

# Genetic Variation in Blue Pine and Applications for Tree Improvement in Pakistan, Europe and North America

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**Abstract**—Stands of blue pine (*P. wallichiana* A.B. Jacks. syn. *P. griffithii* McClelland) are highly diverse throughout its range of distribution in the Himalayan Mountains where the species grows under varying geographic, climatic, and edaphic conditions. The species occurs in two distinctly different ecotypes (mesic monsoon and dry nonmonsoon), and strict avoidance of germplasm transfer between the ecotypes is necessary for survival and productivity in Pakistan, India, and Nepal. The role of these ecotypes in enhancing productivity and in establishing large-scale plantations resistant to blister rust is presented and compared with plantations in India and Bhutan. An alternate management strategy to establishing a pure species stand is to interplant with other native conifers. Testing of blue pine in other countries is discussed, notably the superior performance of blue pine hybrids in the USA at specific sites, which indicates its breeding value as a parent for volume growth rate. In Germany and Japan, the species does not appear to be useful for forest plantations. Further international cooperation in testing of blue pine for rust resistance is proposed, given the variable resistance to blister rust within the species. Research needs to be conducted, especially in neighboring countries, to further assess the extent, nature, and pattern of geographic variability.

**Key words:** genetic diversity, blue pine, Himalayan pine, *P. wallichiana*, blister rust, pine hybrids, ecotypes

## Introduction

Blue pine (*Pinus wallichiana*) is a highly variable species that occurs in the mountainous region of lower Asia. Natural stands of blue pine, generally known outside of southern Asia as Himalayan pine, are distributed in Afghanistan, Pakistan, India, Nepal, Bhutan, Tibet, China, and Burma. The species spans a longitudinal range between 68° and 100° E, a latitudinal range between 25° and 37° N, and an altitudinal range between 1,500 and 3,800 m (Critchfield and Little 1966, Khan, 1986). In the Himalayan Mountains, blue pine occurs under two rainfall regimes, within and outside the monsoon region. Dogra (1972) and Ahsan and

Khan (1972), along with several earlier investigators including Brandis (1906), Osmaston (1927), and Shebbeare (1934), have recognized this variable site distribution of the species occurring in several countries of the region. Pure and mixed patches at varying altitudes are found, but the species grows well at an optimum elevation of 2,000-2,500 M. Although this pine occurs over a wide altitudinal range, there is no evidence of altitudinal races that could be given subspecific or specific taxonomic ranking.

This species has been known by a number of scientific names since first described. The taxonomy of blue pine has been a subject of controversy, probably corresponding to the diversity in the species on the wide range of ecotypes where it occurs. The older scientific names of blue pine were *P. excelsa* Wall. ex Lamb. (1824), *P. chylla* Lodd. (1836), *P. nepalensis* De Chambr. (1845), *P. griffithii* McClelland (1854), and *P. dicksonii* Hort. ex Carriere (1855). *Pinus griffithii* persisted in international botanical acceptance until the mid-twentieth century (Rehder 1940, Little and Critchfield 1969), and in China it is still the accepted taxonomic name (Wang, pers. comm.). Elsewhere, *P. wallichiana* A.B. Jacks. (1938) is the latest revision and is now the internationally accepted name (see citation in the list of five-needle pine species in this volume).

Although ecotypic variation has been observed (Khan 1986, 1994, 1995a), no detailed taxonomic studies of blue pine have been made at the ecotypic level. Patschke (1913), Wilson (1916), Kew Bulletin (1938), Dallimore and Jackson (1961), Ouden and Boom (1965) have mentioned varieties/forms of blue pine. Grierson and others (1980) reported “var. *parra*” as a blue pine variety. Critchfield and Little (1966) also made this distinction and described “var. *parra*” from Arunachal Pradesh (India) as the mesic monsoon zone ecotype of blue pine.

Blue pine has also been found to occur at high altitudes in low rainfall areas and at low altitudes (less than 2,800 m) in high rainfall areas (Khosla and Raina 1995). The soils of mesic habitat were found to be different from those of xeric sites in pH, maximum moisture holding capacity, and Ca and Mg concentrations throughout the species’ distribution in Pakistan (Khan 1986). There were also differences exhibited in the phenology of male and female flowers in the two distinct ecological zones of the species (Khan 1995b).

In view of the importance of geographic variability to any tree improvement program, provenance studies were undertaken in Nepal, India, Bhutan, and Pakistan. In Pakistan, the species has been extensively studied for genetic variability and timber utilization, as well as the species’ role in protection of the fragile ecosystems in the Himalayan Mountains. Such studies have further led to the delineation of

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seed zones with strict prohibition of transfer of germplasm between ecological zones (Khan 1991, 1994). Two geographic ecotypes were identified on the basis of differences in mean annual increment and growth in Pakistan, accounting for 56 percent of the variation among stands (Khan 1997, 2000). These two ecotypes also occur in India, Nepal, and Bhutan under similar geoclimatic conditions and consequently have similar ecological requirements and distribution patterns. The present paper outlines the extent to which genetic diversity in blue pine could be utilized for forest plantings in these countries.

## Genetic Research on Blue Pine in Pakistan

Pakistan has sampled the genetic variation in blue pine more extensively than has any of the other countries in a cooperative project with the USDA Forest Service. Detailed studies of genetic diversity and its utilization in the natural stands of blue pine in Pakistan were conducted in several phases during the past 25 years. Studies of 32 provenances sampled throughout its range of distribution in Pakistan were undertaken to assess genetic variation in several morphological and anatomical traits of the needles, cones, and seeds.

### Seed Movement

The potential for further genetic improvement in blue pine was shown by studies that showed evidence of ecotypic differentiation and suggested strict avoidance of transfer of germplasm from xeric to mesic habitat and vice versa (Khan 1991, 1994).

### Comparison of Blue Pine with Other Species

Paudel and others (1996) tested *P. patula* Schiede & Deppe ex Schlechtendal & Chamisso and blue pine in Nepal. Of these species, blue pine had better survival at age six. Wallace (1989) compared the growth of *P. strobus* L. and blue pine in eastern Nepal and observed little difference in survival, growth, and form. However, he suggested blue pine was a better species overall. Siddiqui and others (1989) explored variability in the wood characteristics of three forest tree species, including blue pine, and found marked differences in percentage of late wood, smaller tracheid dimensions, higher density, and better strength in wood of drier areas when compared to wood from moist areas. Ashley and Fisk (1980) tested 45 species in 15 trial plots and observed that blue pine growing well in Kathmandu Valley, Nepal. Of several exotic temperate pines tested in the past two decades, none seems to thrive better than native blue pine in Pakistan (Annual Progress Reports, Pakistan Forest Institute, Peshawar). The consensus from these reports is that exotic pines have little potential in large-scale plantations in the native habitat of blue pine.

## Interplanting Blue Pine to Increase Overall Yield

In Pakistan, interplanted mixtures of blue pine and other coniferous species in different stands have led to studies that identified the best combinations of associated conifers for high productivity, in addition to further quantifying genetic diversity in blue pine. Differences in mean annual increment between two species habitats were compared with those of the highly associated conifer *Cedrus deodara* (D. Don.) G. Don (Khan 1997, 2000). These studies suggest that blue pine should be planted as a monoculture in the xeric areas (less than  $750 \pm$  mm per annum), whereas it should be planted in mixtures with *C. deodara* in mesic habitats. Similar recommendations were also made by Khan (1979) for moist coniferous forests of northern Pakistan, although he did not report on the dry, nonmonsoon zone. Further research is under way on growth differences of the two ecotypes of blue pine in combination with other associated conifers, for example, *Abies pindrow* (Lamb.) Royle and *Picea smithiana* (Wall.) Boiss., to assess the possibility of improving productivity of mixed stand plantations in the Himalayan Mountains.

### Performance of Blue Pine as an Exotic Species

Blue pine has been tested for variation in growth rate and in breeding for blister rust resistance (*Cronartium ribicola* Fisch. ex Rabenh.) in a few countries of Asia, Europe, and the USA. Stephan (1974) observed differences in rust resistance between trees of two provenances of blue pine in Lower Saxony, Germany at age 11, although there was a high level of mortality in trees from both provenances. In a species comparison test, he found that only 40 percent of the blue pine seedlings were infected by blister rust compared with an infection rate of 100 percent in *P. strobus*, *P. monticola* Dougl. ex D. Don, and *P. flexilis* James (Stephan 1985). Borlea (1992) and Blada (1994) have also used blue pine in Romania in experimental breeding for growth and blister rust resistance. These authors found that blue pine has potential value for genetic improvement in rust resistance.

The growth and blister rust data recorded in Romania indicated that half-sib families from low rainfall areas in Pakistan were more resistant to blister rust at age 11, compared with those originating from high rainfall areas (Blada 1994). Blada reported a correlation between latitude and blister rust ( $r=0.66^{***}$ ), but could not include rainfall data of the native habitat in his studies, as they were in remote locations. To aid in interpretation of results, rainfall of the nearest meteorological station was included. Two of the most important phenomena affecting rainfall in the Himalayas, namely inversion of temperature and rainshadow effect, were also not taken into consideration, as no reliable data were available for such sites. In spite of these limitations, the moderately high correlation between blister rust and rainfall suggests the adaptive potential of the two ecotypes of this pine. The correlation would have been more reliable, however, if the annual rainfall data had been

included from the actual collection sites, as the distribution of rainfall is highly erratic in the Hindukush-Karakorum region. It was concluded that differences in the adaptation of the species to varying moisture regimes in its native habitat, along with morphological and phenological differences between the two ecotypes, might be casually associated with corresponding differences in resistance to blister rust in blue pine. These results, therefore, suggest that the selection of trees/stands for rust resistance should be primarily based upon the origin of seed lots of the native habitat of this pine.

Comparative studies on genetic diversity in natural stands for various traits and the degree of resistance involving blue pine and other five-needle pines have also been reported by Dogra (1972), Ahsan and Khan (1972), and Bakshi (1972). The comparative growth of blue pine as an exotic in Europe, USA and Canada has been studied by Gremmen (1972), Kriebel (1983), Heimburger (1972), and other scientists. These studies emphasized mass production of rust resistant stands through hybridization. However, this approach can be expensive, cumbersome and time-consuming and may not be practical for developing countries. A more feasible strategy would be to collect seed from the xeric habitat of the species range for mass production of desirable trees in Pakistan and Romania. Insufficient cold hardiness is a deterrent in the USA and Canada, where hybridization might be feasible. The authors cited agree that conventional intraspecific breeding may not be the best method due to long generation time, mode of pollination, highly diverse populations due to cross pollination, haploid nature of infecting rust and the presence of an alternate five-needle pine host(s).

A two-way seed exchange of plant material was conducted between Pakistan and the USA. This exchange was part of a worldwide program to test haploxyton pines for resistance to the white pine blister rust and to test other five-needle pine species in Pakistan. This project yielded useful information on the nature of resistance, growth potential of some white pines, inoculation techniques, and breeding schemes for mass production of resistant trees.

Garrett (1992) reported that Himalayan white pine was not resistant to the white pine weevil (*Pissodes strobi* Peck) and suggested that it should only be planted in weevil-free regions of the USA. However, the species has not performed well where tested in weevil-free regions (Ohio and Tennessee), and commercial planting cannot be recommended anywhere in the USA on the basis of present knowledge. In 20-year-old provenance tests in Ohio of trees from India, Pakistan, and Nepal, new terminal shoots on trees of all seed sources were repeatedly killed back by late spring frosts. No trees from Nepal survived the winter climate. Field testing of *P. strobus x wallichiana* hybrids in Ohio over two decades demonstrated superiority in wood volume growth over most *P. strobus* genetic selections (Kriebel 1983). The hybrids also have a higher wood specific gravity than *P. strobus* (Kriebel, pers. comm.). In Tennessee, initial survival of drought was very low (Schlarbaum, pers. comm.). Genys (1979) compared variability among 21 seedlings of blue pine originating from India, Pakistan, and Bhutan. Strains from Pakistan were hardier than those of other countries in Maryland. However, the performance of the species has not been satisfactory in Germany and Japan (Takahashi and others 1974, Stephan

1985). From these studies, it appears that blue pine as a hybrid parent has a potential for better growth and resistance against blister rust in the USA, but its performance in Europe and Asia has yet to be ascertained.

## Conclusions and Recommendations

Seed origin of blue pine is critical to survival, growth, and perhaps blister rust resistance. Two general ecotypes are known and careful attention should be paid to which ecotype is represented in a seed collection. Selections and collection of blue pine seed in native stands from trees growing near glaciers or river banks as well as from buffer zone should be avoided as these sites may represent atypical habitat in blue pine. Efforts should be made to include meteorological data from actual sites to minimize biased estimates derived from the nearest weather stations. Because of dysgenic selection in several countries of the Himalayan region, including Pakistan, the establishment of *in situ* conservation stands in the xeric habitat could assist in mass-producing desirable individuals resistant to blister rust. These efforts should be supported by further research on genetic diversity in this widespread and phenotypically variable species.

Research has shown that blue pine often thrives in planting of mixtures with other coniferous species in certain environments. Additional research should be conducted to better delineate the effects of mixture composition, blue pine genetics, and site variation to maximize productivity.

Establishment of further blue pine provenance tests in the USA and Canada does not appear to be practical because of the demonstrated insufficiency of winter-hardiness in regions where the species might be useful. In contrast, cooperative international trials should be conducted in Pakistan and Romania to continue research and establish seed orchards and seed production areas from ecotypes showing higher degree of blister rust resistance. The prevalence of field races of the rust, as reported by Patton (1972), should also be explored in this species. Multiclonal hybrids, particularly of blue pine and *P. strobus*, could be developed for rust resistance as a cooperative effort of the USA, Canada, Romania, and Pakistan to achieve desirable objectives in breeding both species.

## References

- Ahsan, J.; Khan, M.I.R. 1972. *Pinus wallichiana* A.B. Jackson in Pakistan. In *Biology of Rust Resistance in Forest Trees*. Edited by R. T. Bingham and others USDA Forest Service Misc. Publ. 1221: 151-162.
- Ashley, B; Fisk, T. 1980. Tree species trials in Nepal - some early results. Nepal/Australian Forest Tree Project; Canberra, Australia; 144 p.
- Bakshi, B.K. 1972. Relative blister rust resistance of native and introduced white pines in Asia. In *Biology of Rust Resistance in Forest Trees*. Edited by R. T. Bingham and others USDA Forest Service Misc. Publ. 1221: 251-255.
- Blada, I. 1994. Intraspecific hybridization of Swiss stone pine (*Pinus cembra* L.). *Silvae Genetica* 43:14-20.
- Borlea, G.F. 1992. Preliminary trials into resistance of 5 pine (*Pinus*) species attacked by blister rust (*C. ribicola*). *Revista - Padurilor* 107: 3, 7-10.
- Brandis, D. 1906. *Indian trees*. London, Archibald Constable; 767 pp.
- Critchfield, W.B; Little, E.L. 1966. Geographic distribution of the pines of the world. USDA; Forest Service; Misc. Publ. 991, 97 pp.

- Dallimore, W; Jackson, A.B. 1961. A hand book of Coniferae. London, Edward Arnold, 3<sup>rd</sup> ed. 686 p.
- Dogra, P.D. 1972. Intrinsic qualities, growth and adaptation potential of *Pinus wallichiana*. In Biology of Rust Resistance in Forest Trees. Edited by R. T. Bingham and others USDA Forest Service Misc. Publ. 1221: 163-178.
- Garrett, P.W. 1992. Performance of Himalayan blue pine in north-eastern United States. Tree Planters Notes 43(3):76-80.
- Genys, J.B. 1979. Intraspecific variation in Himalayan white pine, *Pinus griffithii*. USDA Forest Service; Technical Report No. NC-50, pp. 117-130.
- Gremmen, J. 1972. Relative blister rust resistance of *Pinus strobus* in some parts of Europe. In Biology of Rust Resistance in Forest Trees. Edited by R. T. Bingham and others USDA Forest Service Misc. Publ. 1221: 241-249.
- Grierson, A.J.C; Long, D.G; Page, C.N. 1980. Notes relating the flora of Bhutan (III). *Pinus bhutanica*: A new 5-needle pine from Bhutan and India. Notes from the Royal Botanical Garden Edinburgh 38: 2, 297-310.
- Heimbürger, C. 1972. Relative blister rust resistance of native and introduced white pines in eastern South America. In Biology of Rust Resistance in Forest Trees. Edited by R. T. Bingham, and others USDA Forest Service Misc. Publ. 1221: 257-269.
- Kew Bulletin. 1938. Bulletin of miscellaneous information, No. 2. Royal Botanic Gardens, Kew, London. His Majesty's Stationary Office, 549 p.
- Khan, A. 1979. Comments on the proposed intensive forest management in the temperate coniferous forests. Pak. Jour. For. 29: 90-92.
- Khan, S.R. 1986. Ecotypic differentiation in *Pinus wallichiana*. Proc. IUFRO Conference. Williamsburg, Virginia. Edited by R. Weir and others, 325-333.
- Khan, S.R. 1991. The establishment of seed transfer zones of blue pine (*Pinus wallichiana* A.B. Jacks) in Pakistan: A first attempt. Proc. 10<sup>th</sup> World Forestry Congress, Paris, vol. V:72-76.
- Khan, S.R. 1994. Key structural determinants in enhancing intraspecific variability in *P. wallichiana*. In: Proc. Symp. Forest Tree Improvement in the Asia-Pacific region. Edited by X. Shen, Published by China Forestry Publishing House, Beijing, pp. 10-15.
- Khan, S.R. 1995a. Genetic improvement of Himalayan white pine: ecotypic differentiation by phenological differences. In: Proc. IUFRO, XX World Congress, Tampere, Finland. Abstracts of Invited Papers, p. 147.
- Khan, S.R. 1995b. Dryland forestry research vis-B-vis afforestation strategies in Pakistan. In Dryland forestry research. Edited by A. Shahzad and others Proc. IFS/IUFRO Workshop, Hyytyala, Finland, p. 146.
- Khan, S.R. 1997. Genetic diversity and its role in afforestation in Pakistan. In Biodiversity of Pakistan. Edited by A. Shadzad and others eds. Publ. Pakistan Museum of Natural History and Florida Museum of Natural History, p. 107-113.
- Khan, S.R. 2000. Intraspecific variation vis-B-vis management strategies for the natural stands of *Pinus wallichiana* A.B. Jackson. Pak. Jour. For. 50(1-2):17-23.
- Khosla, P.K. Raina, K.K. 1995. Forest resources in the dry Himalaya region: Implications for long term sustainability. In Dryland forestry research. Edited by A. Shahzad and others Proc. IFS/IUFRO Workshop, Hyytyala, Finland, 147-148.
- Kriebel, H.B. 1983. Breeding eastern white pine: a world-wide perspective. Forest Ecology and Management 6: 263-279.
- Little, E.L., Jr. and Critchfield, W.B. 1969. Sub-divisions of the genus *Pinus* (Pines). U. S. Dept. Ag. Misc. Publ. 1144, Washington, D.C.
- Osmaston, A.E. 1927. A forest flora of Kumaon. Allahabad, Indian Government Press; 605 pp.
- Ouden, P.D; Boom, B.K. 1965. Manual of cultivated conifers. Martinus Nijhoff, The Hague. 526 pp.
- Patschke, W. 1913. Über die extratropischen ostasiatischen coniferen und ihre Bedeutung für die pflanzengeographische Gliederung Ostasiens. Bot. Jahrb. XLVIII:626-776. (In German).
- Patton, R. F. 1972. Inoculation methods and problems in testing eastern white pine for resistance to *Cronartium ribicola*. In Biology of Rust Resistance in Forest Trees. Edited by R. T. Bingham, and others USDA Forest Service Misc. Publ. 1221: 373-385.
- Paudel, K.C; Amatya, S.M; Harrison, AS. 1996. Provenance trial of *Pinus maximinoi* and comparison with *Pinus wallichiana* and *P. patula*. Working paper Llumle Regional Agr. Res. Centre, Nepal. No.96-38, 8 pp.
- Rehder, A. 1940. Manual of cultivated trees and shrubs. 2<sup>nd</sup> Edition. MacMillan, New York, 996 pp.
- Shebbeare, E.O. 1934. The conifers of Sikkah, Himalaya and adjoining country. Indian Forester 60:710-713.
- Siddiqui, K.M; Khan, J.A; Mehmood, I. 1989. Comparison of anatomical, physical and mechanical properties of *Abies pindrow*, *Cedrus deodara* and *Pinus wallichiana* from dry and wet temperate forests. Pak. Jour. For. 39:27-33.
- Stephan, B.R. 1974. Geographic variation in *Pinus strobus* on the basis of preliminary results of field trials in Lower Saxony. Silvae Genet. 23:214-220.
- Stephan, B.R. 1985. Resistance of 5-needled pines to blister rust. Allgemeine Forstzeitschrift 28:695-697.
- Takahashi, N; Hamaya, T; Kurahashi, A. 1974. Records of the growth of young samples stands of introduced species in the Tokyo University Forests in Hokkaido. Tokyo University Forests 18:29-66.
- Wallace, D. 1989. Report on provenance trial of *Pinus maximinoi/pseudostrobus*. PAC Tech. Paper, Pakhribas Agr. Centre No. 102, p. 8.
- Wilson, E.H. 1916. The conifers and Taxads of Japan. Cambridge University Press; 85 pp.

## Part II: Genetics, Genecology, and Breeding



***Pinus lambertiana* (sugar pine)**

photo courtesy of B. Dancho

