastal Douglas-fir and western hemlock. Conversations with many geneticists and foresters also proved useful. Resources derived from trees originating in the region but found in other countries were obtained down through literature searches and forest geneticists identified in various internet databases.

## Types of Genetic Resources

**Seed orchards—**Although the role of seed orchards as *ex situ* genetic resources is often mentioned, data on orchards compiled in gene conservation assessments are rare because such assessments typically focus on species with larger tree improvement programs than the ones considered here (loblolly pine [*Pinus taeda* L.; Namkoong 1997], Scots pine [*P. sylvestris* L.; Pliũra and Eriksson 1997], and Douglas-fir [see footnote 1]). For such species, the genetic variation in the seed orchards is often represented in breeding populations and in progeny tests that have more selections serving as both breeding and gene resource populations. These populations are expected to have greater longevity and therefore a greater gene conservation value than most seed orchards, except those intentionally designed to double as clonal archives.

Despite their uncertain longevity, we included seed orchards in our summary for many reasons. Unimproved and untested seed orchards exist for several of the species under evaluation and frequently contain unique genetic variation not found in other *ex situ* sources. There is no breeding population associated with these orchards. Clones of western white and sugar pine determined to be resistant to white pine blister rust (*Cronartium ribicola* J.C. Fisch) are also typically maintained in seed orchards and rarely held in progeny tests. Finally, several tested orchards for noble fir and ponderosa pine are part of breeding programs that are unlikely to advance to subsequent generations, thereby prompting land managers to decide whether to retain these resources beyond the functional life of the seed orchards and progeny tests.

**Progeny tests—**Progeny tests often contain the breeding population and serve as gene resource populations. As such, they are nearly always at the center of strategies for *ex situ* gene conservation of commercial trees (Eriksson and others 1993, Namkoong 1997) (see footnote 1). Such strategies typically address the development of breeding plans capable of maintaining sufficient genetic variation in the breeding program to achieve continued gain in subsequent generations. This issue is critical for species with large tree improvement programs and potential future breeding.

Large, regional, tree improvement programs exist only for Douglas-fir and western hemlock, with the western hemlock restricted to a limited area in the Coast Range. For these species, progeny tests sensibly serve as gene resource populations, possibly containing selections incorporated into the breeding population (see footnote 1). The role of progeny tests as gene resource populations for other species is less clear-cut. Tree improvement is in the early stages for Sitka spruce and western redcedar, and although ponderosa pine and noble fir have relatively sizable first-generation programs throughout the region, continued interest in them is questionable. Also, breeding and testing for western white and sugar pine is done in the special context of selecting for resistance against white pine blister rust, a devastating and deadly disease.

**Seed stores—**For most crop species, *ex situ* conservation means using seed banks. Seed collections also exist for forest trees, but their usefulness for gene conservation is more variable. The collections lose viability over time, and regeneration of seed stock is often cost-prohibitive given the long period and large area required to produce new seed. It is especially difficult to justify this expense for species reasonably well represented in *in situ* or in *ex situ* plantations. For this reason, seed stores apparently are most useful when tied directly into an overall *ex situ* effort that includes a breeding component. The Central America and Mexico Coniferous Resources Program (CAMCORE), for example, collects and stores germplasm and establishes the seed in field gene conservation banks and provenance and progeny trials (Dvorak and others 1996).

In western Oregon and Washington, some stored seed—including seed collected both from wild stands and seed orchards—is intended for general reforestation purposes, whereas the remainder is held as a safeguard against future uncertainty. Seed collections are either stored by family or bulked by seed zone or breeding unit. We include only seed stored by family in this report because it is more valuable for gene conservation. Seed stored by individual family can be planted in progeny tests that allow the genetic component of variation to be determined for traits of interest. This is not possible with bulked lots. Moreover, outplanting bulked lots and selecting for specific traits is risky because it is often impossible to determine whether individuals sharing the traits are related.

Each national forest and BLM district in western Oregon and Washington maintains seed collections stored by individual family (table 1). This seed is coded by various descriptors such as breeding unit or zone, elevation, and ranger district or resource area. Additionally, seed is labeled according to whether it is from natural or designated seed collection stands, selected superior trees, seed orchards, or through various types of controlled pollinations. In some cases, collections included seed produced by different means from one individual such as a plus-tree in the field and in a clonal seed orchard. Because this seed comes from related individuals, we attempted to count these individuals only once in our summary.

Dorena Tree Improvement Center (Dorena TIC) holds all seed collected from national forests. Individual forests own their own seed. Seed accumulated over many years is maintained under low temperature and humidity conditions favorable for short- to mid-term storage. Seed from most conifers in western Oregon and Washington remain viable under such conditions for only a few decades. Aware of this, regional geneticists are considering whether to maintain the seed stores and, if so, how to properly care for them.

**Table 1—Number of families with stored seed for 6 species of conifers, by national forest in the Pacific Northwest Region and Bureau of Land Management (BLM) district in western Oregon and Washington[a]**

| National Forest or BLM district | Noble fir | Ponderosa pine | Western white pine | Sugar pine | Western hemlock | Western redcedar |
|---|---|---|---|---|---|---|
| Deschutes NF | | 1,033 | 139 | 64 | | |
| Fremont NF | | 906 | 150 | 96 | | |
| Gifford Pinchot NF | 448 | 184 | 851 | | 69 | 30 |
| Mount Hood NF | 406 | 268 | 431 | 8 | | |
| Mount Baker-Snoqualmie NF | 293 | | 171 | | | 42 |
| Okanogan NF | | 542 | 10 | | | |
| Olympic NF | | | 91 | | | |
| Rogue River NF | | 94 | 178 | 503 | | |
| Siskiyou NF | | 69 | 57 | 840 | | |
| Siuslaw NF | | | | | | |
| Umpqua NF | | 54 | 193 | 348 | | |
| Wenatchee NF | 62 | 864 | 555 | | | |
| Willamette NF | 160 | 21 | 419 | 235 | 78 | 126 |
| Winema NF | | 928 | 116 | 126 | | |
| Coos Bay District | | | | | 2 | |
| Medford District | | 735 | 10 | 1,396 | | |
| Roseburg District | | 109 | 23 | 276 | | |
| Salem District | 92 | | | | | |
| Total | 1,461 | 1,1361 | 4,041 | 3,892 | 149 | 198 |

[a] National forests store their seed at Dorena Tree Improvement Center; individual BLM districts store their own seed. Note, seed is not stored for Sitka spruce, and BLM Eugene District stores only Douglas-fir seed.

Each BLM district, on the other hand, owns and maintains its own seed storage collection, the age and completion of which differ among districts. In addition to an operational seed collection intended for reforestation and aforestation, BLM Eugene District also has a separate seed bank for Douglas-fir that was started in the early 1970s. Collections were added until 1989, after which all newly collected seed went into the operational seed collection.

**Resources in foreign countries—**For some species, germplasm from western Oregon and Washington also exists in foreign countries. There are large tree improvement programs with advanced generations for Sitka spruce and noble fir in Europe and programs for several additional species in British Columbia, Canada. Some countries have developed gene conservation strategies to maintain the variation in the foreign gene resource population. The role that such populations play in integrated gene conservation strategies for species as a whole, however, is seldom explored. An exception is for Monterey pine, which is unique because although it is planted extensively on several continents, it has limited natural range (Burdon 1997). Inclusion of the foreign resources is important because they are extensive, and landowners in western Oregon and Washington may wish to evaluate their potential benefits.

## Noble Fir

### Background Information

The range of noble fir falls entirely within the study area. The species is found primarily in the Cascade Range between Stevens Pass, Washington (48° north), and McKenzie Bridge, Oregon (44° north). Although most stands occur west of the Cascade crest at elevations of about 900 to 1850 m (Sorensen and others 1990), a few stands exist east of the crest. There are also several disjunct populations at higher elevations in the Coast Range of Oregon and in the Willapa Hills of Washington. Noble fir is a major component of the cool temperate silver fir zone and is associated with many conifers including Pacific silver fir (*A. amabilis* Dougl. ex Forbes), Douglas-fir, western and mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.), western redcedar, and western white pine.

Noble fir hybridizes and introgresses with Shasta red fir (*Abies magnifica* var. *shastensis* Lemm.) south of the McKenzie River in the Oregon Cascade Range. Trees tested from north of the McKenzie River grew taller than progeny from trees south of this point (Randall 1996). Movement of seed across this boundary is therefore not recommended. Within the strict noble fir range, however, the species has relatively little variation within location. It is possible to transfer seed long distances north or south with little risk of maladaptation (Sorensen and others 1990). Thus, Randall and Berrang (in press) concluded that the Cascade and Coast Ranges should each be considered a single seed zone, with the Cascade Range divided into two elevational bands separated at 1372 m.

Noble fir differs from many other Northwest conifers. It is used for both timber production and by the bough and Christmas tree industries. In Oregon and Washington, noble fir commands 50 percent of the $204 million per year Christmas tree market (Pacific Northwest Christmas Tree Association 2000) and is the primary source of boughs used in Christmas wreaths and other seasonal decorations. Noble fir also dominates the Christmas tree and greenery markets in several European countries. This alternative use is important from the standpoint of *ex situ* gene conservation because the traits under selection differ markedly between the timber and Christmas tree and bough industries. Growth and yield are central to timber production, whereas additional traits such as needle color, crown form and shape, needle retention, and overall suitability are important for Christmas trees and boughs. In Europe, but not Oregon and Washington, slower growth is actually preferred for boughs, as it leads to a more desirable form. The various selection processes for different industries and regions create multiple populations that are likely to conserve more genetic variation than if the same number of individuals were subjected to a single selection regime.

## Genetic Resources

Considerable genetic resources reside in the progeny tests and seed orchards established for noble fir timber production in Oregon and Washington (table 2). The first-generation progeny tests include 1,460 selections. These were collected throughout the range of the species, with only the Willapa Hills in southwest Washington omitted. Most noble fir in the Cascade and Coast Ranges are found on federal lands. Of the seven organizations involved in genetic testing, all except Weyerhaeuser Company are federal. The seed orchards for most breeding zones and units contain improved stock. Additionally, national forests in the Cascade Range maintain considerable stores of noble fir by individual family (table 1). The BLM in Salem, however, holds the Coast Range seed stores.

Because of recent harvest reductions on public lands, overall planting of noble fir is decreasing. The long-term maintenance of selections in seed orchards and progeny tests is consequently uncertain. Many of the tests and orchards were established in the 1980s for timber production. Some orchards are, or soon will be, producing more seed than is needed for reforestation. For example, the BLM Salem District harvest is presently less than 20 percent of the harvest estimated when the seed orchard was planned, and the district is selling its surplus seed to industry. Auspiciously, it is possible to modify some seed orchards and progeny tests originally established for timber production for Christmas tree or bough traits. For example, Christmas tree growers recently collected scion from trees in the South Fork seed orchard to use in progeny tests for Christmas tree traits. The Forest Service is also using this orchard to collect boughs and is considering reassessing their roguing plans for the orchard based on bough traits rather than timber traits. Also notable is that there is at least one exceptional area where increased planting of noble fir for timber production might occur: on ODF lands in the Oregon Coast Range at elevations below 900 m, the natural limit of the species, in areas hard hit by Swiss needle cast.

In contrast to the timber industry, the Christmas tree producers have established only a few seed orchards and progeny tests in Oregon and Washington. Most seed collection for Christmas trees is from wild stands, and seed procurement is a perennial problem. Two privately owned orchards, however, produce seed earmarked for the Pacific Northwest Christmas Tree Growers' Association: the Hostetler Seed Orchard and the Barney Douglas/Dixie Mountain Breeding Orchard. The 300 positions at the Hostetler Orchard contain 86 clones from 12 source locations, most of which are privately owned tree farms. Six of the favored selections, however, are from the Riley-Fanno area in the Oregon Coast Range, managed by BLM and Willamette Industries. The Barney Douglas/Dixie Mountain orchard also contains 10 selections from Riley-Fanno, plus 15 selections from BLM breeding unit 51 (Oregon Coast Range) and 4 selections from BLM breeding unit 50 (Oregon Cascade Range). Finally, a few Christmas tree farms maintain small orchards primarily for personal seed stores.

**Table 2—Noble fir genetic resources in seed orchards in western Oregon and Washington; orchards designed to produce seed for Christmas trees and their associated progeny tests are excluded**

| Organization | Seed orchard | Breeding zone/unit | Elevation range | Families/clones in orchard (year planted) | Orchard | Families in tests (year tests established) | Test sites |
|---|---|---|---|---|---|---|---|
| | | | *m* | *No.* | *Ha* | - - - - - - *No.* - - - - - - | |
| Gifford Pinchot NF | French Butte | 3014, 3023, 3024 | Two zones: <1372 and >1372 | 290 (1987) | 20.7 | 180 (1981) | |
| Mount Baker-Snoqualmie NF[a] | RN McCullough | 5022 | <1219 | 129 (1986) | 4.1 | 150 (1982/85) | 3[b] |
| | RN McCullough | 5023 | >1219 | 241 (1986) | 4.1 | | |
| Mount Hood NF | South Fork | 6014, 6015, 6013, 6024, 6025 | 914-1829: 305 m zones | 270 (1987) | 10.5 | 371 (NA) | 9 |
| Willamette NF (north) | Foley | 18033 | 914-1829 | 151 (1983) | 6.5 | 179 (1987) | 8 |
| | Foley | 18034 | 914-1829 | 54 (1983) | 6.5 | 179 (1987) | |
| Willamette NF (south) | Foley | 18015 | 914-1829 | 30 (1983) | 4.1 | 180 (1987) | 8 |
| | Foley | 18024 | 1067-1219 | 46 (1984) | 6.1 | 180 (1987) | |
| | Foley | 18023 | 1067-1219 | 35 (1984) | 3.2 | 180 (1987) | |
| BLM Salem | Walter H. Horning | 51 (Coast) | 700-1067 | 52 (1978) | 2.4 | 51 (1981/87) | 8 |
| | Walter H. Horning | 50 (Cascade) | 853-1350 | 82 (1973) | 4.1 | 50 (1981/87) | 8 |
| Weyerhaeuser Co. | Sequim clone bank | Cascade: seed zones 412, 421 | 610-1524 | 89 (NA) | NA | 89 (NA) | NA |
| | Sequim clone bank | Longview: seed zones 41, 430, 440 | 762-1219 | 102 (NA) | NA | 102 (NA) | NA |
| | Sequim clone bank | Vail: seed zones 241, 422 | 732-1219 | 108 (NA) | NA | 108 (NA) | NA |
| Total | | | | 1,679 (NA) | >72.1 | 1,460 (NA) | >44 |

NA = information not available.

[a] Formerly Cowlitz Tree Improvement Cooperative; presently the progeny test is a cooperative with Champion and Wenatchee National Forest.

[b] Mount. Baker-Snoqualmie National Forest no longer maintains these test sites, although they still exist. Additionally, Champion originally had one test site, but it was abandoned.

Regional progeny tests and provenance tests for noble fir Christmas trees and greenery are generally shorter than those for timber production and are, therefore, less valuable gene conservation vehicles. Chal Landgren, of Oregon State University Extension Service, recently designed and established two progeny tests, each with 24 sources, mostly from western Oregon and Washington with some advanced-generation material from Denmark. The test sites are on Christmas tree farms. After about a 10-year rotation, the test trees will be cut down and sold. Exceptional selections, however, may be grafted in the Dixie Mountain orchard for long-term preservation.

In a separate effort, Washington DNR (central region) is in the process of establishing an 11-ha demonstration forest for bough production that includes 12 advanced-generation families from Denmark selected for superior bough traits. The planting design of this forest is appropriate for progeny testing, although the agency has not yet decided whether it will collect the data. The original sources of most of the third- and fourth-generation Danish material included are unknown, and because the material is generally considered sufficiently improved, returning to wild stand collections is less desirable than obtaining additional Danish material. This is a good example of how *ex situ* genetic resources from other countries can favorably impact the economies of Oregon and Washington.

## Other Resources

In 1978, the International Union of Forest Research Organizations (IUFRO) collected 21 provenances of noble fir. Provenance test sites containing this material are still intact in several European countries and in coastal British Columbia. Individual countries included 10 to 19 provenances in their tests with selections from the Cascade Range in Oregon and Washington and the Oregon coast. The exact provenances differed between countries, but all excluded the Willapa Hills of Washington. Many of the countries also included one or more provenances from selected stands in Denmark. There are 4 test sites in Denmark,[2] 6 in Germany (Ruetz and others 1990), 1 in Ireland,[3] 1 in the Netherlands (Kranenborg 1988), 2 in Norway (Magnesen 1995), 12 in coastal British Columbia (Xie and Ying 1994), and perhaps a few in other countries. To our knowledge, plus-trees were not selected from the IUFRO material.

The importance of noble fir for timber production and the Christmas tree and greenery industries differs widely among the countries participating in the IUFRO trial. Denmark began growing noble fir in the 1950s and has the most extensive planting and breeding program. Today about 300,000 trees are marketed per year (Frampton and McKinley 1999). The primary use for Danish noble fir is for Christmas greenery. It is considered superior to direct imports because it grows slower, has a bluish hue, and is less sensitive to current-season needle necrosis. Several tests exist in addition to the IUFRO ones. These include a combined plus-tree testing and provenance trial established in

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[2] Nielson, U.B. 2000. Personal communication. Danish Forest and Landscape Research Institute, Hørsholm Kongevej 11DDK-2970, Hørsholm, Denmark; abiesone@post6.tele.dk.

[3] Thompson, D. 2000. Personal communication. Genetics and Tree Improvement Research, Coillte Teoranta, The Irish Forestry Board Research Laboratory, Newtownmountkennedy County Wicklow, Ireland; dthompson.coillte@indigo.ie.

the early 1990s by integrating the earlier efforts of several private firms. This trial was recently handed over to the Forest and Landscape Research Institute, which intends to maintain 11 sites in Denmark and 1 in Sweden for at least 5 more years. The tested material includes four advanced-generation Danish seed sources, two sources from the Washington Cascade Range, and one source each from the Oregon Cascade Range, Oregon Coast Range, and Washington Willapa Hills. There is also a Danish breeding program based on second- and later-generation material that emphasizes bough harvest and Christmas tree production. The program includes 175 selected plus-trees, 150 of which were chosen in the late 1980s; all are in test in at least some of the 16 field trials. The original source location of this material is often unknown. A total of 30 ha of seed orchards are established as part of this program (see footnote 2).

Denmark typically supplies seed to several other European countries. Ireland, however, recently established its own program to test the genetic potential of a range of seed sources. The program also evaluates registered seed stands based on progeny test information and promotes the value of Irish collected seed (Fennessy 1999). The program has registered 24 Irish stands as seed stands and has selected 54 plus-trees from these stands. The stands are mostly Danish, although four stands used seed from the Mollala breeding zone in Oregon. The plus-trees were sown recently in five field trials in Ireland, thereby comprising another genetic reserve.

Germany is also interested in noble fir. Seeds are collected from provenance trials, including the IUFRO's, thereby eliminating seed orchards. Saxony is establishing a new provenance trial with 11 test sites. It includes one provenance each from seed zones 42, 53, 252 412, 422, 430, and 440. Importantly, Germany has also set up a small gene archive that includes selections from McKinley Lake and Baw-Faw Peak (Willapa Hills), which are two preferred provenances that the Germans fear are at risk *in situ* (Ruetz and others 1990, Ruetz 2000[4]).

Results from the IUFRO trial show that noble fir also performs well in parts of British Columbia, especially in the maritime zone north of its natural range. Indeed, several authors suggest that the boundary of noble fir is continuing to expand northward following the last glaciation and that under stable environmental conditions, it would eventually reach the area (Xie and Ying 1994). About 500,000 seedlings per year are planted in British Columbia for timber production, and not surprisingly, provenances from the northern portion of its range tend to perform better.[5] Interest in growing noble fir for Christmas trees also is increasing. To date, however, there are no seed orchards or progeny tests for noble fir in British Columbia.

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[4] Ruetz, W. 2000. Personal communication. Research forester. Bavarian Institute for Forest Seeding and Planting. Bavarian Institute for Forest Seeding and Planting, Bayer. Landesanstalt Fur Forstliche, Saat-Und-Pflanzenzuch, Forstamtsplatz 1 D-83317, Teisendorf, Germany.

[5] Ying, C. 2000. Personal communication. Research scientist. British Columbia Ministry of Forests, Research Branch, 31 Bastion Square Victoria, British Columbia Canada V8W 3E7; cheng.ying@gems9.gov.bc.ca.

## Sitka Spruce

### Background Information

Sitka spruce grows in a narrow band along the north Pacific coast from latitude 61° N in Prince William Sound, Alaska to 39° N near Casper, California, including many off-shore islands. In Washington, it is found on the Olympic Peninsula where it thrives on the extensive coastal plain and seaward mountain slopes, a restricted strip on the mainland along the Strait of Georgia around Puget Sound, and up valleys to the east. The range narrows southward along the Washington and Oregon coastal fog belt but extends inland for several kilometers along major rivers. Throughout most of its range, Sitka spruce is associated with western hemlock in stands that have some of the highest growth rates in North America.

Sitka spruce is valuable commercially for lumber, pulp, and other uses. Despite its economic value, it is not a major plantation species because it is highly susceptible to white pine weevil (*Pissodes strobi* (Peck)) infestations. The weevil kills the terminal leader. Laterals that substitute and form new leaders may be attacked in subsequent years. The damage is not lethal, and the affected trees can reproduce. The weevil's impact on genetic variation in natural stands in reserves is therefore minimal. Weevil attack, however, decreases growth potential and results in deformed trees. Planting of Sitka spruce is negligible in Oregon, Washington, and much of British Columbia. Only the Queen Charlotte Islands are free of the weevil, and Sitka spruce is planted successfully there (Hall 1994). The recent discovery of genetic resistance to the weevil, however, may offer the best chance of allowing planting of Sitka spruce throughout the region, possibly in conjunction with other control methods (King and others, in press).

Clear evidence of substantial resistance to the weevil was first evident in the IUFRO provenance trials established by the British Columbia Ministry of Forestry (Ying 1991). Certain provenances showed marked resistance to the weevil, including two from a high weevil-hazard area within the dry Douglas-fir ecological zone on Vancouver Island: Big Qualicum (East Vancouver Island) and Haney (Lower Fraser Valley) (Ying 1991). Additional resistant provenances were identified in north coastal British Columbia from the natural hybridization area between Sitka and white spruce. The identification of weevil resistance in the provenance trial spurred additional research that is leading to the development of a resistant breeding population. The trial, therefore, serves as an outstanding example of how an established *ex situ* genetic resource may unexpectedly provide critical information that enables forest geneticists to take on an important ecological and commercial problem.

### Genetic Resources

The British Columbia Ministry of Forestry has dominated the research on genetic resistance to the weevil since the initial IUFRO trial. The goal of the screening program is to broaden the pool of resistance for selection and breeding and, ultimately, to develop a breeding population containing about 60 genotypes that are highly resistant, or even immune, to weevil attack (King and others, in press). Such a breeding population would allow increased planting of Sitka spruce in British Columbia in the future and perhaps also in Oregon and Washington.

The British Columbia program includes three test series of open-pollinated families. The tests concentrate on resistance found in the dry, weevil-infested, Douglas-fir ecological zone under the assumption that natural selection will lead to widely based resistance there. Some selections from Oregon and Washington are also included (table 3, fig. 2). The first series, sown in 1991, consists of 67 open-pollinated families sampled from 12 populations, most of which are in high hazard areas, plus six bulk lots from lower hazard, wetter zones (King and others, in press). Twenty-two of the open-pollinated families are from four populations around Washington's Puget Sound; the rest are from British Columbia. Although not all families were included at every site, families were tested at two sites in Washington (Quinault and Rayonier), two sites in Oregon (ODF), and three sites in British Columbia. Five ramets from each of the Washington clones are also held at the Cowichan Lake Research Station (CLRS) clone bank. Test results confirm the association between resistance and the dry zone identified in the provenance test and show that resistance tends to be concentrated close to the original Big Qualicum source collection. There was no evidence of resistance from the Washington collections.

The second test series includes 18 open-pollinated families from six populations from the east side of Puget Sound in Washington, as well as seed from 13 trees from northern California. This test was sown in 1993. It was established at two sites in Washington (Quinault and Rayonier), two sites on Vancouver Island, and one on the Queen Charlotte Islands.

The third test series has 16 families from the western slope of the Cascade Range in Washington and 17 families from coastal Oregon, ranging from the Columbia River to the California border. It was sown in 1994 and planted at four sites in British Columbia and one site owned by Weyerhaeuser in Washington. Results are not yet published.

In addition to the British Columbia Ministry of Forests tests, Rayonier's program focuses on growth and form as well as on weevil resistance (table 3). The 86 selections tested by Rayonier originated from coastal Washington in an area extending from Sekiu to Raymond. The organization established a seed orchard with the best material from the early test results. Some of this material was shared with the Quinaults who also planted a seedling seed orchard with the best 30 families.

The Forest Service and BLM do not maintain seed collections for Sitka spruce from Oregon and Washington. The British Columbia Ministry of Forests, however, has seed stored for 88 of the selections included in the field trials, plus an additional 27 seedlots from Oregon parents that were not outplanted in tests.

## Other Resources

Sitka spruce is an important plantation timber species in Europe. It is planted most extensively in Britain, Ireland, and Denmark and is a minor species in France, Norway, and Germany. In the mid-1970s, these countries, and several others, established tests as part of the IUFRO Sitka spruce provenance trial. A total of 84 origins were included in the IUFRO collection, although not all were planted in every country (O'Driscoll 1976). Published results from this and other provenance trials are available for Croatia (Orlic 1998), Denmark (Nielson 1994), France (Roman and Amat 1993, Sutter-Barrot and van-Poucke 1993), Ireland (Pfeifer 1991), Norway (Magnesen 1999), United Kingdom (Lee and Rook 1992, Lines and Samuel 1993), and Yugoslavia (Pintaric 1998).

**Table 3—Sitka spruce genetic resources from western Oregon and Washington in progeny tests, including selections in the weevil resistance trials organized by the British Columbian (BC) Ministry of Forests**

| Test | Programs with tests (number of test sites) | Selections (and populations) from OR and WA | Elevation range | Year test sown |
|---|---|---|---|---|
| | | *No.* | *m* | |
| BC 1st series | ODF (2)<br>Quinault (1)<br>Rayonier (1)<br>BC Ministry of Forestry (3) | 22 (4) | 0-300 | 1991 |
| BC 2nd series | Quinault (1)<br>Rayonier (1)<br>BC Ministry of Forestry (3) | 18 (6) | 0-30 | 1993 |
| BC 3rd series | Weyerhaeuser (1)<br>BC Ministry of Forestry (4) | 33 (15) | 0-520 | 1994 |
| Rayonier | Rayonier (4) | 86 (NA)[a] | NA | 1987 |
| Total | 5 agencies (21) | 159 (>25) | | |

[a] Material also represented in 2 seed orchards (see text).

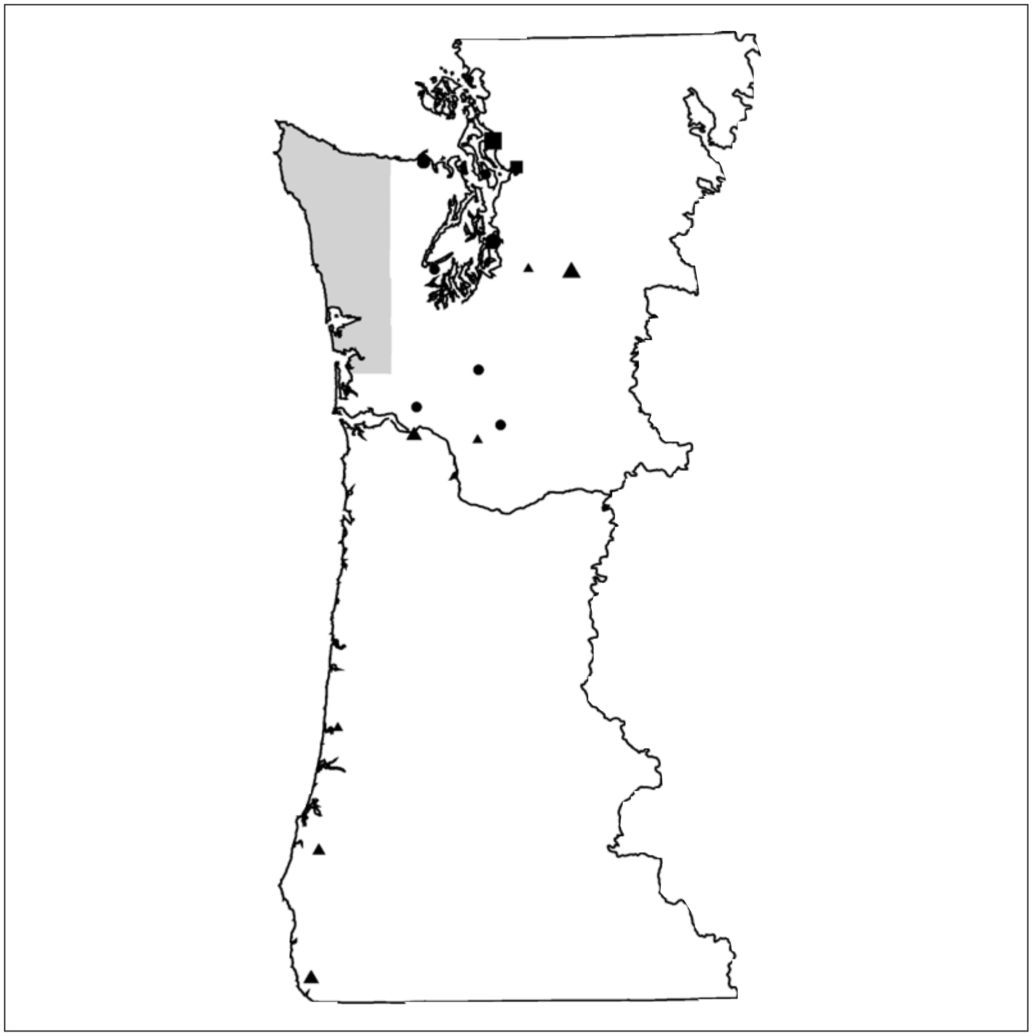

Figure 2—Point locations of the 31 Sitka spruce provenances from Oregon and Washington included in the weevil resistance trials organized by the British Columbia Ministry of Forests (● = 1st series, ■ = 2nd series, and ▲ = 3rd series. Larger symbols represent multiple clones). The shaded area indicates the area from which selections were chosen for Rayonier's independent test.

The most extensive genetic resources for Sitka spruce in Europe exist in the active tree breeding and gene conservation programs in Britain.[6] Sitka spruce is the country's most important commercial tree species, planted on about 700 000 ha. The genetic resources include 2,700 plus-trees specifically selected by forest research for breeding work; more than 800 are already tested. Of these plus-trees, about 12 percent are from Washington, 26 percent are from southeastern Alaska or north coastal British Columbia, 18 percent are from the Queen Charlotte Islands, and 44 percent are of unknown origin, presumably from the Queen Charlotte Islands. The provenances

[6] Lee, S. 2000. Personal communication. Forestry Commission (Forest Research), Tree Improvement Branch, Northern Research Station, Roslin, EH25 9SY Midlothian UK; s.j.lee@forestry.gov.uk.

planted for commercial forestry differ widely in different parts of the country. Provenances from southern Washington are best adapted to the longer growing seasons in Wales and southwest England, whereas for most of Scotland and northern England, Queen Charlotte Islands provenances are more favorable. The plus-trees comprising the first-generation of testing are included in more than 300 progeny tests, most of which are planted at three sites: one in Wales, one near the border of Scotland and England and one in north Scotland. A test typically consists of 50 open-pollinated families planted in eight-tree row plots replicated five times on each site. From the first-generation gene resource population of about 800 trees, backward selection was applied to choose a breeding population of 240 parents for the second generation. The selection was based on a multiple-trait index incorporating diameter, stem form, and wood density. About 120 other selections are anticipated from plus-trees that were not tested in the first generation.

British seed is supplied from nine clonal seed orchards, each of which includes about 40 tested selections. There is also an advanced bulk vegetative propagation program conducted through both state and private nurseries that typically involves 20 tested females and a polymix of 20 unrelated, tested males. The constituent clones are updated annually. Out of the approximately 25 million trees planted annually, about 7 million trees come from the nurseries in this program.

British foresters have adopted strong gene conservation measures. In addition to the breeding population and progeny tests, Forest Research maintains two major Sitka spruce clone banks covering 29 ha. Nearly 1,500 trees were grafted into these banks. The long-term fate of the clone banks is not assured, however, because with the completion of the first generation of progeny testing, some researchers are questioning their utility. There is an effort, however, to create a conservation population of about 400 trees that are not included in the breeding program. These will include the next best trees based on index values, after the best 360 are removed, and plus-trees with special features, such as high wood density, despite poor breeding values for other traits.

Sitka spruce is also the most important commercial timber species in Ireland where both active tree breeding programs and clone banks exist (see footnote 3) (Thompson 2000). Tree breeding centers on 749 plus-trees chosen from commercial stands in Ireland. Most of this material originated from Washington, although some originated from Queen Charlotte Islands, Oregon, and various other unknown sources. Of these plus-trees, 455 were tested in progeny tests, and 54 families were selected for advanced-generation breeding. The oldest first-generation progeny tests are just over 20 years; the youngest are 6 years. Evaluations are first made at 10 years from seed and again at 15 years to confirm the selections to go forward. After that time, first-generation progeny tests are treated as normal plantations, or are thinned in such a way as to retain test structure. Typical tests include 50 trees per family per site replicated on at least three different sites. To date, the only production seed orchards are indoors.

Several clone banks exist in Ireland. These include grafts of phenotypically selected plus-trees. Additionally, 47 of the IUFRO provenances are stored in a gene bank with plots 10 trees wide by varying lengths. At least some of these provenances no longer exist *in situ*, which potentially increases the conservation value of this gene bank.

Sitka spruce is also a common plantation tree in Denmark where it is capable of high yields, even on poor soils and windy sites. There is a long history of provenance testing and tree improvement of Sitka spruce in Denmark. From 1918 to 1978, 27 provenance trials were planted on more than 29 field sites (Nielsen 1994). Most of the sources were north of the study area, although at least 10 Washington and 8 Oregon origins are included. Results show that when direct imports are necessary, Washington material is preferable for milder localities, whereas Queen Charlotte Islands material should be used elsewhere.

## Ponderosa Pine

### Background Information

Ponderosa pine is widely distributed in western North America, although within the general boundaries of its distribution, it tends to occur in many discontinuous areas. There are three commonly recognized varieties, but only the Pacific (*P. ponderosa* var. *ponderosa*) is found in Oregon and Washington (Oliver and Ryker 1990). Two racial subdivisions are recognized within the Pacific variety. The "Californian" race occurs from southern California through the Sierra Nevada and Coast Range, in the Willamette Valley, and on the western slope of the Cascade Range. The "North Plateau" race extends from east of the Cascade crest northwards into British Columbia and eastward into western Montana. A transition zone between the two races is present east of the Cascade crest in southern Oregon and extreme northern California. The racial identity of several isolated populations west of the Cascade Range in Washington, including one near Fort Lewis, is not clear (Randall and Berrang, in press). The Californian race tends to have greener foliage, a denser crown, and a sturdier appearance than the grey, slender-stemmed North Plateau race. The Californian race also grows faster but is not as drought tolerant as the North Plateau race.

Ponderosa pine grows under diverse environmental conditions. The Willamette Valley represents one regional extreme where ponderosa pine grows on wet sites at elevations less than 100 m. In the Fremont National Forest, however, the species grows on much drier sites at elevations over 2000 m. In the Willamette Valley, although historically more common, ponderosa pine is relatively rare, occurring in small, scattered stands. (Hibbs and others 2000). East of the Cascade Range, however, ponderosa pine is often dominant, frequently occurring in pure stands, or stands mixed with western larch (*Larix occidentalis* Nutt.) and Douglas-fir.

Many studies have focused on the genetic variation and adaptability of ponderosa pine. Some were done outside the area under consideration (Rehfeldt 1980, 1986, 1987, 1991). Genecological studies designed to elucidate seed transfer guidelines exist for central Oregon (Sorenson 1994, Sorensen and Weber 1994) and are underway for the Willamette Valley[7] and Wenatchee National Forest.[8] These studies show that adaptation among populations involves a balance between the need to grow rapidly in mild environments and the need to survive under harsh climatic and environmental conditions. Moreover, elevation is the environmental factor that most strongly

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[7] St. Clair, J.B. 1999 Unpublished data. On file with: St. Clair, J.B., USDA Forest Service, Pacific Northwest Research Station, SW Jefferson Way, Corvallis, OR 97331.

[8] Johnson, G.R. 1994. Unpublished data. On file with: Johnson, G.R., USDA Forest Service, Pacific Northwest Research Station, SW Jefferson Way, Corvallis, OR 97331.

affects patterns of genetic variation. Trees at lower elevations tend to grow taller and are more susceptible to frost damage. Consequently, Sorensen and Weber (1994) recommend that seed movement be limited to moderate distances with 305-m bands at elevations below 1524 m and to 213-m bands at elevations above 1524 m.

## Genetic Resources

The importance of and emphasis on seed orchards and progeny tests for ponderosa pine differ in different parts of Oregon and Washington (table 4). Most of the seed orchards were established to supply seed for reforestation. The seed is mostly unimproved. Because ponderosa pine has low seed production, especially at high elevations, it is advantageous to produce the seed in orchards rather than collecting it *in situ*. Even for orchards associated with progeny tests, including the Confederated Tribes of Warm Springs and the mid-Columbia Cooperative (DNR, Boise Cascade, and Champion), seed production is their primary objective, with less emphasis on tree improvement than similarly sized programs for Douglas-fir or western hemlock.

The 22 seed orchards in the study area include genetic resources from approximately 3,427 open-pollinated families or clones. The orchards are well distributed regionally across the range of ponderosa pine. Progeny tests are associated with only a subset of these orchards. Nevertheless, more than 2,700 selections were tested at more than 43 test sites. The fate of several of these trials, however, is uncertain. Three tests on the Fremont National Forest need thinning to prevent losing slower growing families, but there is a lack of funding. The forest has also recently restructured its breeding zones, making the older tests less useful. Similarly, although the Klamath ODF test is presently maintained, its continued upkeep is not assured. The seed from this test was intended primarily for use in Sun Pass State Park; however, because of harvest reductions and increasing emphasis on uneven-age management, Klamath ODF District is presently planting only 20,000 ponderosa pine seedlings per year. This makes it difficult to justify continued funding of the progeny test.

Importantly, there are two ponderosa pine seed orchards designed with gene conservation as an explicit goal. One is at the J.E. Schroeder Seed Orchard, with selections chosen by the Willamette Valley Ponderosa Pine Conservation Association. This Association, established in 1994, seeks to conserve and reestablish the native race of Willamette Valley ponderosa pine for gene conservation and future timber, wildlife, and urban uses. Although in 1800, many of the Willamette Valley foothills and some streamside areas were inhabited by groves of large ponderosa pine, they have decreased due to land conversion for agriculture, urbanization, and Douglas-fir production (Hibbs and others 2000). To prevent further loss of genetic diversity in Willamette Valley ponderosa pine, the association has located and mapped native stands and plantations from known Willamette Valley parent trees and seed sources. It also established a seed orchard to provide an assured supply of high-quality, genetically diverse seed. The orchard was planted in a design that made it possible to evaluate genetic differences. Early results provide little evidence to indicate geographic differentiation within the valley; however, family selection in a tree improvement program or through rouging the orchard could lead to considerable gains in growth (see footnote 7).

*Text continues on page 23*

**Table 4—Ponderosa pine genetic resources in seed orchards and progeny tests in western Oregon and Washington**

| Organization | Seed orchard | Breeding zone/unit or seed zone | Elevation range | Families/clones in orchard (year planted) | Orchard | Families in tests (year test established) | Test sites |
|---|---|---|---|---|---|---|---|
| | | | *m* | *No.* | *Ha* | - - - - - - - - *No.* | - - - - - - - - |
| Deschutes NF, Bend/ Fort Rock RD | Kelsey Butte | Fort Rock 03 | 1219-1524 | 65 (1993) | 7.7 | | |
| Deschutes NF, Bend/ Fort Rock RD | Deer Run | La Pine 02 | 914-1524 | 152 (1986/87) | 9.7 | 308 (1986) | 7 |
| Deschutes NF, Sisters RD | Three Sisters | Sisters 05 | 914-1524 | 203 (1991) | 10.1 | 282 (1988) | 10[a] |
| Fremont NF | Panelli | Fremont 5 | 1356-1768 | 90 (1981) | 4.9 | 119 (1983) | 4 |
| | Desert Springs | 02011 | 1737-1951 | 76 (2000) | | | |
| | Desert Springs | 02012 | >1951 | 25 (2000) | | | |
| | Desert Springs | 02021 | 1524-1737 | 122 (2000) | | 163 (1983) | 4 |
| | Desert Springs | 02022 | 1737-1951 | 76 (2000) | | 163 (1983) | 4 |
| | Desert Springs | 02031 | 1524-1737 | 122 (2000) | | 177 (1983) | 6 |
| | Desert Springs | 02032 | 1737-1951 | 49 (2000) | | 177 (1983) | 6 |
| | Desert Springs | 02041 | 1524-1737 | 62 (2000) | | | |
| | Desert Springs | 02042 | 1737-1951 | 36 (2000) | | | |
| | Desert Springs | 02023, 02033[b] | 1737-1951, >1951 | 58 (2000) | | | |
| | Sugar Pine Mountain[c] | 20011 | 1219-1524 | 21 (1993) | 8.5[c] | | |
| | Sugar Pine Mountain[c] | 20012 | 1524-1676 | 17 (1993) | 8.5[c] | | |
| Mount Hood NF | Keep's Mill | 06023 | <914 | 295 (1986) | 4.1 | 236 (1988) | 7 |
| | | 06024 | >914 | 295 (1986) | | 236 (1988) | 7 |
| Okanogan NF, Methow Valley RD | Frank Berg | Seed zone 600 | 914-1219 | 200 | | | |
| | Polepick | Seed zone 600 | 1219-1524 | 70 (1994) | | | |

**Table 4—Ponderosa pine genetic resources in seed orchards and progeny tests in western Oregon and Washington (continued)**

| Organization | Seed orchard | Breeding zone/unit or seed zone | Elevation range | Families/clones in orchard (year planted) | Orchard | Families in tests (year test established) | Test sites |
|---|---|---|---|---|---|---|---|
| | | | *m* | *No.* | *Ha* | - - - - - - - - *No.* - - - - - - - - | |
| Okanogan NF, Tonasket RD | | Seed zones 612, 613, 614 | 945-1036 | 127 (2000) | | | |
| Wenatchee NF, Cascade block | Ed Cliff | 17013 | 610-1067 | 70 (NA) | 4.5 | | |
| Wenatchee NF, Columbia block | Camas, | 17002 | 610-914 | 56 (NA) | 6.3 | | |
| | Mud Creek | 17004 | 914-1219 | 56 (NA) | 6.3 | | |
| Winema NF, Chemult RD | Sugar Pine | 20011 | 1219-1524 | 66 (1991) | 8.5[c] | | |
| | Mountain | 20012 | 1524-1676 | 78 (1991) | 8.5[c] | | |
| Winema NF, Chiloquin RD | Cascade View | 20061 | 1219-1524 | 140 (1991) | 4.3 | | |
| Winema NF, Chiloquin RD | Cascade View | 20062 | 1524-1676 | 91 (1991) | 3.0 | | |
| Winema NF, Klamath RD | Lost Creek | 30031 | 1219-1524 | 70 (1982/85/97) | 3.2 | | |
| BLM Eugene | Travis Tyrrell | Eugene District | 152-396 | 15 (1994) | .4 | | |
| | Travis Tyrrell | Roseburg District | NA | 94 (1994) | 1.5 | | |
| BLM Medford | Charles Sprague | Seed zone 44 | 914-1219 | 50 (1981) | | | |

**Table 4—Ponderosa pine genetic resources in seed orchards and progeny tests in western Oregon and Washington (continued)**

| Organization | Seed orchard | Breeding zone/unit or seed zone | Elevation range | Families/clones in orchard (year planted) | Hectare of orchard | Families in tests (year test established) | Test sites |
|---|---|---|---|---|---|---|---|
| | | | *m* | *No.* | *Ha* | - - - - - - - - *No.* | - - - - - - - - |
| Confederated Tribes of Warm Springs | Badger Creek | Sisters 05, southern 1/3 of WSIR | 884-1219 | 79 (1986) | 2.7 | See Deschutes NF Sisters 05 | See Deschute NF Sisters 05 |
| | Badger Creek | WSIR and Mount Hood 06024 | 792-1219 | 198 (1986) | 3.7 | See Mount Hood NF 06024 | See Mount Hood NF 06024 |
| Mid-Columbia co-op, Boise Cascade | Goldendale | Primarily seed zone 673, also 652, 651, 642 | 610-1067 | 231 (2000) | | 231 (2000) | See Mount Hood NF 06024 |
| Mid-Columbia co-op, Champion | Crusher | Primarily seed zone 673, also 652, 651, 642 | 610-1067 | 231 (2000) | | 231 (2000) | See Mount Hood NF 06024 |
| Mid-Columbia co-op, DNR | Meridian | Primarily seed zone 673, also 652, 651, 642 | 610-1067 | 231 (2000) | | 231 (2000) | 3 |
| ODF Klamath District | | | | | | 142 (1975) | 2 |

**Table 4—Ponderosa pine genetic resources in seed orchards and progeny tests in western Oregon and Washington (continued)**

| Organization | Seed orchard | Breeding zone/unit or seed zone | Elevation range | Families/clones in orchard (year planted) | Hectare of orchard | Families in tests (year test established) | Test sites |
|---|---|---|---|---|---|---|---|
| | | | *m* | *No.* | *Ha* | - - - - - - - - *No.* - - - - - - - - | |
| Plum Creek Timber Company | Cle Elum West | Seed zones 631, 632 | 914-1524 | 70 (2000) | 2.4 | | |
| Weyerhaeuser/ U.S. Timberlands[d] | NA | Seed zones, 502, 701, 702, 703, 711, 712, 713, 721, 722, 731 | 1036-2012 | NA | NA | 1,079 | NA |
| Willamette Valley Ponderosa Pine Conservation Association[e] | J.E. Schroeder (ODF) | Willamette Valley | <305 | 170 (1996/2000) | 6.1 | | |
| Total | | | | 3,427[f] | >89.3 | 2,737 | >3 |

WSIR = Warm Springs Indian Reservation; NA = information not available.

[a] The progeny test for Deschutes National Forest (Three Sisters Ranger District) and WSIR is planted at 5 sites on national forest land, 2 on WSIR land, and 3 on industry land.

[b] Gene conservation orchard block (see text).

[c] The Sugar Pine Mountain Seed Orchard is part of the Winema National Forest but contains a breeding block with selections from both the Fremont and Winema National Forests. The acreage listed includes selections from both forests.

[d] Originally owned by Weyerhaeuser, presently owned by U.S. Timberlands. Both organizations maintain records of the progeny tests.

[e] The Willamette Valley Ponderosa Pine Conservation Association plans to graft an additional 48 parents into the clone bank. Their goal is to maintain more than 160 families.

[f] Individual families are only counted once when computing total.

The second gene conservation project is at the Desert Springs Seed Orchard on the Fremont National Forest. Most of the blocks in this orchard are established to produce genetically diverse seed for general reforestation purposes. Two blocks, however, will contain a few progeny from each of about 100 selections from the Warner Mountains of Oregon. Seed from these blocks will protect the genetic resource, while exceeding the normal, expected reforestation requirements for this area. The Warner Mountains contain genetically unique and variable populations of ponderosa pine, probably due, in part, to introgression with Washoe pine (*Pinus washoensis* Mason and Stockwell) (Berrang 2000,[9] Sorenson 1994). Because of the unique genetic variation, only local seed sources should be provided for replanting. Forest managers in the area have created seed stores for potential catastrophic events such as forest fire. The sites are extremely harsh and difficult to access, however, and there has not been a good cone crop during the past 20 years. The seed produced by the orchard, therefore, will augment the limited supply collected from natural stands if needed.

Regional seed stores for ponderosa pine are extensive. The Forest Service and BLM hold lots from more than 11,000 families well distributed throughout the regional range of the species (table 1). Additionally, the Willamette Valley Ponderosa Pine Conservation Association regularly monitors and collects seed from trees in the Willamette Valley; it has stored seed for 105 of the approximately 170 clones grafted into its orchard. The association's plans for this seed are unspecified.

### Other Resources

Extensive tree improvement programs exist for ponderosa pine in other parts of its range, including northern California and the Inland Empire area that abuts our region. Selections from western Oregon and Washington outside of our region are unknown.

## Western White Pine

### Background Information

The range of western white pine includes disjunct western and interior portions. The western range stretches from near Butte Inlet in southern British Columbia to southern Tulare County, California. The interior portion extends from western Montana through northern Idaho to eastern Washington and Oregon. Most stands in western Oregon and Washington occur on the western slopes of the Cascade Range and Siskiyou Mountains. They grow in a relatively narrow elevation band that straddles the Douglas-fir and Pacific silver fir zones, and in the Olympic Mountains from sea level to 550 m (Fowells 1965). Western white pine usually grows together with several different tree species.

Western white pine possess abundant genetic variation distributed among individuals within stands but not among stands (Campbell and Sugano 1989, Steinhoff and others 1983). Additionally, in several areas studied, genetic variation was unrelated to elevation of the seed sources (Rehfeldt and others 1984, Steinhoff and others 1983). Consequently, the Forest Service adopted relatively large seed and breeding zones for both Washington and Oregon (Campbell and Sugano 1989; Randall and Berrang, in press).

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[9] Berrang, P. 2000. Personal communication. Area geneticist, USDA Forest Service-Winema National Forest, 2819 Dahlia, Klamath Falls, OR 97601; pberrang@fs.fed.us.

In parts of its range, western white pine is under attack from the deadly white pine blister rust. This introduced rust spread through western Oregon and Washington from about 1920 to 1940, and the severity of infestation continues to increase (Kinloch and Dulitz 1990). The rust kills seedlings and saplings directly, severely limiting regeneration in areas of high rust hazard. Susceptible mature trees survive longer than younger trees, but as they continue to die off, the size of the natural breeding population is reduced, potentially leading to severe bottlenecks or population extirpation in heavily infected areas (Millar and others 1996). Bottlenecks reduce genetic diversity depending on population density, the frequency of natural resistance, and the actions people take to manage resistance and replanting. Fortunately, the genetic structure of western white pine, in which most genetic variation is found within rather than among populations, allows for population decreases without significantly decreasing gene pool diversity.

In 1956, concern about the genetic integrity and continued survival of western white and sugar pine prompted the Pacific Northwest Region of the Forest Service (Oregon and Washington) to establish a resistance program for white pine blister rust. The program is run out of Dorena TIC. It was developed under the assumption that genetic resistance is the most feasible and effective method of rust control. The primary responsibility of Dorena TIC is testing wind-pollinated progeny in rust beds and screening for specific rust-resistant mechanisms. These mechanisms include the reduced frequency of needle lesions, bark reactions, tolerance, and absence and slow growth of cankers. More than 10,000 field selections of western white and sugar pine were screened for blister rust resistance. Most of the tested trees originated on Forest Service or BLM lands. Trees from other federal and state agencies, Indian nations, and private organizations also were included.

Geneticists at Dorena TIC are in the process of compiling and summarizing results from the center’s 40 year history of screening for rust resistance. They intend to develop databases containing detailed information on the geographic location of screened and resistant selections to use with a geographic information system (GIS). They also will describe the selections that have been incorporated into seed orchards and other *ex situ* plantings in more detail than is possible here.

## Genetic Resources

Dorena TIC screened nearly all regional western white pine germplasm in *ex situ* forms for rust resistance. Most of the selections display one or more resistance mechanisms. Some seed stores and clones in older seed orchards were not included. Dorena TIC began putting resistant clones in a clone bank/seed orchard in 1967. It presently includes 868 clones from the study area, plus additional clones from the Malheur and Colville National Forests (table 5). While selections are continually added, since 1985 most of the resistant selections were placed in orchards managed by other programs. In the 1980s, second-generation resistant clones also were planted at Dorena. Other seed orchards were established on eight national forests, two BLM districts, two Indian nations, and Plum Creek Timber Company land (table 5). Overlapping occurs between selections in these orchards and those at Dorena. The selections in the orchards span the range of western white pine west of the Cascade crest. There are no seed orchards for areas east of the Oregon Cascade crest. In general, newer orchards begun during the past decade tend to contain fewer selections, all of which display resistance; whereas the orchards initiated in the 1970s often include many selections without resistance mechanisms.

**Table 5—Western white pine genetic resources in seed orchards in western Oregon and Washington**

| Organization | Seed orchard | Breeding zone/area | Elevation range (m) | Families/ clones (year planted) | Orchard | Families in test (year established) | Test sites |
|---|---|---|---|---|---|---|---|
| | | | *m* | *No.* | *Ha* | *No.* | *No.* |
| Gifford Pinchot NF | Coyote | 6020 (Mount Hood/ Gifford Pinchot NF) | 610-1676 | 424 (1982) | 9.3 | | |
| Mount Hood/ Gifford Pinchot NF[a] | Monticola | 6020 (Mount Hood/ Gifford Pinchot NF) | All | 48 (1979) | 6.1 | Performance trial (1985/97) | 5 |
| Mount Baker-Snoqualmie NF | RN McCullough | 05010 | All | 100 (1992/93) | 2.4 | | |
| Olympic NF | Dennie Ahl | 09070 | All | 50 (1984) | 1.2 | | |
| Rogue River/ Siskiyou/Umpqua NF | Jim Creek | 15040 | All | 282 (1979) | 3.6 | Performance trial (1989/96) | 4 |
| Wenatchee NF | Knox Creek | Cle Elum West 17110 | All | 11 | .4 | Performance trial (1995/97) | 6 |
| Wenatchee NF[b] | RN McCullough | 17110 | All | 175 (1975) | 2.4 | | |
| Willamette NF | Pebble Creek | 18030 (Willamette/ Deschutes NF) | All | 120 (1985) | 10.1 | 200 (1993) | 8 |
| USDA Forest Service | Dorena Tree Improvement Center[c] | 5010 (Mount Baker-Snoqualmie NF) | All | 96 (1967-present) | 17.4 | | |
| | | 6020 (Mount Hood NF) | All | 301 (1967-present) | 17.4 | | |
| | | 18030 (Willamette/ Deschutes NF) | All | 570 (1967-present) | 17.4 | | |

**Table 5—Western white pine genetic resources in seed orchards in western Oregon and Washington (continued)**

| Organization | Seed orchard | Breeding zone/area | Elevation range (m) | Families/ clones (year planted) | Orchard | Families in test (year established) | Test sites |
|---|---|---|---|---|---|---|---|
| | | | *m* | *No.* | *Ha* | *No.* | *No.* |
| USDA Forest Service | Dorena Tree Improvement Center[c] | 15040 (Umpqua, Rogue River NF) | All | 591 (1967-present) | 17.4 | | |
| | | 11050 (Siskiyou NF) | All | 26 (1967-present) | 17.4 | | |
| | | 12060 (Siskiyou NF, ODF) | All | 3 (1967-present) | 17.4 | | |
| | | 9070 (Olympic NF) | All | 41 (1967-present) | 17.4 | | |
| | | 17110 (Wenatchee NF) | All | 74 (1967-present) | 17.4 | | |
| | | 2180 (Fremont NF) | All | 2 (1967-present) | 17.4 | | |
| BLM Medford | Walter H. Horning | 93 (zones 02 and 03) | All | 100 (1993) | 1.2 | | |
| BLM Eugene | Travis Tyrrell | BLM Eugene District | 1219-1372 | 3 (1994) | .04 | | |
| Confederated Tribes of Warm Springs[d] | Swamp Creek | WSIR | 975-1676 | 97 (1985) | 2.9 | | |
| Plum Creek Timber Company | Whidbey Island | SW Washington and NW Oregon Cascades | All | 40[e] (UE) | | | |
| Quinault | Quinault | Quinault Indian Nation | | 15[e] (UE) | | | |

UE = under establishment; WSIR = Warm Springs Indian Reservation.

[a] The Monticola Seed Orchard was originally established as a progeny test but was subsequently converted to a seed orchard. It is located at 1220 m in a frost pocket and is expected to produce frost-resistant seed.

[b] The RN McCullough Seed Orchard is managed by Mount Baker-Snoqualmie National Forest. The selections come from Wenatchee National Forest breeding zone 17110.

[c] Dorena Tree Improvement Center has both a seed orchard and an arboretum, and resources in both are shown.

[d] The Confederated Tribes of Warm Springs also maintains a clone bank containing the clones in the orchard plus 477 additional genotypes. Of these, 123 are from wind-pollinated parent trees, 333 are from parent-tree controlled crosses, and 21 are of unknown identity. Seed from original collections and first-generation tests is also held in storage.

[e] Goal for the orchard.

Two series of outplanted field trials for western white pine were initiated by Dorena TIC: performance and rust validation trials. Performance trials that compare different levels of rust resistance among selected trees are underway for five breeding zones (table 6). In these trials, a set of families is planted at several sites within a breeding zone in a large block design. Sets typically contain 10 first-generation families, 10 second-generation families, 10 select-tree open-pollinated families, and a control bulked lot; they are planted in 49 tree plots with four replications. The first- and second-generation families were produced by controlled crosses. In some trials, family identity was retained.

There is also a series of rust validation trials designed to further examine individual rust-resistance mechanisms in families previously tested in the Dorena screening program. The main goal of these trials is to determine whether the resistance identified at Dorena over a 7-year period of artificial disease inoculation and nursery culturing holds up under field conditions that more closely mirror normal reforestation conditions. The trials track family performance and are expected to better elucidate the genetics of blister rust resistance. There are four series of western white pine trials comprising 158 families and 16 test sites (table 7). Test details differ in different trial sets.

Regional seed stores for western white pine are extensive and consist of more than 4,000 family lots well distributed across the range of the species. Progeny from many of these seed lots were screened for rust resistance, but unlike seed orchard selections, most showed no resistance.

### Other Resources

Blister rust resistance programs for western white pine are underway in all regions surrounding western Oregon and Washington, including British Columbia, California, and Idaho (the Inland Empire area). Regional selections planted outside of Oregon and Washington are unknown.

## Sugar Pine

### Background Information

Sugar pine is the tallest of all pines and is highly valued for the quality and even grain of its wood. Its range extends from the western slopes of the Cascade Range in north-central Oregon to the Sierra San Pedro Martir in Baja California Norte. Nearly 80 percent of the growing stock occurs in California (Kinloch and Scheuner 1990). In Oregon, it is rarely a dominant species; it exists as a minor component in many plant associations. Scattered individuals or small groups typically are found on drier sites at mid to low elevations in the southern and central Cascade Range, in the extreme southern Coast Range, and in the adjacent Siskiyou mountains.

Sugar pine, like western white pine, succumbs to white pine blister rust. It too is suffering from lack of regeneration, the threat of bottlenecks, and population extirpation. Dorena TIC has an ongoing resistance program for sugar pine that is similar to the one for western white pine.

**Table 6—Location and breeding zone of material included in performance trials comparing different levels of white pine blister rust for western white (WWP) and sugar pine (SP)**

| Species | Breeding zone | Location of test sites | Number of test sites | Date established |
|---|---|---|---|---|
| WWP | 06020 | Gifford Pinchot and Mount Hood NF | 5 | 1985/97 |
| WWP | 12060 | Oregon Department of Forestry | 8 | 1989/91 |
| WWP | 15040 | Rogue River and Umpqua NF | 4 | 1989/96 |
| WWP | 17110 | Wenatchee NF | 5 | 1987 |
| WWP | 18030 | Willamette and Deschutes NF | 6 | 1995/97 |
| SP | 02176 | Oregon Department of Forestry Klamath District | 1 | 1991 |
| SP | 10044 | Rogue River and Umpqua NF | 6 | 1994 |
| SP | 11054 | Siskiyou NF, BLM Medford District | 4 | 1994 |

Table 7—Summary of the white pine blister rust validation trials for the western white (WWP) and sugar pine (SP)

| Species | Number of families | Number of trees | Geographic origin of material | Type of families | Location (and number) of test sites | Date established |
|---|---|---|---|---|---|---|
| WWP | 13 | 1144 | Colville, Gifford Pinchot, Mount Baker-Snoqualmie, Mount Hood, Siskiyou, and Willamette NF | 10 wild OP lots and 3 Dorena seed orchard crosses with different resistance characteristics | Klamath NF (1), Umpqua NF (3) | 1996/97 |
| WWP | 15 | 846 | Colville, Gifford Pinchot, Mount Baker-Snoqualmie, Mount Hood, Umpqua, and Willamette NF | 7 wild OP lots and 3 Dorena seed orchard lots with evidence of bark reaction resistance; 5 Dorena seed orchard crosses from Champion Mine parents | Klamath NF (1), Umpqua NF (3) | 1996/97 |
| WWP | 50 | 4800 | Colville, Gifford Pinchot, Mount Hood, Rogue River, Umpqua, and Willamette NF | 5 wild OP lots, 6 Dorena seed orchard OP lots, and 39 Dorena seed orchard controlled crosses with evidence of various resistance mechanisms | Umpqua NF (1), WSIR (2) | 1998 |
| WWP | 80 | 9993 | Colville, Gifford Pinchot, Mount Baker-Snoqualmie, Mount Hood, Rogue River, Umpqua, Wenatchee, and Willamette NF and 1 north Idaho lot | 59 families from four 6-parent diallels, 7 lots from Grass and Blodgett outplantings, 5 OP wild lots, 8 Dorena seed orchard lots, and 1 Idaho seed orchard bulk lot | WSIR (1), Willamette NF (1), Umpqua NF (2), BLM Salem (1) | 1999 |
| SP | 12 | 1056 | Fremont, Rogue River, Siskiyou, and Willamette NF | Wild OP lots with different resistance characteristics | Klamath NF (1) Umpqua NF (3) | 1996/97 |
| SP | 42 | 3246 | BLM Medford | BLM diallels from 3 breeding zones | Klamath NF (1), Eldorado NF (1) | 1997/99 |
| SP | 33 | 3025 | Fremont, Rogue River, Siskiyou, Umpqua, and Willamette NF and BLM Medford | 19 wild OP lots, 2 Dorena seed orchard OP lots, and 12 Dorena controlled cross lots with evidence of various resistance mechanisms | Umpqua NF (1), Josephine County (1), BLM Medford (1) | 1998/99 |

WSIR = Warm Springs Indian Reservation.

OP = open pollinated.

Common garden studies of sugar pine in Oregon (Campbell and Sugano 1987) and across a wider range (Jenkinson 1996) suggest considerable genetic variation and a fair degree of genetic differences among locations. These differences are considerably less than for Douglas-fir but greater than for western white pine. In southwest Oregon, local populations appear to have intricate patterns of genetic variation that most likely reflect the complex environment of the area. This complexity could potentially lead to a greater loss of genetic diversity from blister rust in sugar pine than in western white pine. The complexity led Randall (1996) to propose three low-, two mid-, and two high-elevation seed zones that allow for more moderate seed movement than in western white pine.

**Genetic Resources**

As with western white pine, most of the *ex situ* sugar pine germplasm was screened by Dorena TIC. Not all of the resistant selections identified, however, ended up in *ex situ* plantations. Several agencies, including ODF (Klamath and Grants Pass Districts) and some national forest and BLM districts, chose plus-trees from the field and, rather than setting up seed orchards, collect seed from the resistant plus-trees for reforestation purposes. Nevertheless, Dorena TIC maintains 802 clones, some from the 1,140 first-generation selections included in other seed orchards (table 8), which span much of the range of sugar pine in Oregon. Although parts of the Fremont, Winema, and Deschutes National Forests were not included in the first generation selections, they are developing an orchard to cover this area. Additionally, BLM (Medford District) has recently started a second-generation orchard at Provolt.

Dorena also established performance and rust validation trials for sugar pine, similar to those for western white pine. Performance trials for sugar pine are currently conducted in three breeding zones (table 6). Unlike the western white pine trials, they omit second-generation families and are planted in 64-tree plots. The three rust validation trials for sugar pine are planted on nine test sites; they contain 7,327 trees from 87 families (table 7).

Additional genetic resources for sugar pine are found in a common garden study established in 1984 (Jenkinson 1996). This study includes five trees chosen by “roadside selection” from each of 69 provenances in southern Oregon plus additional collections from California. The southern Oregon provenances are distributed across 12 seed zones and range in elevation from 2000 to 5500 m. They are planted at two test sites in California and two in Oregon. Details of test design are published in Jenkinson (1996).

**Other Resources**

A blister rust resistance screening program has existed in California for more than 30 years. More than 1,100 rust-resistant sugar pine trees are identified and many more are being tested.

**Table 8—Sugar pine genetic resources in seed orchards in western Oregon and Washington**

| Organization | Seed orchard | Breeding zone | Elevation range (m) | Clones (year planted) | Orchard |
|---|---|---|---|---|---|
| | | | *m* | *No.* | *Ha* |
| Fremont NF | UE | Winema, Fremont, and southeastern Deschutes NF | | Goal of 90 (UE) | |
| Rogue River and Siskiyou NF | Bean Gulch | 10025 | >1219 | 70 (1989) | 3.2 |
| Rogue River and Umpqua NF | Provolt-Zim | 10044 | 762-1219 | 74 (1996) | 2.0 |
| Rogue River and Umpqua NF[a] | Provolt-Junction | 10045 | >1219 | 41 (1995) | .4 |
| Rogue River and Umpqua NF | Meridian | 15043 | <762 | 134 (1990) | 4.9 |
| Siskiyou NF | Wayout Saddle | 11053 | <762 | 97 (1990) | 4.9 |
| Siskiyou NF | Horse Mountain | 11054 | 762-1219 | 193 (1982) | 5.3 |
| USDA Forest Service | Dorena Tree Improvement Center[b] | 02176 (Deschutes and Fremont NF) | All | 15 (1967-2000) | 3.6 |
| | | 10025 (Rogue River and Siskiyou NF) | All | 74 (1967-2000) | 3.6 |
| | | 10043 (Rogue River and Umpqua NF) | All | 63 (1967-present) | 3.6 |
| | | 10044 (Rogue River and Umpqua NF) | All | 124 (1967-present) | 3.6 |
| | | 10045 (Rogue River and Umpqua NF) | All | 103 (1967-present) | 3.6 |
| | | 11053 (Rogue River and Siskiyou NF) | All | 88 (1967-present) | 3.6 |
| | | 11054 (Rogue River and Siskiyou NF) | All | 182 (1967-present) | 3.6 |

**Table 8—Sugar pine genetic resources in seed orchards in western Oregon and Washington (continued)**

| Organization | Seed orchard | Breeding zone | Elevation range (m) | Clones (year planted) | Orchard |
|---|---|---|---|---|---|
| | | | *m* | *No.* | *Ha* |
| | | 11055 (Rogue River and Siskiyou NF) | All | 22 (1967-present) | 3.6 |
| | | 15045 (Rogue River and Umpqua NF) | All | 82 (1967-present) | 3.6 |
| | | 18033 (Willamette NF) | All | 49 (1967-present) | 3.6 |
| BLM Medford | Charles Sprague (Cascade block)[c] | B1042 | 305-610 | 27 | 1.8 |
| | | B1043 | 610-914 | 48 | 3.2 |
| | | B1044 | 914-1219 | 47 | 2.8 |
| | | B1045 | 1219-1524 | 43 | 2.0 |
| | | B1046 | 1524-1829 | 6 (1984/91) | |
| BLM Medford | Charles Sprague (Coast block) | B1052 | 305-610 | 143 | 3.2 |
| | | B1053 | 610-914 | 146 | 7.5 |
| | | B1054 | 914-1219 | 37 | 2.5 |
| | | B1055 | 1219-1524 | 6 (1984/98) | <.4 |
| BLM Medford | Provolt[d] | Coast | 914-1219 | | 2.0 |
| BLM Salem | Walter H. Horning | 91 | 610-914 | 60 (1993) | 2.4 |

[a] The Provolt-Junction orchard of the Rogue River/Siskiyou National Forest serves as a clone bank.

[b] Dorena Tree Improvement Center has both a seed orchard and arboretum. Resources in both are shown.

[c] At the Charles Sprague Seed Orchard, there are an additional 15.4 acres of sugar pine maintained as an arboretum.

[d] Provolt is a second-generation orchard intended to replace the unit at Charles Sprague.

## Western Redcedar

### Background Information

The wide natural distribution of western redcedar extends from southeast Alaska to northwest California including a disjunct inland region in the Rocky Mountains. In western Oregon and Washington, the species is becoming progressively more important in reforestation because of the trend toward mixed-species plantations and the deleterious effects of Swiss needle cast (*Phaeocryptopus gaeumannii* (Rohde) Petrakon) on coastal Douglas-fir stands. Consequently, interest is growing in the development of effective seed procurement strategies. Several organizations are establishing seed orchards to supply a reliable seed source. Additionally, a recent economic analysis by Forest Renewal BC (a BC Crown Corporation) identified western redcedar as its highest priority for genetic improvement in British Columbia. Cooperation with the well-funded British Columbia program has accelerated the establishment of seed orchards in western Oregon and Washington.

A primary goal in the development of seed orchards is to produce outcrossed seed. Western redcedar selfs readily (El Kassaby and others 1994, Perry and Knowles 1990, Xie and others 1991). A 50-percent selfing rate was detected in seed orchards and natural stands (El Kassaby and others 1994). Selfed seed and seedlings are nearly as viable as outcrossed seeds and seedlings but, upon outplanting, selfed seedlings exhibit a reduction in growth of more than 10 percent. Because of high selfing rates and inbreeding depression, collection of open-pollinated seed from wild stands for progeny or genecological tests is not recommended. British Columbia, a region with more experience planting western redcedar than western Oregon and Washington, is alone in its genetic testing in using seed produced by controlled crosses.

Studies of genetic variation in western redcedar, including seedling studies (Cherry 1995, Rehfeldt 1994) and wild-field tests,[10] suggest that although significant variation exists for growth and fitness traits, it is still less than for most other conifers. Moreover, most variation between populations is random. Only widely separated populations show significant differences associated with the geographic seed origin. Because of this generalist strategy, western redcedar seed is transferred over a wide environmental and geographic range (Randall 1996; Randall and Berrang, in press). It requires less extensive gene conservation than species with greater population differentiation and genetic variation.

### Genetic Resources

Although genetic testing of western redcedar is nonexistent, western Oregon and Washington have seven seed orchards for it (table 9). These orchards contain about 340 unique clones, many derived from the CLRS clone bank. Although resources in the clone bank have a better longevity than those in the seed orchards, replication of the material in seed orchards provides assurance against losses due to disease, fire, or other catastrophic events. Also, with clones, there is considerable overlap among seed orchards. Willamette Industries and ODF, for example, have identical sets that include some selections present in the Monmouth orchard (which is owned by the PNW Research Station).

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[10] Russell, J. 2000. Personal communication. Research scientist, British Columbia Ministry of Forests, Cowichan Lake Research Station, P.O. Box 335, Mesachie Lake, BC Canada, VOR 2NO; john.russell@gems1.gov.bc.ca.

Table 9—Western redcedar genetic resources in seed orchards and clones banks in western Oregon and Washington[a]

| Geographic origin of collection | Clones | Elevation range | Total acres of seed orchard or number of ramets per clone of clone banks (year established) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Siuslaw NF (Beaver Creek) | PNW Research Station (Monmouth) | BLM Salem (Walter H. Horning) | BLM Eugene (Tyrell) | DNR (Meridian) | ODF (J.E. Schroeder) | Willamette Industries (Eola Hills) | Cowichan Lake Research Station |
| | *No.* | *m* | | | | | | | | |
| OR, WA, and northern CA | 253 | 0-1219 | | | | | | | | 5 ramets/ clone |
| WA Coast Range | 26 | 0-762 | | | | | | 2 acres (1997/99) | 2 acres (1999) | 5 ramets/ clone |
| OR Cascades | 22 | 0-762 | | | | | | 2 acres (1997/99) | 2 acres (1999) | 5 ramets/ clone |
| OR Coast Range | 110 | 0-762 | | | | | | 2 acres (1997/99) | 2 acres (1999) | 5 ramets/ clone |
| Siuslaw NF | 51 | 0-1219 | UE | | | | | | | UE |
| DNR Puget Sound seed zone | 50 | 0-610 | | | | | UE | | | UE |
| DNR Twin Harbors seed zone | 50 | 0-610 | | | | | UE | | | UE |
| BLM Eugene District | 48 | 152-914 | | | | 2 acres (1994) | | | | |
| Oregon Coast Range | 18 | NA | | 1 acre (1980) | 1 acre[b] (1979) | | | | | |
| Oregon Cascades | 12 | | | | | | | | | |

UE = under establishment.

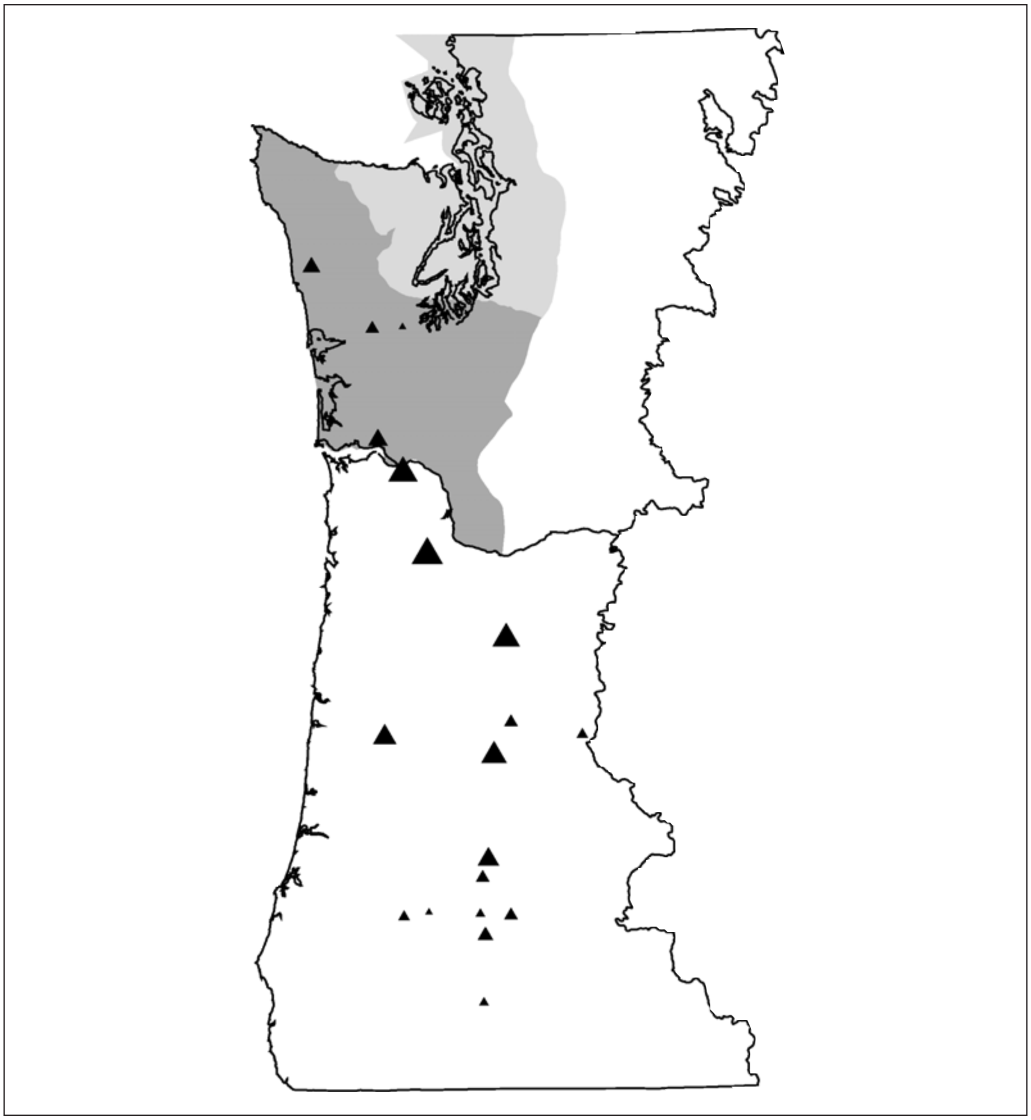

Figure 3—Western redcedar *ex situ* genetic resources (▲ = source of the 196 clones at the Cowichan Lake Research Station for which latitudes and longitudes are available. Larger triangles represent multiple clones). Lightly shaded area indicates the Puget Sound seed zone and the darkly shaded area the Twin Harbors seed zone for which Washington DNR is establishing an orchard using 50 clones per zone.

The clone sources in the CLRS clone bank and in the Meridian seed orchard (Washington DNR) are shown in figure 3. Most of the clones at CLRS were derived from either the Oregon Coast or Oregon Cascade Ranges. Clones put into the Meridian orchard likely will also be incorporated into CLRS. However, gaps probably exist toward the eastern edge of the range of the species in Washington. Further collections are anticipated and desired for southern and eastern Oregon because these areas are also underrepresented.

Only three national forests hold seed stored by individual family for western redcedar (table 1). This seed all originated from the Cascade Range. The species is found in 11 other national forests in the region and on all BLM districts.

### Other Resources

*Ex situ* genetic resources for western redcedar from British Columbia are considerable. They include extensive clone banks, progeny and provenance tests, and material in several seed orchards. Their clone banks include about 400 genotypes from the south coast of British Columbia and Queen Charlotte Islands and more than 150 genotypes selected from high-elevation and coast interior transition areas.

## Western Hemlock

### Background Information

Western hemlock has a wide natural distribution in western North America. It extends down the Pacific coast from the Kenai Peninsula in Alaska to central California. It also occupies the Rocky Mountains from southeast British Columbia to northern Idaho. In Oregon and Washington, it is found from the coast, where stands are better developed, through the western and upper eastern slopes of the Cascade Range. In the Cascade Range, it occurs in elevations of up to about 1,000 m. It ranges from sea level to about 1,100 m in the Olympic Mountains (Franklin and Dyrness 1973). Western hemlock is a prolific seed producer that, while occasionally forming pure stands, is more commonly found mixed with Sitka spruce, Pacific silver fir, western redcedar, or Douglas-fir.

Despite a relatively large investment in first-generation breeding programs, there is relatively little information on geographic variation in western hemlock. The species has not undergone extensive genecological studies like those used to define seed movement boundaries in ponderosa pine and noble fir, species with comparable levels of tree improvement investment. We know, however, that seed should not be moved between the Coast and Cascade Ranges, nor should it be moved more than two degrees in latitude in western Oregon and Washington (Foster and Lester 1983). Consequently, the newly revised seed zone maps show eight zones for western Oregon (Randall 1996) and seven for western Washington with elevation bands ranging from 305 to 457 m (Randall and Berrang, in press).

### Genetic Resources

Nearly all *ex situ* genetic resources for western hemlock represent sources from the Coast Range where commercial activity is concentrated. Completed or near-complete first-generation progeny tests and the associated seed orchards are considerable, as are those in the recently established second-generation programs. Two local cooperatives, organized under the Northwest Tree Improvement Cooperative, and seven independent programs conducted the first generation of breeding. The British Columbia Ministry of Forestry and Canadian Pacific Forest Products also engaged in first-generation breeding. In the mid-1990s, most programs, excluding Weyerhaeuser Company and the Olympic National Forest, agreed to pool their first-generation resources in a western hemlock tree improvement coop (HemTIC) formed under the umbrella of the Northwest Tree Improvement Cooperative. This pooling provided high-gain clones for seed production and made available the genetic resources necessary for a second round of recurrent selection (King and Cress, 1994).

The first-generation tree improvement programs established many small breeding zones delineated conservatively to emphasize local adaptation. Small breeding zones maintain population structure, which is advantageous for gene conservation, but provide limited gain. The first-generation programs tested more than 2,200 open-pollinated families from Oregon and Washington (table 10), with an excess of 500,000 progeny planted. Many of these selections also were included in seed orchards.

Table 10—Western hemlock genetic resources in seed orchards and progeny tests in western Oregon and Washington

| Organization | Seed orchard | Seed/ breeding zone | Elevation range | Families/clones (year planted) | Orchard | Families in test (year established) | Test sites |
|---|---|---|---|---|---|---|---|
| | | | *m* | *No.* | *Ha* | - - - - - - - - - *No.* | - - - - - - - - - |
| Olympic NF | Dennie Ahl | 09022 | 457-914 | 49 (1983) | 1.2 | | |
| BLM Eugene | Tyrell | Eugene District | 305-1219 | 45 (1994) | .5 | | |
| BLM Salem | Horning[a] | 61, OR Coast | <762 | 44 (1980) | 1.4 | See Tillamook Co-op | See Tillamook Co-op |
| | Horning | 60, OR Cascade Range | 366-1067 | 78 (2000) | 1.6 | 180 (1992) | 4 |
| ODF Cooperative Orchard[b] | J.E. Schroeder | HEMTIC[c] | | 32 (1999) | 1.8 | 150 (UE) | 10 |
| Simpson Timber Company[b] | Simpson | HEMTIC[c] | | 32 (UE) | .81 | 150 (UE) | 10 |
| The Timber Company | Camas Prairie[d] | Seed zone 53 with some 61 | 0-213 | 175 (1980) | 3.2 | 175 (1980) | 1 |
| | Olsen Creek | Seed zone 53 with some 61 | 0-213 | 51 (1980) | NA | | |
| Tillamook Co-op | J.E. Schroeder[a] | Tillamook area | 24-701, mostly <305 | 227 (1980) | 1.4 | 332 (1976-81) | 12 |
| Willamette Industries | Eola Hills | NW OR and SW WA Coast Range | NA | 103 (1981/83) | 1.4 | 332 (1976-81) | 12 |

**Table 10—Western hemlock genetic resources in seed orchards and progeny tests in western Oregon and Washington (continued)**

| Organization | Seed orchard | Seed/ breeding zone | Elevation range | Families/clones (year planted) | Orchard | Families in test (year established) | Test sites |
|---|---|---|---|---|---|---|---|
| | | | *m* | *No.* | *Ha* | - - - - - - - - - *No.* | - - - - - - - - - |
| Quinault Indian Nation | Quinault | Grays Harbor, WA | | NA | NA | 432 (1980-82) | 22 |
| Rayonier | Sequim | Grays Harbor, WA | | NA | NA | 150 (UE) | 10 |
| | Sequim | Forks, WA | | NA | NA | 290 (1980) | 10 |
| | Sequim | Grays Harbor, WA | | NA | NA | | |
| Weyerhaeuser Co. | NA | Cascade: seed zones 202, 411, 412, 421 | 91-549 | NA | NA | 111 | NA |
| | | Longview: seed zones 41, 430, 440 | 396-610 | NA | NA | 106 | NA |
| | NA | Vail: seed zones 242, 422 | 0-457 | NA | NA | 277 | NA |
| | NA | Twin Harbors: seed zones 30, 41 | 213-610 | NA | NA | 111 | NA |

UE = under establishment; NA = information not available.

[a] BLM Salem breeding unit 61 was part of the Tillamook co-op. Selections contained in the orchard block are also in the J.E. Schroeder seed orchard.

[b] The ODF Cooperative (Schroeder) and Simpson orchards have the same set of clones.

[c] HemTIC uses a combination of the best 30 parents from each of 5 first-generation programs from British Columbia, Washington, and Oregon.

[d] Camas Prairie serves both as a seed orchard and the progeny test site.

The structure of HemTIC created a breeding strategy for the second generation that is relatively consistent across ownerships. This strategy incorporates results from first-generation tests that suggested the breeding zones were overly small. HemTIC did not specifically define new breeding zones but developed a crossing and testing plan heavily weighted toward the original breeding zones, including additional elite crosses of the best selections across the region. This approach is designed to retain local population structure should future data contradict the current belief of widespread adaptation, without compromising desirable short-term gains.

HemTIC originally was designed to include five programs. The Timber Company, a recently added latecomer, is not conducting as many crosses as the other programs. The original five programs each chose, by backward selection, 30 selections that were the fastest growing and most stable after 10 to 15 years of field testing. This roughly represents a 1:10 selection intensity. The planned local crosses consist of five six-parent partial diallels per first-generation program (15 full-sib crosses per diallel) to create 375 full-sib families. Each of these local diallels will be planted on at least 5 of the 10 total test sites; Oregon and Washington each have three test sites and British Columbia has four. Additional trials will compare the best six parents from each program crossed within and among the regions in diallel matings.

The genetic resources for coastal western hemlock in the second-generation breeding populations and in the first-generation tests that now serve as gene resource populations are impressive. It is important to realize, however, that although the species is present in much of the study area, the selections were chosen from a limited area in the Coast Range. There are only a few selections from the Oregon Cascade Range (BLM Salem District breeding unit 60) and none from the Washington Cascade Range, Willamette Valley, Puget Trough, or Siskiyou Mountains.

The seed stores for western hemlock also cover a limited geographic area. Although the species occurs on 16 national forests and all BLM districts, only the Gifford Pinchot and Willamette National Forests store seed by individual family; the one BLM holding is by the Coos Bay District for only two families. The lack of stored seed is attributed to the fact that western hemlock is mainly planted along the coast where its capacity for natural regeneration is extraordinary.

### Other Resources

Selections from western Oregon and Washington outside of the region, except for the HemTIC material being used in British Columbia, are unknown.

## Other Species

The conifers considered above and Douglas-fir are the species in western Oregon and Washington most subject to tree improvement and other forms of genetic manipulation. Several other conifers native to the region also have genetic resources in *ex situ* forms (tables 11 through 12).

More *ex situ* genetic resources in western Oregon and Washington exist for lodgepole pine (*Pinus contorta* Dougl. ex Loud.) than for any other conifer not specifically targeted by the GCG. Three varieties of lodgepole pine, shore pine (var. *contorta*), Sierra (var. *murrayana*), and Rocky Mountain (var. *latifolia*) are found. Although *ex situ* genetic resources for the small, short-lived shore pine are nonexistent, there are breeding programs, seed stores, and mass selection plantations for the more desirable Sierra and Rocky Mountain varieties. Weyerhaeuser Company includes both varieties among

**Table 11—*Ex situ* genetic resources for other conifers in the study area**

| Species | Organization (geographic area) | Type of *ex situ* genetic resource | Scope of resource |
|---|---|---|---|
| Pacific silver fir | Mount Baker-Snoqualmie NF | Seed orchard | 272, 2 breeding zones, 22 acres, 1984 |
| | Olympic NF | Seed orchard | 95, 2 breeding zones, 6 acres, 1980/87 |
| Grand fir | British Columbia Ministry of Forestry | IUFRO provenance test | Includes 12 Oregon and Washington sources |
| Port-Orford-cedar | USFS/BLM (throughout the species' range) | Screening program at Dorena TIC<br>Performance trials<br>Common garden studies | >100 selections |
| Whitebark pine | Dorena TIC | Clonal archive/screening | |
| Lodgepole pine | Weyerhaeuser Co./U.S. Timberlands (Siskiyou Mountains, south-central Oregon) | Progeny tests<br>Seed orchards | 1,118 selections |
| | Deschutes NF | Progeny test<br>Mass selection plantation | ~250 selections |
| | Fremont NF | Six evaluation plantations | 212 selections; 2 breeding zones in Silver Lake District plus some from nearby Winema and Deschutes NF), ~1983 |
| | | Two seed orchard blocks planned | 72 selections (36/block); Warner Mountains |
| | Winema NF | Mass selection plantations | 180 selections |
| | Europe | Provenance tests | |
| Coast redwood | The Timber Company (southwestern Oregon) | Seed orchard | NA |
| | Simpson (southwestern Oregon) | Seed orchard | NA |
| | Siskiyou NF | Provenance tests | |
| | Simpson | Seed orchard | |
| Pacific yew | BLM Salem | Horning seed orchard | .4 ha |

NA = information not available.

Table 12—Number of families with seed stored for other native conifers for the national forests and BLM districts in the study area

| National forest or BLM District | Alaska-cedar | Brewer spruce | Engleman spruce | Grand fir | Incense cedar | Knobcone pine | Lodgepole pine | Mountain hemlock | Pacific silver fir | Port-Orford cedar | Shasta red fir | Subalpine fir | Western larch | White fir | Whitebark pine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deschutes NF | | | | | | | 450 | | | | | | | 3 | |
| Fremont NF | | | | | | | 454 | | | | | | | 61 | |
| Gifford Pinchot NF | | | 63 | 53 | | | | 49 | 121 | | | 37 | 95 | | |
| Mount Hood NF | 12 | | | | | | | | 24 | | | | 120 | | 3 |
| Mount Baker-Snoqualmie NF | | | | | | | | 274 | | | | | | | |
| Okanogan NF | | | | | | | | | | | | | 349 | | |
| Olympic NF | | | | | | | | | | | | | | | |
| Rogue River NF | | | | | | | | | | | 64 | | | 108 | |
| Siskiyou NF | | 17 | | | 19 | | | | | 39 | 12 | | | 109 | |
| Siuslaw NF | | | | | | | | | | | | | | | |
| Umpqua NF | | | | 9 | | | | | | | 46 | | | 81 | |
| Wenatchee NF | | | 4 | | | | | | 71 | | | | 143 | | |
| Willamette NF | 1 | | 67 | 126 | 51 | 5 | 3 | 10 | 63 | | | | | | |
| Winema NF | | | | | 5 | | 543 | 1 | | | 64 | | | 285 | |
| Coos Bay District | | | | | | | | | | 107 | | | | | |
| Medford District | | | | | | | | | | 20 | | | | | |
| Total | 13 | 17 | 134 | 188 | 75 | 5 | 1,450 | 60 | 553 | 166 | 186 | 37 | 707 | 647 | 3 |

the 1,118 tested selections from the Siskiyou Mountains and south-central Oregon (revised seed zones 3-6) (Randall 1996). The Deschutes National Forest has progeny tests and mass selection plantations that provide seed for reforestation. The Fremont and Winema National Forests have additional mass selection plantations as well as six evaluation plantations. The Fremont National Forest is also planning to plant two small blocks of lodgepole pine selections from the Warner Mountains at the Desert Springs Seed Orchard. Gene conservation is the primary purpose of these orchard blocks because they, like the ponderosa pine blocks with selections from the same area, serve breeding zones with low seed needs. Additionally, the Deschutes, Fremont, Ochoco, Willamette, and Winema National Forests also maintain lodgepole pine seed stores. Finally, several provenance trials with lodgepole pine are found in Europe.

Port-Orford-cedar (*Chamaecyparis lawsoniana* (A. Murr.) Parl.) is another conifer with genetic resources conserved *ex situ*. An introduced root disease, *Phyophthora lateralis* Tucker and Milbrath, is devastating natural populations of Port-Orford-cedar. Over the past few years, the Forest Service and BLM in both Oregon and California have engaged in a cooperative conservation effort to (1) identify resistant individuals through screening, (2) establish breeding zones that maintain adaptability based on results from common garden studies, (3) identify disease-free stands, and (4) recommend measures to minimize introduction of the root disease (*in situ* gene conservation). The screening program, like that for western white and sugar pine, is run from Dorena TIC. It includes both nursery and field performance trials. The Forest Service and BLM will summarize the results from screening and other research in a rangewide assessment to guide future gene conservation efforts for Port-Orford-cedar on federal lands.

*Ex situ* genetic resources for the remaining species in the region are more limited. There are a few seed orchards and provenance tests for coast redwood (*Sequoia sempervirens* (D. Don) Endl.), grand fir (*A. grandis* (Dougl.) Lindl.), Pacific silver fir, and Pacific yew (*Taxus brevifolia* Nutt.) (table 11). There is also a restricted screening program for blister rust on whitebark pine (*Pinus albicaulis* Engelm.) run out of Dorena TIC. At least some seed is stored for several additional conifers including Alaska yellow cedar (*Chamaecyparis nootkatensis* (D. Don) Spach), Brewer spruce (*Picea breweriana* Wats), Engleman spruce (*P. engelmannii* Parry ex Engelm.), incense-cedar (*Calocedrus decurrens* (Torrey) Florin), knobcone pine (*Pinus attenuata* Lemm.), mountain hemlock, Shasta red fir (*Abies magnifica* var. *shastensis* Lemm.), subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), western larch (*Larix occidentalis* Nutt.), and white fir (*Abies concolor* (Gord. & Glend.) Lindl. Ex Hildebr.) (table 12). Generally, this seed is from a limited number of parents and does not span the range of the species.

## Conclusions

This summary provides land managers with necessary data to evaluate the extent and importance of various types of *ex situ* genetic resources for gene conservation. It shows that the *ex situ* genetic resources greatly differ among conifers in Oregon and Washington and largely reflect historical and present priorities for reforestation and tree improvement.

Tree improvement for growth and yield traits is a primary force driving the development of *ex situ* genetic resources for noble fir throughout its range, for western hemlock in the Coast Range, and for ponderosa pine in limited breeding zones. Their genetic resources sampled in first-generation progeny tests are considerable.

Selections in progeny tests are valuable not only because they enable forward selection for advanced generations of breeding but also because they provide for rapid screening of new, important economic or ecological traits (such as disease resistance). For western hemlock, the best first-generation selections will comprise the breeding population of the second generation, accessible for at least several more decades. Individual programs will determine the fate of the poorer first-generation hemlock selections, noble fir, and ponderosa pine selections. Also, while some programs may question whether to continue to maintain test sites after obtaining growth and yield data, such programs may wish to consider the benefits of holding on to the test sites for the purpose of gene conservation.

Seed orchards represent a large proportion of the genetic variation found in the first-generation progeny tests for western hemlock and noble fir. There are several ponderosa pine seed orchard blocks, however, with no associated progeny tests. Seed procurement, not genetic gain, was a driving force behind the establishment of these *ex situ* genetic resources. Similarly, all seed orchards for western redcedar in the region, established to produce outcross seed, contain untested selections.

Most regional *ex situ* genetic resources for western white and sugar pine (excluding seed stores) display some resistance to white pine blister rust, which is devastating many natural populations in the study area. Continued genetic testing for rust resistance and conserving resistant selections may be essential to the long-term survival and evolution of western white and sugar pine.

Most of the *ex situ* genetic resources for Sitka spruce was established to test for resistance to white pine weevil. The weevil has limited impact on genetic variation in natural populations but restricts the use of Sitka spruce in commercial forestry. No known resistant selections from Oregon and Washington were identified. Additional testing coupled with the establishment of resistant selection in seed orchards is required for the species to regain commercial importance.

The extent of the *ex situ* genetic resources in seed stores greatly differs among species in the region. They are extensive for noble fir, ponderosa pine, western white pine, and sugar pine but are limited for western hemlock, western redcedar, and Sitka spruce. The long-term viability of this seed under its present storage conditions is questionable, and the usefulness of it for gene conservation is therefore uncertain.

Finally, Europe has extensive *ex situ* genetic resources for noble fir and Sitka spruce, which can potentially prove useful to landowners in Oregon and Washington.

## Acknowledgments

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## English Equivalents

| When you know: | Multiply by: | To find: |
|---|---|---|
| Centimeters (cm) | 0.39 | Inches |
| Meters (m) | 3.28 | Feet |
| Square meters ($m^2$) | 1.20 | Square yards |
| Kilograms (kg) | 2.21 | Pounds |
| Grams (g) | 0.035 | Ounces |
| Hectares (ha) | 2.47 | Acres |
| Kilograms per hectare (kg/ha) | 0.89 | Pounds per acre |
| Liters (l) | 1.057 | Quarts |
| Celsius (°C) | 1.8 and add 32 | Fahrenheit |

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## Appendix

Names and addresses of contacts from the major organizations with *ex situ* genetic resources in western Oregon and Washington followed by contacts for individual species

| Organization | Name (phone number) | Address |
|---|---|---|
| **National Forest:** | | |
| Deschutes | John Young (541-383-5589) | Deschutes National Forest<br>1645 Highway 20 East<br>Bend, OR 97701<br>jryoung@fs.fed.us |
| Fremont | Paul Berrang (541-883-6714) | USDA Forest Service-Winema NF<br>2819 Dahlia<br>Klamath Falls, OR 97601<br>pberrang@fs.fed.us |
| Gifford Pinchot | David Doede (509-395-3389) | USDA Forest Service<br>Mount Adams Ranger District<br>Trout Lake, WA 98650<br>ddoede@fs.fed.us |
| Mount Baker-Snoqualmie | Carol Aubry (360-956-2361) | USDA Forest Service, Olympic NF<br>1835 Black Lake Blvd. SW<br>Olympia, WA 98512<br>caubry@fs.fed.us |
| Mount Hood | David Doede | See Gifford Pinchot NF |
| Okanogan | Tom DeSpain (509-684-7225) | USDA Forest Service, Colville NF<br>695 South Main<br>Colville, WA 99114<br>tdespain@fs.fed.us |
| Olympic | Carol Aubrey | See Mount Baker-Snoqualmie NF |
| Rogue River | Jim Hamlin (541-957-3374) | USDA Forest Service, Umpqua NF<br>PO Box 1008<br>Roseburg, OR 97470<br>jhamlin@fs.fed.us |
| Siskiyou | Jim Hamlin | See Rogue River NF |
| Siuslaw | David Doede | See Gifford Pinchot NF |
| Umpqua | Jim Hamlin | See Rogue River NF |
| Wenatchee | Carol Aubrey | See Mount Baker-Snoqualmie NF |
| Willamette | Jim Hamlin | See Rogue River NF |
| Winema | Paul Berrang | See Fremont NF |

| | | |
|---|---|---|
| PNW Research Station | Randy Johnson (541-750-7290)<br>J. Brad St. Clair (541-750-7294) | PNW Research Station<br>3200 SW Jefferson Way<br>Corvallis, OR 97331<br>randyjohnson@fs.fed.us<br>bstclair@fs.fed.us |
| Dorena Genetic Resource Center | Richard Sniezko<br>Jude Danielson<br>(541-942-5526) | Dorena Tree Improvement Center<br>34963 Shoreview Road<br>Cottage Grove, OR 97424<br>rsniezko@fs.fed.us<br>jdanielson@fs.fed.us |
| **BLM District:** | | |
| Coos Bay | Alan England<br>(541-756-0100) | BLM Coos Bay District<br>1300 Airport Lane<br>North Bend, OR 97459<br>aengland@or.blm.gov |
| Eugene | Rich Kelly<br>(541-683-6405) | BLM Eugene District<br>PO Box 10226)<br>Eugene, OR 97440<br>rkelly@or.blm.gov |
| Medford | Jim Langhoff<br>(541-618-2345) | BLM Medford District<br>3040 Biddle Road<br>Medford, OR 97504<br>Jim_Langhoff@blm.gov |
| Roseburg | Rod Stevens<br>(541-440-4930) | BLM Roseburg District<br>777 NW Garden Valley Blvd.<br>Roseburg, OR 97470<br>Rod_Stevens@blm.gov |
| Salem | Bob Ohrn<br>(541-375-5646) | BLM Salem District<br>1717 Fabry Road SE<br>Salem, OR 97306<br>bohrn@or.blm.gov |
| **Other organizations:** | | |
| Boise Cascade | Phil Cannon<br>(208-384-6522) | Boise Cascade Corp.<br>PO Box 50<br>Boise, ID 83728<br>Phil_Cannon@bc.com |
| Confederated Tribes of Warm Springs | Larry Hansen<br>(541-553-2416) | Confederated Tribes of the Warm Springs Reservation of Oregon<br>Branch of Forestry<br>Warm Springs, OR 97761 |

| | | |
|---|---|---|
| Oregon Department of Forestry | Bill Voelker<br>(503-945-7369) | Oregon Department of Forestry<br>2600 State Street<br>Salem, OR 97310<br>bvoelker@odf.state.or.us |
| Plum Creek Timber Company | Loren Hiner<br>(509-649-2166) | Plumb Creek Timber Company<br>PO Box 51<br>Roslyn, WA 98941<br>lhiner@plumcreek.com |
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| The Timber Company | Jim Smith<br>(541-42-5516) | The Timber Company<br>PO Box 1059<br>Cottage Grove, OR 97424<br>jim_smith@ttcmail.com |
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| Weyerhaeuser Company | Christine Dean<br>(253-24-6892) | Weyerhaeuser Technology Center WTC-1A3<br>32901 Weyerhaeuser Way South<br>Federal Way, WA 98003<br>deanc@wdni.com |
| Willamette Industries | Greg Johnson<br>(541-24-5264) | Willamette Industries, Inc.<br>PO Box 907<br>Albany, OR 97321<br>gjohnson@wii.com |

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**Western redcedar**

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**Noble fir**

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| **Ponderosa pine** | | |
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| **Sitka spruce** | | |
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