



United States  
Department  
of Agriculture

Forest Service

Rocky Mountain  
Research Station

Proceedings  
RMRS-P-32

May 2004



# Breeding and Genetic Resources of Five- Needle Pines:

## Growth, Adaptability, and Pest Resistance

IUFRO Working Party 2.02.15  
International Conference  
Medford, Oregon, USA  
July 23-27, 2001



## Abstract

Snieszko, Richard A.; Samman, Safiya; Schlarbaum, Scott E.; Kriebel, Howard B. eds. 2004. **Breeding and genetic resources of five-needle pines: growth, adaptability, and pest resistance**; 2001 July 23-27; Medford, OR, USA. IUFRO Working Party 2.02.15. Proceedings RMRS-P-32. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 259 p.

This volume presents 29 overview and research papers on the breeding, genetic variation, genecology, gene conservation, and pest resistance of five-needle pines (*Pinus* L. subgenus *Strobus* Lemm.) from throughout the world. Overview papers provide information on past and present research as well as future needs for research on white pines from North America, Europe, and Asia. Research papers, more narrowly focused, cover various aspects of genetics. Throughout the distribution of five-needle pines, but particularly in many of the nine North American species, the pathogen *Cronartium ribicola* J.C. Fisch. continues to cause high levels of mortality and threatens ecosystems and plantations. Studies on genetic resistance to *C. ribicola* are described in papers from different regions of the world. Use of *P. strobus* as an exotic species in Europe and Russia and corresponding problems with white pine blister rust are discussed in several papers. Other papers focus on examining and exploiting patterns of genetic variation of different species.

**Key words:** five-needle pines, white pines, *Cronartium ribicola*, genetic variation, conservation, restoration

### ***Pinus* L. Subgenus *Strobus* Lemm. Species**

Classification of the species as used in these proceedings follows: Price, R.A., A. Liston, and S.H. Strauss. 1998. Phylogeny and systematics of *Pinus*. In Richardson, D.M. (ed.), *Ecology and Biogeography of Pinus*. Cambridge University Press. p. 49-68.

#### **Section *Strobus*, Subsection *Strobi* Loud.**

- P. armandii* Franchet. Armand pine
- P. ayacahuite* Ehrenberg ex. Schlechtendahl. Mexican white pine
- P. bhutanica* Grierson, Long & Page. (no English common name)
- P. chiapensis* (Martinez) Andresen. (formerly *P. strobus* var. *chiapensis*) Mexican white pine
- P. dabeshanensis* (formerly syn. for *P. armandii*; now separate species)
- P. dalatensis* de Ferré (Vietnamese common names only)
- P. fenzeliana* Handel-Mazzetti (Vietnam; no English common name)
- P. flexilis* James. Limber pine
- P. lambertiana* Douglas. Sugar pine
- P. monticola* Douglas ex. D. Don. Western white pine
- P. morrisonicola* Hayata. Taiwan white pine
- P. parviflora* Siebold & Zuccarini. Japanese white pine
- P. peuce* Grisebach. Macedonian pine; Balkan pine
- P. strobiformis* Engelm. Southwestern white pine
- P. strobus* Linnaeus. Eastern white pine
- P. wallichiana* A.B. Jackson (syn. *P. griffithii* McClelland). Blue pine; Himalayan white pine
- P. wangii* Hu & Cheng. (no English common name)

#### **Section *Strobus*, Subsection *Cembrae* Loud.**

- P. albicaulis* Engelm. Whitebark pine
- P. cembra* Linnaeus. Swiss stone pine; Arolla pine
- P. koraiensis* Siebold & Zuccarini. Korean pine
- P. pumila* von Regel. Japanese stone pine
- P. sibirica* du Tour. Siberian stone pine

#### **Section *Parrya* Mayr, Subsection *Balfourianae* Engelm.**

- P. aristata* Engelm. Rocky Mountain bristlecone pine
- P. balfouriana* Greville & Balfour. Foxtail pine
- P. longaeva* D.K. Bailey. Great Basin bristlecone pine

# **Breeding and Genetic Resources of Five-Needle Pines: Growth, Adaptability, and Pest Resistance**

**Proceedings of the  
IUFRO Five-Needle Pines Working Party Conference  
July 23-27, 2001  
Medford, Oregon, USA**

## **Organizing Committee**

Richard A. Sniezko, USDA Forest Service, Chair  
Scott E. Schlarbaum, University of Tennessee  
Howard B. Kriebel, Ohio State University (retired)  
Safiya Samman, USDA Forest Service  
Harvey Koester, USDI Bureau of Land Management  
Joseph Linn, USDA Forest Service

## **Sponsors**

International Union of Forest Research Organizations (IUFRO)  
U.S. Department of Agriculture, Forest Service  
U.S. Department of the Interior, Bureau of Land Management  
University of Tennessee  
Washington Department of Natural Resources  
Oregon Department of Forestry  
U.S. Department of the Interior, Crater Lake National Park  
Sierra Pacific Industries  
Inland Empire Tree Improvement Cooperative (IETIC)  
White Pine Working Group (IETIC)  
Forest Renewal BC

IUFRO Working Party 2.02.15





## Preface

An international conference on breeding and genetic resources of the five-needle pines took place in southwestern Oregon, USA, July 23-27, 2001. The scope was worldwide, including 25 species of subgenus *Strobus* found in North and Central America, Europe, and Asia. The conference was held under the auspices of Working Unit 2.02.15 of the International Union of Forest Research Organizations (IRFRO), with the support of the USDA Forest Service and several other forestry organizations. The goals of the conference were to review available knowledge from research on the genetics and genetic resources of this diverse group of pines, and to report current research on genetic diversity and natural hybridization and on the genetics of growth, adaptability, pest resistance, and other traits of interest in applied tree genetics and gene resource conservation.

The five-needle pines are nearly all in three sections of Subgenus *Strobus*. Although there is no universal agreement on the systematics of the subgenus, we have chosen to adhere to the recent classification by Price and others (Richardson 1998), although new phylogenetic research results based on isozyme and molecular analysis do not fully concur with this arrangement. We include two sections, Section *Strobus* and Section *Parrya*, the latter including the foxtail and bristlecone pines, two groups quite different from the rest of the species, of interest for *in situ* conservation of species with an ecological role important in their habitat. Most genetic research to date has been conducted within Subsections *Strobi* and *Cembrae* of Section *Strobus*. Until recently, the greatest attention was given to the approximately 17 species of Subsection *Strobi*, which includes several species of great importance as timber trees, many of which are capable of interspecific hybridization. More recently, research in Subsection *Cembrae*, especially in Siberia, has been focused on genetic diversity and natural hybridization. In addition to two important timber species, this subsection has some species that, although slow-growing, have great importance in horticulture and watershed protection.

The conference had 53 participants from nine countries, including the USA, Canada, Germany, Romania, Bulgaria, Russia, Pakistan, China, and South Korea. Papers were also contributed by nonattending scientists in Japan, Austria, New Zealand, and Russia. Because of the worldwide natural distribution of the five-needle pines, overview papers were invited covering the regions where five-needle pines are of major importance from a forestry standpoint. The exception was the Mexico/Central America region, from which we were unable to secure scientist participation. Research papers addressed genetics and genecology, blister rust resistance, breeding and propagation, genetic diversity, and gene conservation. In addition to paper sessions, the conference, held in Medford, Oregon, included excursions to seed orchards, research plantations, native stands, Crater Lake National Park, and the Dorena Genetic Resource Center of the USDA Forest Service. Indigenous species of five-needle pines included in the field trips were *P. monticola*, *P. lambertiana* and *P. albicaulis*.

In Subsection *Strobi*, the white pine blister rust (*Cronartium ribicola*) is the major target of applied research, with the goal of removing this obstacle to survival and growth of natural and artificial stands, especially of sugar pine, western white pine, and eastern white pine. Resistance screening and breeding are proving to be effective strategies for restoring susceptible western North American species of five-needle pines. In eastern North America, rust resistance breeding has been more difficult in eastern white pine, although screening and breeding continues in the USA and Canada. In Europe, *P. strobus* would be a premier species for forestry were it not for the blister rust, which is a serious problem throughout the region, including Russia. For this reason other species are employed in forest planting.

The Balkan or Macedonian white pine has a dual role in the Balkans, critical for watershed protection and to a lesser degree as a timber species. Provenance research has shown that geographic variation in *P. peuce* can be exploited to some extent for optimum productivity, and population research has facilitated gene conservation. The blue or Himalayan pine, *P. wallichiana*, is an important timber tree, especially in India and Pakistan; its wide geographic and altitudinal range requires much more research on population variation and gene diversity for effective conservation of genetic resources. This will only be possible through regional cooperation with support from international organizations.

Subsection *Cembrae* includes several cold-climate and high-elevation five-needle pines of Eurasia and western North America. Research on the phylogenetics of the Siberian stone pines (*P. sibirica* and *P. pumila*) and *P. parviflora* indicates that the current partitioning of Subsections *Strobi* and *Cembrae* needs revision. Research on within-species genetic diversity in Siberia shows that there are relatively low interpopulation differences within the stone pines, and that natural hybridization occurs between the species. Korean pine also has small genetic distances between populations, even over a wide area; the main diversity occurs within populations. All of these species are nut pines, related to the North

American *P. albicaulis*. The interconnection between subsections is shown by the similarity of ecological role between the high elevation species limber pine, the pines of Subsection *Cembrae*, and the Rocky Mountain bristlecone pine (*P. aristata*), all of which occupy and stabilize habitats not likely to be occupied by other, less tolerant tree species. They are for the most part, less susceptible to blister rust, some much less, than is *P. albicaulis*.

These are but a few of the many findings of recent research brought out in the conference. The extensive worldwide distribution of the five-needle pines, their varied and critical ecological roles in the plant and animal diversity of the world's forest ecosystems, and their aesthetic and economic importance to human society are all indicators of the need for continued worldwide research on these important forest trees. We look forward to continued cooperation and information exchange in the future.

**Howard Kriebel**  
Medford, New Jersey, USA  
June 13, 2003

## Acknowledgments

The impetus for this volume came from the IUFRO Five-Needle Pine Breeding and Genetic Resources Working Party international conference that was held at the IUFRO XX World Congress in Tampere, Finland, in 1995. Many people and organizations facilitated the planning and undertaking of this conference and the subsequent compilation of this volume. We wish to thank the USDA Forest Service (FS - the International Forestry, Research, and Forest Health groups from the Washington Office as well as the Region 6 Genetics group all provided vital contributions) and USDI Bureau of Land Management (BLM) which served as local hosts for the meeting and field excursions. Thanks to Regional Geneticist Sheila Martinson for opening remarks and support. Along with the editors, Harvey Koester and Joe Linn helped coordinate local arrangements. Many people contributed to success of the meeting including Andy Bower, Jeremy Kaufman, Jeremy Pinto, Bob Danchok, Sally Long, Ryan Berdeen, Laura Berdeen, Jerry Berdeen and Clinton Armstrong from Dorena Genetic Resource Center, Umpqua National Forest (FS); Tom Atzet and Don Goheen (FS); Liang Hsin, Terry Tuttle, Gordon Lyford, Tammy Jebb, Larry Price, Bill Robinson, and Dennis Pyle from BLM; Joel King and the staff (including Smokey Bear) at Prospect Ranger District, Rogue River National Forest. We thank Mike Cloughesy, Cindy Wardles, and Nathalie Gitt of the Forestry Outreach Education office at Oregon State University for support in planning and logistics, and external reviewers S. Aitken, P. Berrang, J. Dunlap, J. Hamlin, R. Hunt, R. Johnson, A. Kegley, B. Kinloch, J. King, S. Kolpak, S. Martinson, D. Oline, and P. Zambino for their technical reviews of the papers. We specifically acknowledge Konstantin Krutovskii (FS) for facilitating communication with Russian scientists and assistance with Russian manuscripts.

The sponsors of the conference and this volume include IUFRO, USDA Forest Service, USDI BLM, Crater Lake National Park, Oregon Department of Forestry, Washington Department of Natural Resources, The University of Tennessee, Inland Empire Tree Improvement Cooperative (IETIC), White Pine Working Group (IETIC), Sierra Pacific Industries, and Forest Renewal BC (British Columbia); this array of sponsors allowed us to invite speakers from throughout the world. The hospitality shown by both the conference hotel (Rogue Regency Inn in Medford), and the town of Jacksonville was truly outstanding. The conference banquet hosted by Dennis and Mary Ann Ramsden in the gardens of the McCully House Inn in Jacksonville on a beautiful southern Oregon evening was truly superb.

We thank all participants of the conference and all authors of papers. A special thanks to Angelia Kegley (Dorena Genetic Resource Center) who was invaluable with many phases from conference planning to publication. We thank Louise Kingsbury (FS) and her staff at Rocky Mountain Research Station Publishing Services for their patience and for preparing the final publication and the RMRS for distribution of this volume.

# Contents

	Page
Preface .....	iii
Acknowledgments .....	iv
<b>Part I: Regional Overview Papers</b> .....	<b>1</b>
G. Daoust J. Beaulieu	Genetics, Breeding, Improvement and Conservation of <i>Pinus strobus</i> in Canada ..... 3
John N. King Richard S. Hunt	Five Needle Pines in British Columbia, Canada: Past, Present and Future ..... 12
Howard B. Kriebel	Genetics and Breeding of Five-Needle Pines in the Eastern United States ..... 20
Geral McDonald Paul Zambino Richard Snieszko	Breeding Rust-Resistant Five-Needle Pines in the Western United States: Lessons from the Past and a Look to the Future ..... 28
Ioan Blada Flaviu Popescu	Genetic Research and Development of Five-Needle Pines ( <i>Pinus</i> subgenus <i>Strobus</i> ) in Europe: An Overview ..... 51
Alexander H. Alexandrov Roumen Dobrev Hristo Tsakov	Genetic and Conservation Research on <i>Pinus peuce</i> in Bulgaria ..... 61
Anatoly I. Iroshnikov Dmitri V. Politov	Five-Needle Pines in Russia: Introduction and Breeding ..... 64
Huoran Wang Jusheng Hong	Genetic Resources, Tree Improvement and Gene Conservation of Five-Needle Pines in East Asia ..... 73
Shams R. Khan	Genetic Variation in Blue Pine and Applications for Tree Improvement in Pakistan, Europe and North America ..... 79
<b>Part II: Genetics, Genecology, and Breeding</b> .....	<b>83</b>
Dmitri V. Politov Konstantin Krutovsky	Phylogenetics, Genogeography and Hybridization of Five-Needle Pines in Russia and Neighboring Countries ..... 85
Bruno Richard Stephan	Studies of Genetic Variation with Five-Needle Pines in Germany ..... 98
Jay H. Kitzmiller	Adaptive Genetic Variation in Sugar Pine ..... 103
A.W. Schoettle	Ecological Roles of Five-Needle Pines in Colorado: Potential Consequences of Their Loss ..... 124
Raphael Thomas Klumpp Marcus Stefsky	Genetic Variation of <i>Pinus cembra</i> Along an Elevational Transect in Austria ..... 136
J.T. Miller F.B. Knowles R.D. Burdon	Five-Needle Pines in New Zealand: Plantings and Experience ..... 141

	Page
Kwan-Soo Woo Lauren Fins Gerald I. McDonald	Genetic and Environmentally Related Variation in Needle Morphology of Blister Rust Resistant and Nonresistant <i>Pinus monticola</i> ..... 148
Andrew D. Bower Richard A. Sniezko	Eight-Year Growth and Survival of a Western White Pine Evaluation Plantation in the Southwestern Oregon Cascades ..... 154
Danilo D. Fernando John N. Owens	Development of an In Vitro Technology for White Pine Blister Rust Resistance ..... 163
Sergej N. Goroshkevich	Natural Hybridization between Russian Stone Pine ( <i>Pinus siberica</i> ) and Japanese Stone Pine ( <i>Pinus pumila</i> ) ..... 169
Wan-Yong Choi Kyu-Suk Kang Sang-Urk Han Seong-Doo Hur	Estimation of Heritabilities and Clonal Contribution Based on the Flowering Assessment in Two Clone Banks of <i>Pinus koraiensis</i> Sieb et Zucc. .... 172
<b>Part III: Genetic Diversity and Conservation</b> .....	<b>179</b>
M.F. Mahalovich G. A. Dickerson	Whitebark Pine Genetic Restoration Program for the Intermountain West (United States) ..... 181
Sei-ichi Kanetani Takayuki Kawahara Ayako Kanazashi Hiroshi Yoshimaru	Diversity and Conservation of Genetic Resources of an Endangered Five-Needle Pine Species, <i>Pinus armandii</i> Franch. var. <i>amamiana</i> (Koidz.) Hatusima ..... 188
Vladimir Potenko	Genetic Diversity and Mating System of Korean Pine in Russia ..... 192
<b>Part IV: White Pine Blister Rust Resistance</b> .....	<b>201</b>
R.A. Sniezko A.D. Bower A.J. Kegley	Variation in <i>Cronartium ribicola</i> Field Resistance Among 13 <i>Pinus monticola</i> and 12 <i>P. lambertiana</i> Families: Early Results from Happy Camp ..... 203
A.J. Kegley R.A. Sniezko	Variation in Blister Rust Resistance Among 226 <i>Pinus monticola</i> and 217 <i>P. lambertiana</i> Seedling Families in the Pacific Northwest ..... 209
R.S. Hunt G.D. Jensen A.K. M. Ekramoddoullah	Confirmation of Dominant Gene Resistance (Cr2) in U.S. White Pine Selections to White Pine Blister Rust Growing in British Columbia ..... 227
Ioan Blada Flaviu Popescu	Age Trends in Genetic Parameters of Blister Rust Resistance and Height Growth in a <i>Pinus strobus</i> x <i>P. peuce</i> F1 hybrid population ..... 230
Richard A. Sniezko Bohun B. Kinloch Jr. Andrew D. Bower Robert S. Danchok Joseph M. Linn Angelia J. Kegley	Field Resistance to <i>Cronartium ribicola</i> in Full-Sib Families of <i>Pinus monticola</i> in Oregon ..... 243
Kwan-Soo Woo Gerald I. McDonald Lauren Fins	Influence of Seedling Physiology on Expression of Blister Rust Resistance in Needles of Western White Pine ..... 250
<b>Part V: Conference Attendees</b> .....	<b>255</b>
	Conference Attendees ..... 257

**Part I: Regional  
Overview Papers**

**Part II: Genetics,  
Genecology, and  
Breeding**

**Part III: Genetic Diversity  
and Conservation**

**Part IV: White Pine Blister  
Rust Resistance**

**Part V: Conference Attendees**



# Part I: Regional Overview Papers



***P. balfouriana* (foxtail pine), *Pinus aristata* (Rocky Mountain bristlecone pine) and *P. flexilis* (limber pine)**

*P. aristata* and *P. flexilis* photos courtesy of A. Schoettle

*P. balfouriana* photo courtesy of D. Burton

