EUFORGEN

Norway spruce

Picea abies

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These Technical Guidelines are intended to assist those who cherish the valuable Norway spruce genepool and its inheritance, through conserving valuable seed sources or use in practical forestry. The focus is on conserving the genetic diversity of the species at the European scale. The recommendations provided in this module should be regarded as a commonly agreed basis to be complemented and further developed in local, national or regional conditions. The Guidelines are based on the available knowledge of the species and on widely accepted methods for the conservation of forest genetic resources.

Biology and ecology

Norway spruce (*Picea abies* (L.) Karst) is monoecious, having both male and female flowers on the same individuals, but on separate organs. The reproductive buds are initiated during the previous year's growth season. The temperature conditions play an important role in both floral initiation and development of reproductive buds, and in seed development and maturation. Unfavourable temperature conditions may explain why seed crops are both rare and irregular far north and at high altitudes. In seed orchards, flowering has occurred less frequently than was expected.

The highest proportion of spruce seeds is produced by cross-fertilization, both between neighbouring trees and among distant individuals in the same or in nearby stands. Spruce pollen is able to move over long distances, a fact that can cause considerable gene flow among populations. The actual rate of self-fertilization in natural populations may vary considerably between trees, but estimates show that only a small proportion of filled seeds (less than 1%) may originate from self-fertilization. Inbred spruce trees generally have reduced fitness compared with their outbred relatives.

Norway spruce trees undergo a rather long juvenile period during which they will not flower and set seeds. In the open canopy, sexual maturity will generally be reached at an age of 20-30 years, while it occurs later in closed stands. Most spruce seeds are dispersed close to the mother tree, but some also over longer distances. Under natural regeneration the access to soil moisture seems to be the most critical factor for germination and establishment. Natural regeneration is also dependent on the species composition of the bottom and field layer. The most productive spruce forests seem to be the most problematic for natural regeneration.

Picea abies is a shade-tolerant tree species that can grow on a variety of site types, in both dry and wet habitats. It reaches its best growth on deep nutritious soils with enough fresh moisture. It can grow in single stands or in mixtures with other conifers or deciduous trees.

Distribution

The total natural distribution of *P. abies* covers 31 degrees of latitude from the Balkan Peninsula (latitude 41°27'N) to its northernmost extension near the Chatanga River, Siberia (latitude 72°15'N). Longitudinal range is from 5°27'E in the French Alps to 154°E at the Sea of Okhotsk in Eastern Siberia. The vertical distribution is from sea level and to altitudes above 2300 m in the Italian Alps. Outside the natural distribution the species has been widely planted, in particular in Central Europe and in Scandinavia.

The natural European range of *P. abies* can be divided into three major regions as the result of postglacial re-colonization: the Nordic-Baltic-Russian, the Hercyno-Carpathian and Alpine regions

Importance and use

Picea abies is the most economically important conifer tree species in Europe. It has shown good yield and quality performance on very different site conditions, and this favoured the species over a long period. The species has a long history of cultivation in Central Europe and has been seeded and planted very intensely since the middle of the 19th century. This has changed natural forests into artificial forests and has led to the introduction of the species far outside its natural range, both in countries where it occurs naturally, e.g. in Germany and Norway, and in new countries such as Denmark, Belgium and Ireland. To some extent, Norway spruce also has been planted in North America.

Picea abies produces high-quality timber and its long fibres make it important for the pulp and paper industry. The species also has high ecological importance, being a key species in northern regions of Europe.

Genetic knowledge

The genetic variability in *P. abies* has been studied in provenance and progeny trials, often planted at several sites, and by genetic markers such as isozymes and DNA markers. The neutral markers reveal a great genetic variability within populations. Some differentiation occurs between populations derived from different glacial refugia, and appears to reflect their post-glacial evolutionary history. Central European provenances appear to have somewhat reduced genetic diversity compared with those from Eastern Europe and Scandinavia.

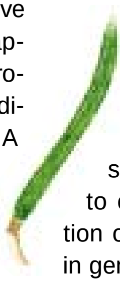
The most pronounced adaptive patterns that have been demonstrated in provenance trials relate to the populations' responses to the climatic conditions. In northern Europe these patterns of variability often can be related to latitude and longitude, and with degree of continentality, and will sometimes vary clinally. They are expressed by variation in the timing and duration of the annual growth period and the corresponding release and development of frost-hardiness in spring and autumn, respectively. These annual growth patterns have implications for frost-hardiness, growth potential and wood quality traits, and are important for proper choice of reforestation materials. At the same time there is large variability for the same traits within natural populations. In Central Europe, the regional variation patterns are less clear, owing to a long history of planting and provenance transfers.

Threats to genetic diversity

In some areas where maladapted provenances of *P. abies* have been planted, damage and reduced yield have occurred. During the last two decades the species has suffered severely with the forest decline in Central Europe, resulting in stands with high percentages of trees with needle loss, or completely destroyed stands. The health problems of the Central European spruce forest and the reduced possibilities for recreation in young spruce stands have to some extent reduced its popularity in reforestation, in particular outside its natural range. Fragmentation of former continuous forest areas is another threat for the genetic diversity of the species, and its response to global warming is uncertain. The most serious biotic threats to *P. abies* are root rot (*Heterobasidion annosum*) and bark beetles (*Ips typographus*).

Guidelines for genetic conservation and use

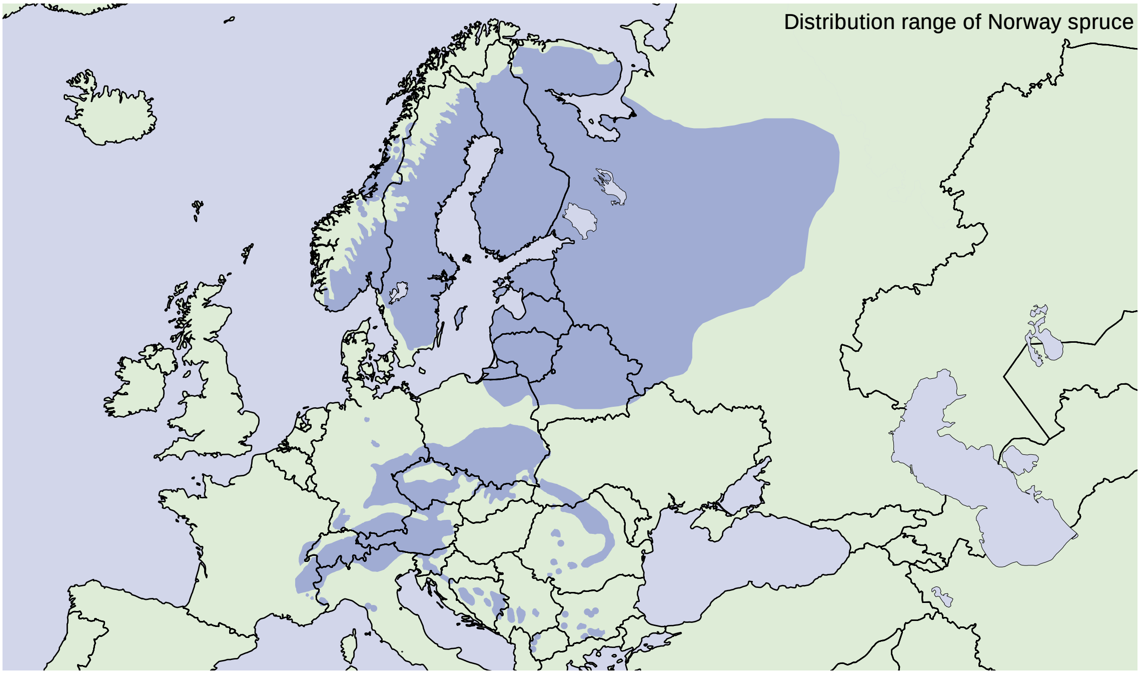
Genetic conservation of *P. abies* is done by proper use of reforestation materials and by specific *in situ* and *ex situ* conservation activities. In reforestation, the minimum requirement should be that the origin of the reproductive material is known, and its adaptive properties should be appropriate for the ecological conditions at the regeneration site. A system for the control of reproductive materials should be established and recommendations for proper use of different materials should be developed. The OECD Scheme and EU regulations provide basic definitions of different categories of reproductive materials. The *P. abies* seed samples of recommended seed lots for practical reforestation should be harvested in years with abundant flowering and seed production and be stored in sufficient amounts in seed banks.



In situ conservation of *P. abies* is often successfully done in protected areas. In several countries, however, protected areas alone do not fulfil the actual needs and requirements for the conservation of genetic resources of forest trees. There may therefore be a need for gene reserve forests, established in natural stands and managed according to silvicultural practice, such as thinning and harvesting, ensuring the potential for successful regeneration. The objective is to maintain the potential for continuous future evolution of the population. It has been suggested that gene reserve forests should cover areas of at least 100 ha, but smaller areas can also serve the purpose. Such forests may consist of a mixture of different species, if that is their natural species composition. In areas where *P. abies* is not a native species, it may be desirable to conserve the genetic variation of well-adapted “landraces” in gene reserve forests.

Establishment of *ex situ* conservation plantations of *P. abies* may be necessary in order to conserve the genetic variability of threatened populations that cannot be maintained at the original site. The objective will be to establish a new population that maintains as much as possible of the original genetic variability and allows for long-term adaptation to the local conditions at the planting site. It can be established by planting of seedlings, but also by direct sowing or vegetative propagules. Sizes of 2–5 ha are generally recommended.

Specific genotypes of *P. abies* are conserved *ex situ* as vegetative propagules, in most cases as grafts, in clone banks or clonal archives. Several replicates should be made of each clone to reduce the risk of loss due to fire and other disasters. Clonal archives are static gene conservation units, with no natural regeneration intended in the plantation. They often contain members of breeding populations that are characterized genetically and are used to provide scions to be grafted in seed orchards or to make controlled crosses. All populations belonging to a breeding programme, such as seed orchards and progeny tests, are important gene conservation units as they contain materials with known genetic properties that can be used to generate new populations with known adaptive and wood-production characteristics. Breeding populations organized in a system of multiple populations at different sites have particular value for conserving genetic variability both within and between populations.



Field experiments with provenances, families and clones of *P. abies* have provided important genetic information for both breeding and conservation activities. Although such trials were not designed with gene conservation in mind, they are important reservoirs of characterized genetic variability and should be managed and maintained as long as possible and be considered part of a national conservation strategy.

Any type of forest reproductive material of *P. abies* (seeds, pollen, vegetative parts) can be conserved in genebanks. This will be a complementary method to the *ex situ* and *in situ* plantations, and will, apart from genetic changes due to loss of viability, conserve the original genetic structures.

These Technical Guidelines were produced by members of the EUFORGEN Conifers Network. The objective of the Network is to identify minimum genetic conservation requirements in the long term in Europe, in order to reduce the overall conservation cost and to improve the quality of standards in each country.

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The distribution map was compiled by members of the EUFORGEN Conifers Network based on an earlier map published by H. Schmidt-Vogt in 1977 (Die Fichte, Verlag Paul Parey, Hamburg and Berlin, p.647).

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