Mountain pine

Pinus mugo

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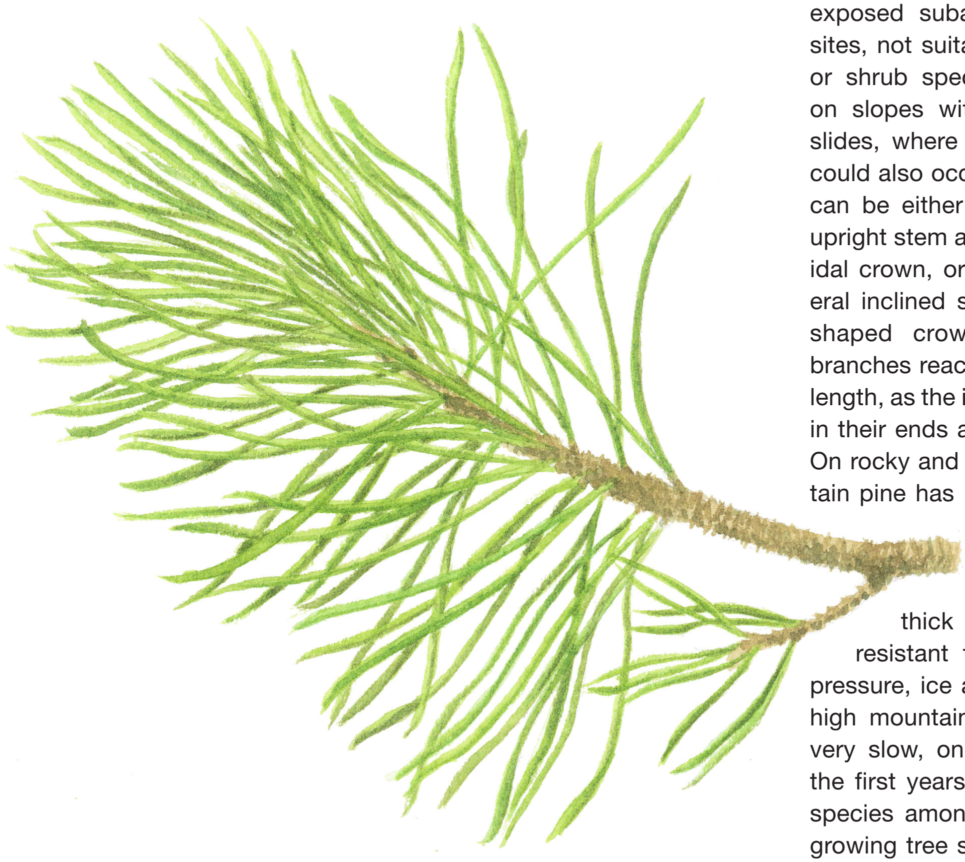
These Technical Guidelines are intended to assist those who cherish the valuable mountain pine genepool and its inheritance, through conserving valuable seed sources or use in practical forestry. The focus is on conserving the genetic diversity of the species at European scale. The recommendations provided 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 available knowledge of the species and on widely accepted methods for conservation of forest genetic resources.



Biology and ecology

Pinus mugo is a species of exposed subalpine and alpine sites, not suitable for other tree or shrub species, for example on slopes with frequent snow slides, where only *Alnus viridis* could also occur. Mountain pine can be either monopodial with upright stem and narrow pyramidal crown, or with one or several inclined stems with shrub-shaped crown. Some lateral branches reach up to 9–10 m in length, as the inclined stems rise in their ends and form a clump. On rocky and poor soils, mountain pine has mostly multi-stem and shrub-shape forms. Branches are relatively thick and very elastic, resistant to storms, snow-pressure, ice and avalanches in high mountains. The growth is very slow, only 2–3 cm during the first years, which ranks the species among the most slow-growing tree species in Europe. Shrub-shaped specimens reach up to 3–5 m height, while monopodial ones reach up to 20–25 m and 50–60 cm in diameter at the age of 150–200 years. The species' maximum age is 250–300 years.

The root system is horizontal, usually without a central root, and side roots are thick and branched with lengths up to 8–9 m.

The bark is thin, grey-brown to dark grey, and peels off in rectangular flakes on old individuals. Shoots are smooth, brown to grey-black, and buds are conical, red-brown and very resinous.

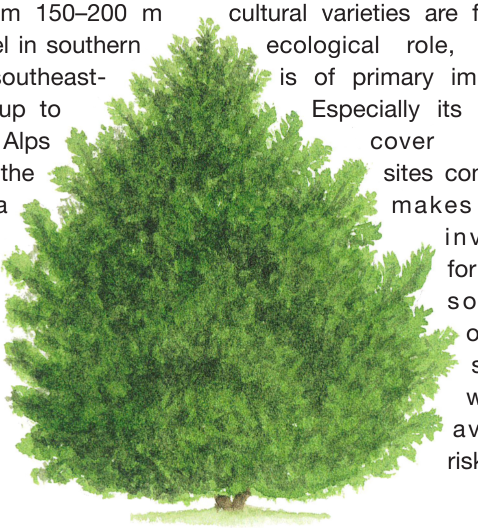
Needles occur in pairs in a fascicle, from 2-8 cm in length and 1 to 2 mm in width, and are slightly tortuous, with a light to dark green colour. They remain on the tree from 4–5 to 10–12 years.

Mountain pine is mostly dioecious but can be monoecious as well, with cones growing on some and catkins on other individuals. Male catkins are 10 mm long, with a yellow or red colour, dispersing pollen from May until the end of June. Female cones sit singly or 2 to 4 together usually in a node, young ones being purple and mature ones dark brown with a length up to 5–6 cm and width up to 3 cm. After 15–17 months of growth, the cones mature by October of the following year. Their apophyse is convex and surrounded by a black ring. The seeds are black, 3–4 mm in size with 10 mm long, yellow wings with dark nerves.

Pinus mugo is often found mixed with limited participation of *Picea abies* (L.) Karst., *Pinus sylvestris* L., *Larix decidua* Mill., *Pinus cembra* L. (or, respectively, *Pinus peuce* Gris.), *Betula pendula* Roth., *Alnus viridis* (Chaix) DC., *Sorbus aucuparia* L. It also occurs in pure and often dense, impenetrable associations; in peat bogs, where the species is a glacial relict; and mixed with *Juniperus communis* L.

Distribution

The geographic range of *Pinus mugo* includes mountains in the Balkans, Carpathians, the Ore Mountains, Alps, Vosges mountains, Apennines (to Abruzzo) and Pyrenees, predominantly in subalpine parts and above the treeline. Separate populations and solitary individuals occur from 150–200 m above sea level in southern Poland and southeastern Germany up to 2500 m in the Alps and 2700 m in the Pirin and Rila mountains (Bulgaria). Communities at low altitudes in Central Europe occur in peat bogs.



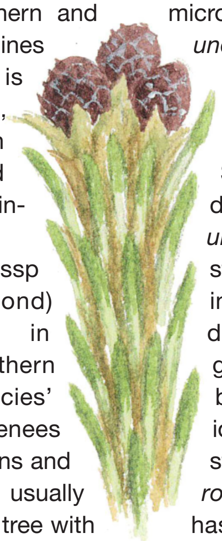
Importance and use

The role of *Pinus mugo* in water protection and soil erosion control is of primary importance in the high-mountain belt. The species is quite suitable for cultivation on poor soils and in windy places along the Baltic Sea coast. In many regions in Central and Northern Europe it is used for landscape design. It is tolerant to different soil conditions, growing well both on peat bogs and dry stony soils, but requiring high atmospheric humidity. The resinous, durable and elastic wood with specific weight up to 0.83 g cm-3 finds its application in making lasting wooden decorations, for production of medicinal turpentine, fragrant bath oils, reduction coal and for fuel. The species is frequently used for landscape design in parks and gardens, where manifold horticultural varieties are found. Its ecological role, however, is of primary importance. Especially its ability to cover exposed sites continuously makes it invaluable for the consolidation of steep slopes with high avalanche risk.

Genetic knowledge

The following subspecies can be identified:

- *Pinus mugo* ssp *mugo* Turra occurring in central and eastern parts of the species' range, mainly in the Southern and Eastern Alps, Apennines and Balkans. It is shrub-shaped, 3–6 m height, with several stems, and has symmetrical thin-scaled cones.



- *Pinus mugo* ssp *uncinata* (Raymond) Domin occurring in western and northern parts of the species' range—in the Pyrenees and Vosges mountains and southern Poland. It usually forms a monopodial tree with heights up to 20–25 m and with asymmetrical, thick-scaled cones.

Both subspecies can also hybridize, and in the western Alps and northern Carpathians *Pinus mugo* ssp *rotundata* (Link) Janchen & Neumayer is confirmed.

Pinus mugo subsp. *pumilio* is also distinguished as a subspecies. It occurs in the Alps, Carpathians and Jura and is shrub-shaped and has symmetrical cones.

Hybrids between *Pinus mugo* Turra and *Pinus sylvestris* L. have been recorded in various parts of the species' range, which have an upright stem and short side branches, forming a pyramidal crown. These hybrids are also partially interfertile, but the incidence of natural hybridization seems to be very low.

The geographical pattern of genetic diversity has recently been described using chloroplast microsatellites (cpSSRs) for *P. uncinata* with a homogeneous Pyrenean gene pool and strongly differentiated populations in the Iberian Systems. A lack of genetic differentiation between P. *uncinata* and *P. mugo* sensu stricto has been observed in the Alps. A stronger differentiation between geographical regions than between morphologically identified taxa (*P. mugo* sensu stricto, *P. uncinata* and *P. rotundata/P. pseudopumilio*) has been observed. Some authors identified a Pyrenean and an Alpine gene pool, along with several smaller genetic clusters corresponding to peripheral populations. The core regions of the Pyrenees and Alps were probably recolonized, respectively by *P. uncinata* and *P. uncinata/P. mugo* sensu stricto, from multiple glacial refugia that were well connected by pollen flow within the mountain chains. *Pinus rotundata/P. pseudopumilio* populations from the Black Forest, Vosges and Jura mountains were very likely recolonized from various glacial populations that kept their genetic distinctiveness despite late glacial and early Holocene expansion. Marginal *P. uncinata* populations from the Iberian system are compatible with elevational shifts and long-term isolation.

Nucleotide polymorphisms in nuclear, chloroplast and mitochondrial DNA fragments were used to study the speciation history of *Pinus mugo*, *P. uliginosa* and *P. sylvestris*. Overall, the genetic data indicate that *P. mugo* and *P. uliginosa* share the same gene pool and that the phenotypic differences (e.g. growth form) are most likely due to very limited areas of the genome. *P. mugo* and *P. uliginosa* are more divergent from *P. sylvestris* than from each other. The nucleotide patterns can best be explained by the divergence with migration speciation scenario, although the hybrid speciation scenario with a small genomic contribution from *P. sylvestris* cannot be completely excluded.

Threats to genetic diversity

The relatively wide distribution range of mountain pine in Europe gives no reason to fear for its genetic diversity, with the exception, for example, of some isolated occurrences in Central Spain, Southern France, Abruzzo (Italy), and the western Balkan Range (Serbia and Bulgaria). Clear cutting of fragmented stands and particularly forest fires were a danger in the second half of the 20th century, and currently risks are linked to climate changes and anthropogenic impact caused by construction of ski slopes and accompanying facilities.

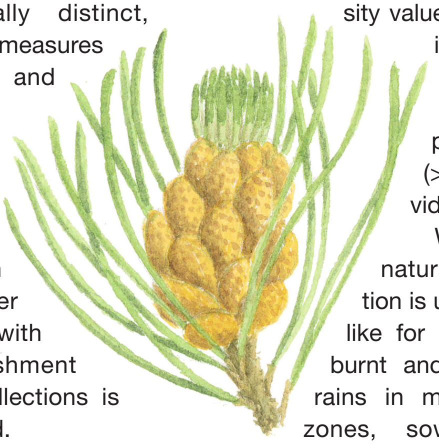
In general, the health status of mountain pine is stable, because it does not suffer from dangerous fungal diseases and insect pests. Specific diseases are white snow mould, caused by *Phacidium infestans* P. Karst. and black snow mould, caused by *Herpotrichia juniperi* (Duby) Petrak, which affect needles during snow cover and cause their gradual decay on separate branches, without being lethal for the entire mountain pine ecological system.

It is predicted that in the Iberian Peninsula montane conifer species such as *P. sylvestris* and *P. uncinata* will suffer intense and rapid reduction of their distribution ranges because global warming will induce their migration to limited areas at higher elevations. Some *P. uncinata* populations from the Iberian Peninsula are in this situation. These populations are strongly differentiated and, as southern 'rear edge' populations, they may harbour important adaptations relevant to the conservation of the species. In the Black Forest, many *P. rotundata*/*P. pseudopumilio* populations show considerable dieback and insufficient natural regeneration. These seem to be delayed consequences of the drainage of bogs for peat collection. After at least 200 years of regular burning of peat bogs in the Black Forest, fire disturbance has ceased, reducing the availability of open habitats for bog pine regeneration. At the same time, the lowering of water tables has allowed the establishment of a dense undergrowth and invasion of the drier bog margins by the shade-tolerant *Picea abies* (L.) Karst. Because global warming is expected to aggravate the dieback, and these populations are genetically distinct, conservation measures are justified and necessary.

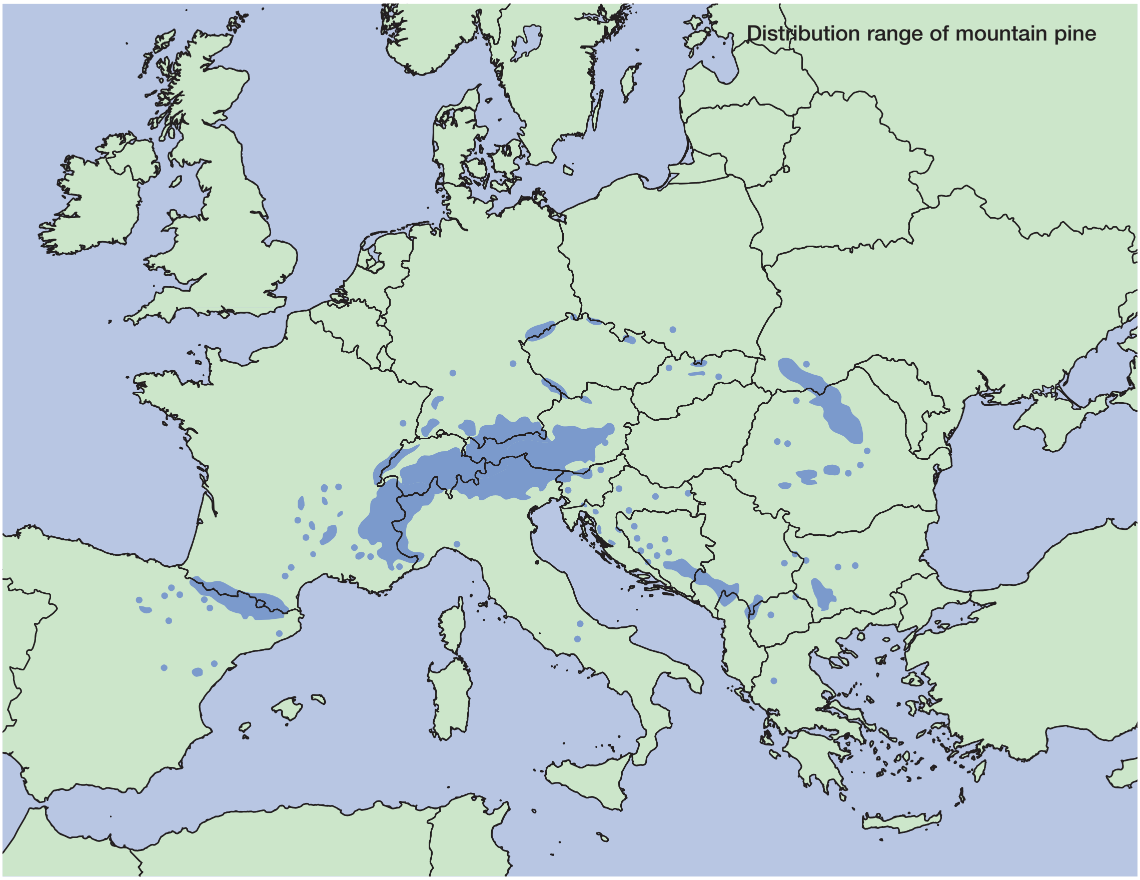
A combined strategy of *in situ* conservation of the larger bogs along with the establishment of *ex situ* collections is recommended.

Guidelines for genetic conservation and use

Large autochthonous mountain pine populations are characterized by high genetic diversity and adaptability which suggest in situ conservation as the main strategy. In situ conservation of mountain pine contributes to the natural recovery of the treeline, which is lowered in many places due to anthropogenic impact (fires, felling, grazing, building activities). National parks often harbour large mountain pine formations and provide in situ genetic conservation of this species. However, it still needs protection due to extension of natural and man-made disturbances. Therefore it is recommended that genetic conservation programmes start with the following objectives: conservation of endangered, marginal populations and habitats of Pinus mugo; sampling the genetic diversity; establishment of Dynamic Conservation Units based on long term autochthony, high biodiversity value and location in ecologically diverse regions of large populations (> 1000 individuals).



Whenever natural regeneration is unsatisfactory, like for restoration of burnt and eroded terrains in mountain pine zones, sowing and/or



planting need to be carried out. When artificial regeneration is carried out according to the principles of genetic conservation, then the following requirements for the use of reproductive material must be observed:

- Preference should always be given to local material, unless results from provenance trials point to inferior quality or growth characteristics in the local population. Local material usually guarantees retention of the evolutionary and adaptive characteristics that have developed at a given site under specific conditions over generations. Lack of adaptability can lead to serious failures at any stage of the long lifespan of mountain pine and other forest tree species.

- If there is no local material available or if there are signs of inbreeding, then restoration may rely on the introduction of material from outside. Material from localities sharing the site conditions with the regeneration site should be preferred.

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EUFORGEN

This series of Technical Guidelines and distribution maps were produced by members of the EUFORGEN Networks. The objective is to identify minimum requirements for long-term genetic conservation in Europe, in order to reduce the overall conservation cost and to improve quality standards in each country.

Citation: Alexandrov, A., G. von Wühlisch, G. Vendramin. 2019. EUFORGEN Technical Guidelines for genetic conservation and use for mountain pine (Pinus mugo). European Forest Genetic Resources Programme (EUFORGEN), European Forest Institute. 6 pages.

Drawings: Pinus mugo, *Claudio Giordano.*

ISBN 978-952-5980-64-6

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The distribution map is based on: Caudullo, G., Welk, E., San-Miguel-Ayanz, J., 2017. Chorological maps for the main European woody species. Data in Brief 12, 662-666. https://doi.org/10.1016/j.dib.2017.05.007

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