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Jean-Charles Bastien

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BREEDING OF INTRODUCED TO EUROPE FOREST
TREE SPECIES**





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Table of contents

- 2 Editorial
Monika Konnert, Paraskevi Alizoti
- 3 *Abies grandis*
Jean Charles Bastien
- 6 *Cedrus atlantica and Cedrus libani*
Monika Konnert
- 9 *Juglans nigra*
Marcela van Loo
- 13 *Larix kaempferi and Larix x eurolepis*
Georg von Wühlisch
- 16 *Picea sitchensis*
Georg von Wühlisch
- 20 *Pinus contorta*
Bo Karlsoon, Johan Kroon
- 25 *Pinus strobus*
Paraskevi Alizoti
- 30 *Pseudotsuga menziesii*
Monika Konnert
- 36 *Quercus rubra*
Marjana Westergren
- 40 *Robinia pseudoacacia*
Marcela van Loo, Renata
Milcevicova, Marjana Westergren



Abies grandis

Jean Charles Bastien

INRA - Centre Val de Loire, 2163 Avenue de la Pomme de Pin, CS 40001 ARDON
45075 ORLEANS Cedex 2, France

Natural distribution range

Grand fir (*Abies grandis* (Douglas ex D. Don) Lindley) grows naturally in northwestern United States and southern British Columbia (Canada), while its geographical distribution ranges from latitude 51° to 39° N. and from longitude 125° to 114° W. Its coastal range stretches along the Pacific coast from southern British Columbia to Northern California. Its continental range extends in eastern Washington and Oregon, northern Idaho and western Montana. Grand fir grows generally on acid, rich and deep soils, and on a variety of sites with a mean annual precipitation range from 360 mm (eastern Oregon) to 2500 mm (western Washington). Depending on the site, growing season can vary from 3 months (Idaho) up to 8 months (California).

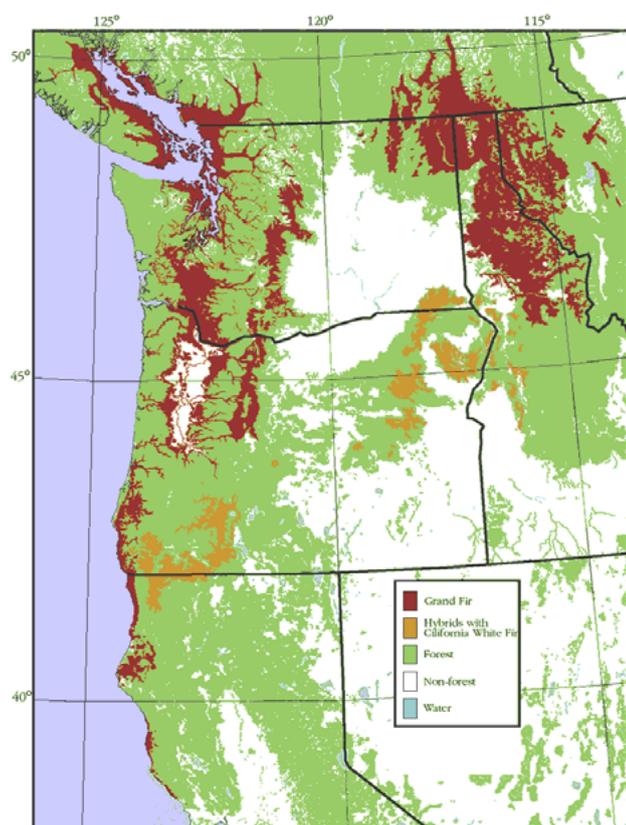


Figure 1. *Abies grandis* natural range (in dark brown)
[Source: Van Pelt (2002)]

Grand fir intercrosses with both varieties of white fir, i.e. *Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr. and *Abies lowiana* (Gordon & Glend.) A. Murray, considered as a variety of *Abies concolor* (Steinhoff, 1978). Introgression zones between grand fir and the two white fir varieties are recognized in northern California through southwestern Oregon and through the Oregon Cascade Range into northeastern Oregon and west-central Idaho (Steinhoff, 1978).

Genetic Variation

a. Adaptive genetic variation

Results of breeding efforts within the species natural range

In its natural range, *Abies grandis*, as well as other firs, is considered as a minor forest species compared to more predominant species like *Pseudotsuga menziesii*, *Pinus contorta*, or *Picea sitchensis*. It is generally planted for ecological reasons or to foster stand resilience through species richness. Based on the literature, there is virtually no breeding activity on Grand fir.

In USA, a Grand fir private seed orchard from coastal origin has been reported (Cress and Daniels – 1990: Simpson timber seed orchard – Shelton – alt. 90 m). This seedling seed orchard has been planted on 5 acres (about 2 ha) in 1978. In Idaho, the Inland Empire Christmas Tree Association (IECTA) runs a small Grand fir seed orchard (19 trees - 40 years old) near Sandpoint, ID.

In British Columbia (Canada) the forest genetics program for *Abies grandis* focuses on provenance testing, aiming towards testing seedlings originating from sources across the species' range in different sites and environmental conditions. Periodically, these trials are measured to evaluate Grand fir's level of adaptation at the various test sites. Results have been of value to produce seed transfer guidelines for the tested provenances. Fast

growing populations were also being identified and effects of climate change on the species could be predicted. Moreover, superior trees of coastal and interior origins have been grafted for gene conservation purposes, as well as for potential non recognized till now uses (Woods 2014).

Results of breeding efforts in Europe

In Europe, most of the knowledge on *Abies grandis* genetic variability is based on the research carried out in the framework of the IUFRO network of provenance trials (41 seed lots collected in 1976 over the whole natural distribution range). Results for three major traits (frost resistance, growth and wood density) are summarized below:

- **Frost resistance:**

In a provenance test planted at 800 m elevation in Poland, Dolnicki and Kraj (1998) was observed that *Abies grandis* provenances exhibited weaker frost fall hardiness than *Abies alba*. However, only two provenances of the species were characterized by similarly high hardiness; namely the eastern Oregon (elev. 1400 m) and the western Washington (elev. 825 m) ones.

Based on results obtained from one year old grand fir seedlings, Larsen and Ruetz (1980) reported that their frost resistance (early, winter and late frost) increased with the increase of the distance of their place of origin from the coast. The most inland provenances were also the last to bud burst. In the specific trial the Oregon provenances proved to be less frost resistant than the Washington ones. Elevation alone had no significant influence on the frost resistance.

- **Growth Traits:**

Based on measurements carried out in 18 *Abies grandis* provenance tests in central and northern Germany, Rau et al. (2008) and Kleinschmit et al. (1996) showed that for height and volume the fastest growing provenances originated from low to mean elevations in the Pudget Sound area, from the Vancouver Island, from southern Washington west of the Cascades and from northern Oregon. Nearly all central and southern Oregon provenances were growing slowly. A significant positive correlation of growth traits with latitude was recorded. Mean volume differences between provenances ranged among 30% to 176%. An overall ranking including height, diameter, and losses showed that 7 Washington provenances, 3 British Columbia provenances and 1 Oregon provenance surpassed the overall mean by at least 10%. These results are also supported by the findings reported later on by König (2007), Kulej and Socha (2008) and Kulej (2010).

In Great Britain, Samuel (1996) tested the growth of different seed lots of *Abies grandis* originating from 36 locations, that were representing almost all the natural range of the species. Performance was evaluated in 10 experimental sites, 15 years after planting, by measuring height and breast height diameter. Provenances from northern coastal Washington performed better, followed by provenances from British Columbia (Canada) and southern coastal Oregon. Washington provenances Louella (1005) and Elma (1003) outperformed all other provenances in most of the test sites. Similar results were obtained by Kranenborg (1995) in the Netherlands, Vancura and Veran (1995) in Czech Republic and Bastien (1995) in France.

- **Wood density:**

Polge (1968) compared the tree ring width and the within ring density of 3 years old seedlings that represented 25 *Abies grandis* provenances. The results of this study raised the interest on using the percentage of summer wood to discriminate populations of the species. Percentage of summer wood of continental (interior) provenances ranged among 75 to 80%, whereas, for the coastal or French land races, the percentage ranged among 62 to 73%.

In a provenance test planted in France, Bastien (1995) observed that at the age of 19 years a strong and unfavorable relationship existed between diameter growth and wood density. However, four fast growing provenances, all originating from the northern part of the Puget Sound in Washington State, broke this type of correlation, exhibiting fast growth and comparatively higher wood density. This observation was also supported by the findings of Samuel (1998).

b. Neutral genetic variation

To our knowledge only the publication of Konnert and Ruetz (1996) - reported results on the differentiation of *Abies grandis* based on genetic markers. Genetic analysis of 9 isozyme loci was carried out to investigate the genetic structure of 11 *Abies grandis* sources, out of which 9 were populations tested in a 17 years old field trial and 2 were commercial seed collections. Pronounced differences were identified among the different sources for the polymorphic gene loci Idh-B and Pgm-A. When all gene loci were jointly considered there was a clear regional differentiation between provenances from Washington/British Columbia and western Oregon, while the northern provenances had higher genetic diversity and heterozygosity. The provenance Post (1450 m) from central Oregon (Interior) exhibited by far the highest genetic variability together with a very specific genetic structure and thus, it could not be assigned to any one of the two regional groups.

Natural regeneration in Europe

In its natural range, Grand fir regenerates satisfactorily on most sites after overstory's removal to encourage rapid growth in height and diameter.

In a monograph on *Abies grandis*, Konnert and Ruetz (2009) reported that due its shade tolerance, the natural regeneration of the species is feasible in Germany, as long as there is a good weed and understory control.

In an experiment undertaken in Wykeham forest in North England to monitor the effect of enrichment planting with 25 different species to increase the productivity of a first rotation stand of *Pinus sylvestris*, a number of *Abies* species was included (*A. grandis*, *A. procera*, *A. concolor*, *A. nordmanniana*, and *A. veitchii*). Mason (2012) reported that 10 years after the process of transforming the even-aged stands to irregularly structured ones only *Abies procera*, *Abies grandis* and *Abies veitchii* have successfully contributed to the development of the enriched *Pinus sylvestris* stand. The natural regeneration cohort was dominated by *Abies* species which were 65% of seedlings and saplings in the thinned plot and 97% in the unthinned plot, while in the thinned plot both seedlings and saplings were present in nearly equal proportions and *Abies* species comprised over 60 per cent in each category.

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