Technical Guidelines for genetic conservation and use of Scots pine

1. Latin name

Pinus sylvestris L.

2. Authors

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3. Introduction

These Technical Guidelines are intended to assist those who cherish genetic resources of Scots pine, through conserving valuable seed sources and managing forests in an ecologically and genetically sustainable way. The focus is on conserving the genetic diversity of the species on the European scale. The recommendations provided in this module should be regarded as a commonly agreed basis to be complemented and further developed according to 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.

4. Biology and ecology

Scots pine is a pioneer species and it readily regenerates after major natural or man-made disturbances, if weed competition and grazing pressure are low. Natural stands are often pure and fairly even-aged. The species grows predominantly on poorer, sandy soils, rocky outcrops or close to the forest limit. On fertile sites, Scots pine is outcompeted by other (usually broadleaved) tree species.

The species is wind-pollinated and has both male and female flowers on the same tree. Flowering is frequent and abundant starting at the age of 15 years on solitary trees or 25-30 years in closed stands. It produces enormous amounts of pollen. In Scandinavia, pollen quantities between 30 and 130 kg/ha are common, which may surpass the weight of net seed crop. Mast years are relatively frequent but, at the boreal forest limit, seed maturation is impeded by the short growing season; seed years may occur as seldom as 1-2 times in 100 years.

5. Distribution

Scots pine has a wide distribution across the whole Eurasian continent, ranging in latitude from 37° N to 70° 20’ N. At the boreal forest limit it survives with less than 100 frost-free days per year and 300 mm annual rainfall. Towards the steppe plains of Central Asia its occurrence is limited by the length of the drought period. In southern Europe and Asia Minor, isolated occurrences are confined to the montane zone (up to 2200 m in altitude in the Balkans and Spain, and 2700 m in the Caucasus).

6. Importance and use

Scots pine is a commercially important tree species in Europe. Its wood is easily workable with good mechanical proprieties and has many uses, primarily as construction timber and pulpwood.

Its moderate site demands render Scots pine an ideal species for artificial regeneration and afforestation. Accordingly, its seed has been traded and used across Europe for centuries. The indiscriminate planting of seed of uncontrolled origin sometimes resulted in blatant quality loss, triggering provenance research well before present-day genetic knowledge was available.

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7. Genetic knowledge

Taxonomic status and hybridisation

There were numerous attempts to subdivide the immense distribution area into various subspecies, which are rather unconvincing due to the lack of any clear discontinuities in the contiguous range. Isolated southern occurrences, regarded as glacial relics, were occasionally described as separate species, such as *P. hamata* (Stev.) Sosn., *P. armena* Koch, *P. sosnowskyi* Nakai for the Caucasus region.

Under natural conditions Scots pine does not readily intermate with other pine species. Spontaneous hybrids with *P. nigra*, *P. densiflora* and *P. mugo* have been reported. Towards other taxa, the species shows a robust hybrid incompatibility.

Intraspecific variability

The high migration potential of both pollen and seed results in an effective gene flow within the contiguous range, causing a distinct, clinal pattern of variation within the species, at least for adaptive traits. This is typically the case with growth and phenology characters, which are determined primarily by the temperature conditions in the vegetation period. Northern and continental populations need less heat sum to complete phenophases and reach hardiness. Southern and coastal provenances have longer vegetation cycles and are less hardy. Intensive gene flow also maintains a high within-population diversity in both adaptive and neutral traits. Stem form, crown form and branchiness show great variability within the area of distribution (the geographic variation in Scots pine was probably the first to be observed and systematically investigated among tree species). Only the provenances of Northern Europe / Siberia and those from higher elevations are straight-stemmed with an ideal conic crown form and fine branches. Certain regions (*e.g.* southeastern Baltic coast populations) show superior growth traits and high phenotypic stability, while in other areas growth and stem form are typically unfavourable, possibly indicating improper silvicultural practices in the past (e.g. in SW Germany or in the Carpathian Basin).

In accordance with growth and stem form, mechanical properties of Scots pine timber show differences according to origin. This includes also the chemical composition, e.g. the extractive and oleoresin content of wood. Density values are lower in high-elevation and northern populations.

Intraspecific variation in resistance traits has been recorded as well. Resistance to fungal pathogens, such as *Lophodermium* sp. are higher in the western, coastal parts of the range, while southeastern forest steppe populations are especially susceptible. Geographic variation in susceptibility to insect pests has been proven for a number of insects; for instance Central European populations are susceptible to root collar weevil and pine moths, but more resistant to pine shoot borer and pine weevil.

Biochemical and molecular studies have clearly indicated that there is high diversity in Scots pine throughout Europe with most variation occurring within, rather than between populations. Analyses based on monoterpenes and isozymes have been used e.g. to group the remnant areas in Scotland. Both approaches identified one region lying at the extreme north-west of the species' distribution with distinctive characteristics. These approaches have been superseded by DNA-based markers for the chloroplast, mitochondrial and nuclear genomes.

Variation in mitochondrial DNA (maternally inherited in pines) has indicated that the 3 major mitotypes present in Spanish populations encompass all the variability found in the rest of Europe. However, their individual occurrence throughout Europe separated Italian, west-central European and Fennoscandian populations into 3 clear groupings. At the extremes of the natural range, only one mitotype occurred in the isolated populations in southern Spain whereas in Scotland, although most sources matched the west-central European grouping, the Italian mitotype was present. Overall, molecular studies support the existence of 3 evolutionary routes within Europe for Scots pine and the higher variability in Spanish populations suggests that this area may have been an original centre of diversity.

The study of variation in chloroplast DNA (paternally inherited in conifers) identified some differences between populations but no clear geographical structure throughout Europe was evident.

8. Threats to genetic diversity

Due to its wide distribution, threats to local populations may strongly differ in various parts of the range. The main threats to its survival lie at the extremes of its distribution. In particular, this is recognised at the north-western and south-western fringes (Scotland and southern Spain). Here the distribution of the species has become discontinuous and fragmentation into isolated populations is common. In extreme circumstances, this has left several remnant populations with less than 100 trees. Regeneration at the boreal timber limit is also problematic. At least in patches of the distribution this has led to a shift of species, and measures such as fencing or reduction of game populations have been used to safeguard populations, to achieve successful natural regeneration, increase stocking levels and expand the areas concerned. In a number of instances, the need for grafted seed orchards to supply seed representing individual, highly vulnerable sources has been recognised.

In the core area of the European distribution, where large-scale artificial regeneration was the rule for a long time, loss of locally adapted, autochthonous populations may have happened in many areas. In regions, where the species has been cultivated outside its natural range (e.g. Germany, France, Hungary) Scots pine stands are often of poor quality. Planted stands of uncontrolled origin may exert a certain genetic pollution threat to natural populations in the surroundings.

Expected climatic changes will prolong droughts in central and continental southeast Europe and this must be recognised as a potential threat not only to populations at the southern limits of the distribution area but also to high-elevation populations. Higher temperatures and aridity could lead to loss of competitive ability and vitality. This is likely to cause a northward shift of the area where the species can be successfully cultivated.

9. Guidelines for genetic conservation and use

Conservation priorities

Because Scots pine is a species with an extremely wide distribution and occupying a broad range of habitats, genetic conservation seems to be a task of low priority. However, the need to address genetic resources of Scots pine is supported by the widely proven genetic diversity between populations, the effects of century-long cultivation and the expected environmental changes at the margins of the distribution.

As Scots pine is one of Europe’s most important species under forest management the anthropogenic influence is obvious. The survey and recording of native local (autochthonous) stands is an important task for gene conservation. These records could include various identification data; molecular markers become increasingly useful for this task.

Long-term provenance tests have proven the value and importance of locally adapted populations. This fact is valid primarily for extreme site conditions, such as higher altitudes, coastal environments, extreme boreal conditions, rocky or semiarid sites. Preserved populations on these sites exhibit less plasticity when transferred to other conditions, but are usually superior locally. Special care should be taken, therefore, to select representative populations for conservation on such sites. Native stands selected for conservation will also serve as “population standards” when compared with man-made forests.

Similar to populations on extreme sites, isolated outliers might have been exposed to specific selection pressures or drift and may carry specific alleles. Such populations should be carefully protected and steps to collect forest reproduction material at the sites have to be taken. Local material should be used for regeneration and material from endangered sites should also be established in *ex situ* conservation stands.

Expected climate change will affect first of all the populations at the southern fringes of the distributional range. These populations are often remarkably vigorous and tolerant and may be of value for future breeding. Here also *ex situ* measures should be applied in order to safeguard long-term survival.

The long tradition of artificial regeneration may have developed land races that could also be targets for gene conservation efforts. These populations usually represent diverse, rather plastic genetic resources, valuable for future breeding and reproduction.

Establishment and management of conservation units

When selecting gene conservation units along a continuous cline, ecological information should be preferred to neutral markers. In the absence of drift, in a contiguous distribution range, adaptively different populations may be expected at distances where annual mean temperature differs by minimum 1-1,5^{o}C (equal to ca. 200 kms in a flat landscape).

The size of genetic conservation units of Scots pine should be sufficiently large to compensate for and buffer against outside gene flow. 100 hectares should be considered as a minimum. Nearby occurrences of genetically degraded, or otherwise unsuitable stands should be either avoided or removed. A conservation unit may consist of numerous adjoining stands of various age, provided their origin is the same. In areas of scattered occurrence, initial size may be 10 hectares as minimum, which can be increased in course of successive regeneration.
In many instances the pioneer character of Scots pine demands human interaction to prevent ecological succession. As far as possible, natural regeneration should be applied which is less problematic on drier or poorer sites. Usually site preparation with discs or special ploughs are necessary. The regeneration of admixed species should be tolerated for ecological reasons. The light demand of the species does not allow the development of a very complex stand structure, but this is also not necessary as even-aged stands may hold equal diversity. Regeneration felling should be carried out stepwise, allowing for the recruitment from numerous seed years. Scots pine is genetically rather insensitive to the type of regeneration cutting used. However, if the influx of outside pollen were minimized (a goal which can be met only with partial success), shelterwood cutting would be preferred to other regeneration regimes. Fencing of the unit has to be considered where high game density threatens natural selection processes.

In certain cases artificial regeneration may be necessary (e.g. for *ex situ* conservation). To sample a genetic resources effectively, at least 50 or more well distributed trees have to be harvested in a good seed year. Mixing of seed from repeated harvests is beneficial. Direct sowing would be preferred to planting. Planting should be carried out with much higher density than usual (around 40-50 thousand/ha) to leave enough place for natural selection.
Intermediate low-intensity fellings and management should maintain a relatively dense stand structure. Selective removal of trees should be confined to malformed individuals, otherwise a broad variation of phenotypes should be allowed. Where fire danger is high, natural mortality should be cleared and debris removed from the reserve at regular intervals.

Purpose and management objectives of the reserve have to be included in the management plan. Gene conservation units should not be regarded as “untouchable” reserves, they may be utilized for timber production with only one limitation: to serve the sustained maintenance of the genetic resources of the target species. The owner has to be encouraged to manage gene conservation units routinely to secure the fulfilment of prescribed tasks. If harvesting on standing trees is practiced, the use of reserves for seed collection is acceptable.

All available historic information on the unit should be carefully collected and recorded (especially natural or man-caused disturbances), together with actual silvicultural treatments, calamities etc.

In summary, priorities for specific genetic conservation measures will differ regionally. Preservation of genetic resources of Scots pine should be visualized in the context of locally applied forest management practices (especially control of seed sources for artificial regeneration), the extent of protected or unmanaged areas and the occurrence, density or fragmentation of the species at the landscape level, together with actual threats and risks. The urgency to set up gene conservation units will be much higher in an area with fragmented remnants of local populations, surrounded by planted forests of uncontrolled origin, than in a region where a sustainable forestry relying on natural regeneration and local seed sources is practised.

10. Selected bibliography

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12. Drawings Author:

Drawings: *Pinus sylvestris*, Claudio Giordano. © IPGRI, 2003.

13. Network:

These Technical Guidelines were produced by members of the EUFORGEN Conifers 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.