Pedunculate and sessile oaks

Quercus robur/Quercus petraea

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These Technical Guidelines are intended to assist those who cherish the valuable white oaks 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

Pedunculate (*Quercus robur* L.) and sessile (*Q. petraea* (Matt.) Liebl.) oaks are large deciduous trees that reach 30–40 m in height and live 800 years and more. They are monoecious and allogamous, anemophilous and predominantly outcrossing. Trees usually reach seed-bearing age at between 40 and 100 years old. Mast seed crops vary according to individual tree, population, region and year. Vegetative reproduction through coppicing has been widely used to regenerate oak stands.

Natural hybridization in oaks has been reported in many studies. In European white oaks hybridization is asymmetric: *Q. petraea* preferentially pollinates *Q. robur*. This asymmetry can reinforce the succession of species, replacing the pioneer species (*Q. robur*) with a late successional species (*Q. petraea*). The hybrid foliar characteristics resulting from controlled crosses resemble more the female parent and are not intermediate between the parental forms.

Pedunculate oak is very tolerant to soil conditions and the continental climate but it prefers fertile and well-watered soils. Mature trees tolerate flooding. Sessile oak has a very large ecological niche because it accepts soil pH from 3.5 to 9 and xeric to humid conditions. It is more tolerant to drought and poor soil than pedunculate oak but more sensitive to airless soil conditions. The minor species of sessile oak in southeastern Europe are well adapted to wide ecological niches from humid to extremely xeric.

In plains, plateaux and hills, pedunculate oak is a pioneer species and sessile oak a late successional species. Sessile oak could reach climax stage if summers are dry. In valleys and flood plains pedunculate oak is a late successional species which reaches climax with sycamore, plane, maple, ash and elm.

Distribution

Sessile and pedunculate oaks are widely distributed in Europe from northern Spain to southern Scandinavia and from Ireland to Eastern Europe. The pedunculate oak reaches the Ural Mountains. The natural range of sessile oak is generally included in that of pedunculate oak but the eastern limit is the Ukraine. They occur in plains on most types of soil from sea level to 1800 m elevation. Some minor species are restricted to southeastern Europe.

Importance and use

Among the 13 European white oak species, pedunculate and sessile oaks are the most important. They are among the economically and ecologically most important deciduous forest tree species in Europe.

High forest, coppice-with-standards and coppice are the three main silvicultural regimes. Since the beginning of the 19th century, foresters have converted many coppice and coppice-with-standard stands to high forest. Recently, silviculture that is close to nature has been promoted in most European countries. Natural regeneration should be a priority but as it presents difficulties, plantations are sometimes required. The genetic quality of the forest reproductive material is crucial for the technical and economic issues of these plantations.

Oak timber is traditionally used for building, ships and furniture. Today the best woods are used for quality cabinet-making, veneers and barrel staves. Rougher material is used for fencing, roof beams and specialist building work. It is also a good fuel wood.

During autumns with good acorn crops (the mast years) animals are grazed under the trees to fatten them. This tradition still exists in some restricted areas, such as the Basque region and eastern Europe.

Genetic knowledge

Oak classification has raised conflicting opinions. There is so much variation within species that the concept of species is questioned and further complications in taxonomy are due to frequent interspecific hybridization. The genus *Quercus* is subdivided into two subgenera: *Euquercus* and *Cyclobalanopsis*. The subgenus *Euquercus*, now called subg. *Quercus*, has been further subdivided into four sections: *Rubrae*, *Protobalanus*, *Cerris* and *Quercus*. Both *Q. petraea* and *Q. robur* belong to the last of these, also named white oaks. These taxa are divided into subspecies or minor species.

Oaks are among the most diverse species of forest trees. High levels of diversity are most likely due to the maintenance of large population sizes, long-distance geneflow and interfertility. Long delays between generations may be advocated, which prevent oak populations from undergoing genetic drift.

White oaks make up a complex of species where genes are commonly exchanged. The interspecific differentiation, regardless of the molecular markers used, is only slightly larger than the intraspecific variation.

The geographic distribution of genetic diversity of chloroplast genomes is strikingly different from that found using nuclear markers. The chloroplast genome of oak stands tends to be completely fixed within populations but fully differentiated among stands, whereas the nuclear genetic diversity resides mostly within populations. Molecular markers in the nucleus show a weak geographic structure with an east-to-west cline.

As for molecular traits, phenotypic and adaptive traits also exhibit extremely high levels of diversity, even for fitness-related traits. Phenotypic traits exhibit important population differentiation, but not as much as for chloroplast genome. Geographic trends of variation exist for phenological traits, growth and form attributes.

During the Quaternary era, oaks were subjected to important migrations in response to climatic changes. During the last ice age, their natural ranges were restricted to the southern Iberian peninsula, central Italy and the southern Balkan peninsula. In less than 7000 years, oaks have spread to their modern-day range. Interspecific hybridization was a key migration mechanism as it facilitated the dispersion of late successional species (*Q. petraea*) into pioneer species (*Q. robur*). The subsequent recolonization by various post-glacial migration routes has left a genetic trace which chloroplast DNA reveals. These movements have profoundly impacted the genetic diversity distribution.

Effective pollen dispersion has been measured by using parentage analysis. In *Q. petraea* and *Q. robur*, more than half the male parents contributing to pollination of female parents located in a 5-ha study stand were actually located outside the stand. Although nearest neighbours contributed preferentially to pollination, pollen dispersion curves are clearly composed of a short- and long-distance contribution most likely related to different wind-transport mechanisms. Acorns are dispersed by small rodents and the European jay, which is very efficient in seed dispersal.

The distribution of adaptive diversity is not correlated to neutral diversity; there is no footprint left of the maternal origin on the variation of adaptive traits. It is more likely that geographic variation for adaptive traits resulted from more recent local selection pressures and human impact than from the ancient origin of the stand. Humans are modifying the genetic resources by population transfers and also by silviculture regimes.

Threats to genetic diversity

Since 8500 BP, humans have strongly reduced the distribution of oaks although the oak forest coverage has increased since the 19^{th} century owing to silvicultural management. Now, most oak forests are managed, primeval forests like Bialowieza in Poland being very rare. A long tradition of oak forest management exists in Europe which seems very conservative regarding genetic resources but the impact of the different silvicultural practices is relatively unknown. The main threat is the introduction of exotic genotypes through plantations. This menace was neglected in the past. White oaks have very large ecological niches and sometimes occupy extreme habitats (rocky slopes in mountains, sand dunes, saline soils, peat bog, garigues).

These populations are at high risk of disappearing because the number of individuals is low, habitats are unstable and human impact is often considerable. Pedunculate oak is suffering recurrent decay due to the forest dynamic and the evolution of forestry practices (forsaking of coppicing, ageing of the populations). Insects and pathogens also might be dangerous, such as oak mildew (*Microsphera alphitoides*) which is reported to be of the most common pathogens. American oak wilt (*Cerastocystis fagacearum*) is also a considerable risk for European forests. The severity of the problem alone does not guarantee that practical, social, administrative and legal problems will be solved rapidly. Therefore, an emergency action plan must be drawn up on a European scale.

Guidelines for genetic conservation and use

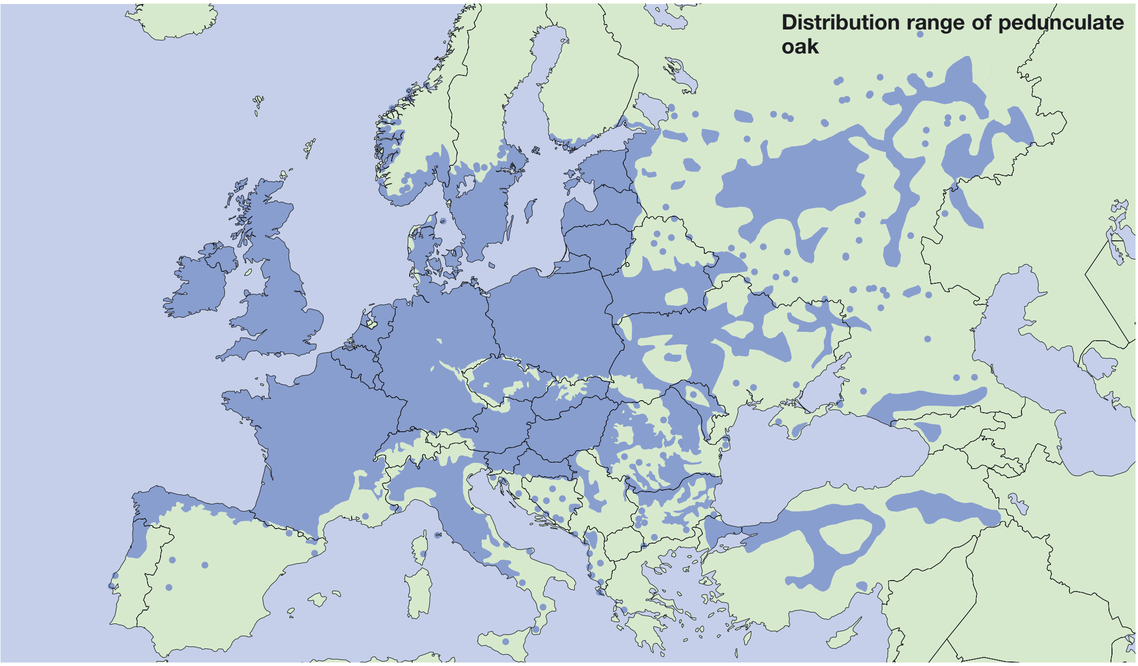
The forest reproductive material transfer in international trade must be in agreement with EU Directives and the OECD scheme. All scientific studies are congruent for the promotion of local material. Forest managers are urged to follow these guidelines:

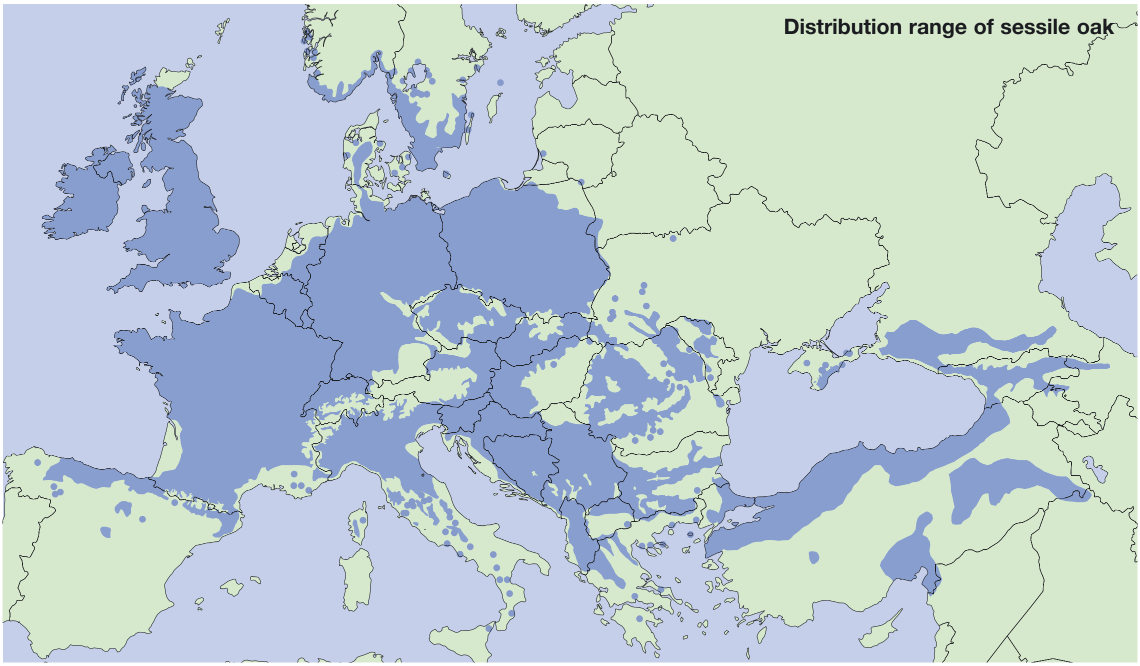
1) Natural regeneration must be a priority.
2) Reproductive material must be transferred only at a local scale; transfers among provenance regions must be strictly limited. Foresters must use genetic resources for artificial regeneration from local seed stands, that have been selected for their phenotypic values and silvicultural histories.
3) Development of seedling-raising agreements between nurseries and forest managers is needed.

At present in Europe, these genetic resources are not really endangered except in some situations (marginal populations in coastal sand dunes or peatbogs; altitudes >1400 m) and at the limits of the natural range. These genetic resources are potentially threatened by introduction of exotic genotypes, species purification, neglected practices and conversion to high forest. For these reasons, we recommend development of programmes of gene conservation with the following objectives:

1) Sampling of genetic diversity: sampling strategies defined empirically or according to results obtained with molecular and quantitative markers.
2) Conservation of evolutionary mechanisms: the high genetic diversity of white oaks is the result of evolutionary mechanisms such as interspecific hybridization.
3) Conservation of oak ecosystems: humans have created ecotypes adapted to different management for wood production and acorn crops. Most of these management systems are neglected because foresters have undertaken conversion to high forest.
4) Conservation of endangered populations and minor species: marginal or endangered populations in Europe need conservation measures. The first step is to take a census, then define a policy for each situation.

In situ conservation methods should be generally preferred. If natural regeneration methods are not sufficient, an adapted and specified *ex situ* conservation programme including a controlled autochthonous reproductive material system (e.g. clonal seed orchards) should be used as well to preserve the endangered genepool.


Distribution range of pedunculate oak


Distribution range of sessile oak

EUFORGEN

These Technical Guidelines were produced by members of the EUFORGEN Temperate Oaks and Beech 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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