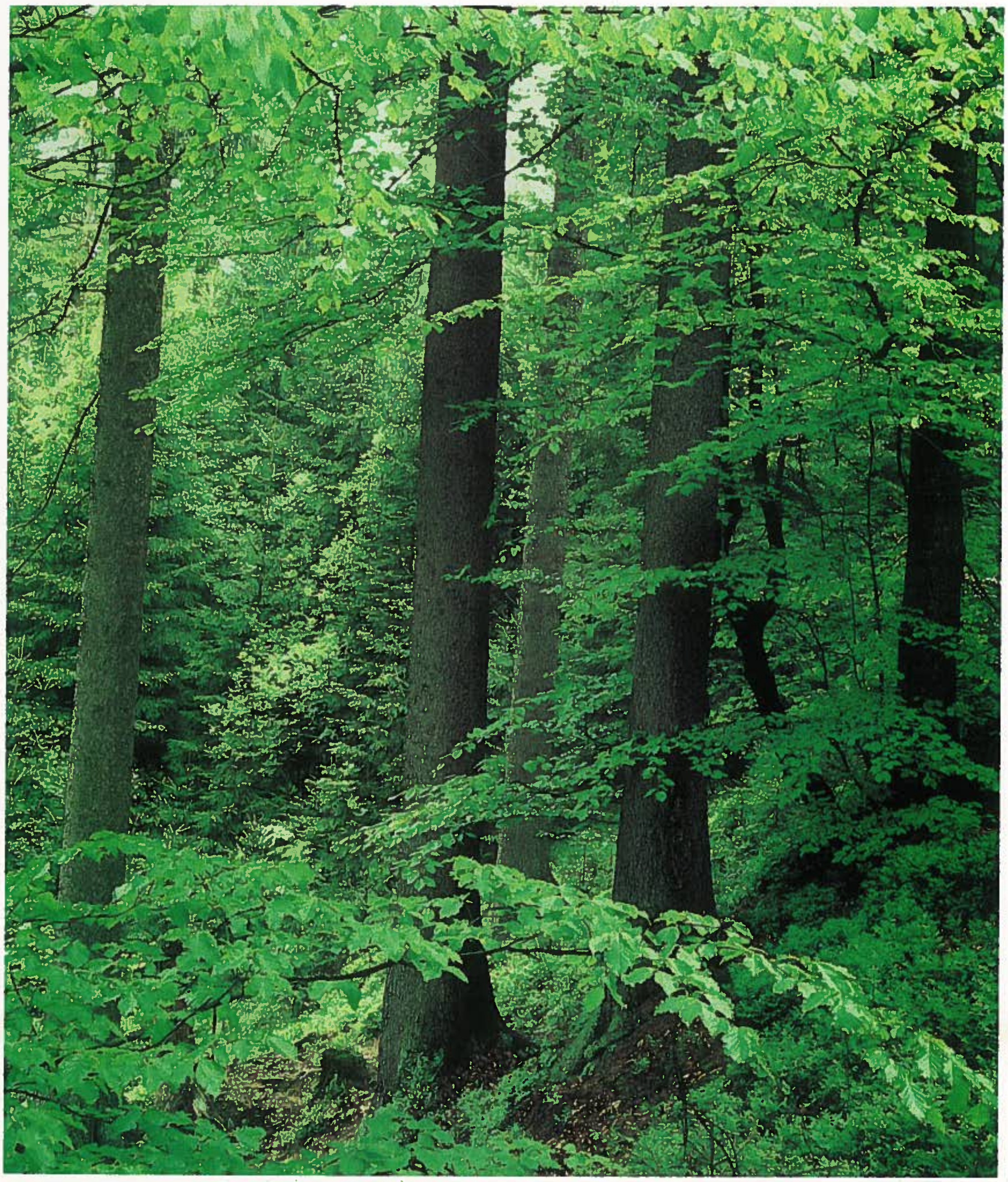
EUROPEAN FOREST GENETIC RESOURCES PROGRAMME (EUFORGEN)

First EUFORGEN Meeting on Social Broadleaves

EUFORGEN

23-25 October 1997
Bordeaux, France

J. Turok, A. Kremer *and* **S. de Vries,** *compilers*



International Plant Genetic Resources Institute
IPGRI

IPGRI is an institute of the Consultative Group on International Agricultural Research (CGIAR)

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The European Forest Genetic Resources Programme (EUFORGEN) is a collaborative programme among European countries aimed at ensuring the effective conservation and the sustainable utilization of forest genetic resources in Europe. It was established to implement Resolution 2 of the Strasbourg Ministerial Conference on the Protection of Forests in Europe. EUFORGEN is financed by participating countries and is coordinated by IPGRI, in collaboration with the Forestry Department of FAO. It facilitates the dissemination of information and various collaborative initiatives. The Programme operates through networks in which forest geneticists and other forestry specialists work together to analyze needs, exchange experiences and develop conservation objectives and methods for selected species. The networks also contribute to the development of appropriate conservation strategies for the ecosystems to which these species belong. Network members and other scientists and forest managers from participating countries carry out an agreed workplan with their own resources as inputs in kind to the Programme. EUFORGEN is overseen by a Steering Committee composed of National Coordinators nominated by the participating countries.

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Introduction

The first EUFORGEN meeting on Social Broadleaves was held from 23 to 25 October 1997 at the Station de Recherches Forestières (INRA) in Bordeaux-Cestas, France. Participants representing 23 countries attended the meeting (see List of Participants). They presented country reports, identified common needs, agreed on a joint workplan and established a Network concerned with the conservation and sustainable use of genetic resources in Social Broadleaves.

For the immediate future, the scope of the Network includes European white oaks (*Quercus robur, Q. petraea, Q. pubescens* and related species) and beech (*Fagus sylvatica, F. orientalis*).

The establishment of this Network – a fifth one within the framework of EUFORGEN – had been previously requested by the participating countries through their National Coordinators. It was felt that the existing Networks (Noble Hardwoods, *Picea abies, Populus nigra* and *Quercus suber*) do not cover adequately the European temperate oaks and beech, considering their importance, and in view of the specific gene conservation strategies they require. The coverage of species by the Network and its title will be addressed at the next Steering Committee meeting of National Coordinators (to be held in Vienna, Austria, 26-29 November 1998).

The common needs concern in particular:

- to improve information flow among countries
- to harmonize research priorities and disseminate available research results
- to address legislation-related issues
- to develop joint, long-term, practically oriented strategies and standardize or develop methodologies
- to raise awareness of decision-makers, the general public and forest owners about the necessity of conserving genetic resources of Social Broadleaves.

The participants of the meeting developed a common workplan with shared responsibilities. It aims at strengthening collaboration among European countries by providing practical outputs such as technical guidelines for the sampling, design and management of gene conservation units, databases, information resources and public awareness tools (see Workplan).

To obtain a comprehensive overview of the current developments, four participants were invited to deliver introductory presentations during the first part of the meeting. They reviewed the results of research on the genetic diversity of oaks and beech throughout Europe, summarized the concerns associated with oak decline and introduced the international network of beech provenance trials established recently. Overview presentations as well as country reports presented at the meeting are published in this volume.

The country reports typically include, but are not strictly limited to, information on the occurrence and origin of the European temperate oaks and beech in each country, their economic importance, silvicultural approaches used, health state of the forest stands and threats to their genetic diversity, genetic conservation activities, relevant nature protection policies and activities, tree-improvement, use of reproductive material, institutions involved, research capacities, needs and priorities for international collaboration. The order of the country reports is based on ecogeographic regions where these species can be characterized in a similar way as relevant to gene conservation. It does not imply any order of importance or priorities.

The meeting was held immediately after the French National Committee for the Conservation of Forest Gene Resources meeting. This enabled participants of both meetings to interact closely.

The participants of the meeting elected Dr A. Kremer (France) as Chair of the Network. Drs T. Geburek (Austria) and L. Paule (Slovakia) were elected to act as Vice-chairs.

Both research and practice of gene conservation in Social Broadleaves are fast evolving and have attracted significant attention in European countries during recent years. Regular Network meetings are foreseen to further the exchange of information and experience, to review the progress made in the implementation of the workplan and to coordinate action at the all-European level. The second meeting will be hosted by Switzerland in early 1999.

Workplan

Country reports

These will be completed according to the discussion at the meeting. They should be no more than 10 pages of text (standard format: Palatino font size 12, single line spacing). Figures and statistics (e.g. area occupied by the species, overview of conservation activities) should be given in additional tables. The reports should follow the structure outlined previously (see circular letter dated 1 October 1997). All participants will send their reports (electronic version and in printed form) to Jozef Turok for compilation and inclusion in the Report of the meeting **before 1 December 1997**. J. Turok will contact countries not represented in the meeting and ask for their input as well according to the agreed structure and deadline. The Report will be available **in April 1998**. It was agreed that the introductory presentations by A. Kremer, T. Oszako, L. Paule and R. Stephan also be included in the Report (to be submitted **no later than 1 February 1998**).

Synthesis of legislation and other regulations related to genetic resources of Social Broadleaves

This will be prepared by Sven de Vries on the basis of information available in the country reports. It will be presented and discussed **during the next Network meeting** (circulated one month before the meeting). Lennart Ackzell will send a copy of the latest version of the OECD and EU regulations to all participants.

Overview of ongoing research projects

An overview of the objectives, available results and collaborating partners of ongoing EU-funded projects, related IUFRO Working Parties and other relevant international projects will be compiled by Antoine Kremer (oaks) and Richard Stephan (beech) **before 1 February 1998**. A compilation of ongoing national projects and programmes related to genetic resources will be extracted from the country reports by J. Turok. Participants are, therefore, encouraged to collect and include information representing the whole research spectrum of their respective country. Both outputs will be included in the Report of the meeting.

Development of joint, long-term, practically oriented gene conservation strategies

This was considered to be the fundamental task of the new Network. A working group composed of Thomas Geburek (responsible for the task), Patrick Bonfils, Richard Stephan and Alexis Ducousso will send a questionnaire asking for information about methodologies currently used for the *in situ* and *ex situ* conservation in European countries. The questionnaire will be circulated **by 1 February 1998** and replies are to be sent back to T. Geburek **before 1 July 1998**. This basic information (empirical knowledge and experience available in countries) will lead to preparing a background document to be presented at the next Network meeting. The activity will help to identify topics where additional research is needed (spatial structure of diversity in gene conservation units, influence of silvicultural practices, etc.). The ultimate aim is to provide technical recommendations (guidelines) for the sampling, design and management of gene conservation units of oaks and beech. The draft background document will be circulated by T. Geburek **one month before the next meeting**.

Terminology

The terminology of the Network will be harmonized using the agreed Norway spruce glossary. All participants should send comments and additional terms they wish to include to J. Turok **by 10 November 1997**. The adjusted list will be circulated to all participants

before 20 November 1997, in order to facilitate the use of common terms in the country reports (to be submitted by 1 December 1997).

Descriptors and databases

Jan S. Jensen prepared a list of common minimum descriptors for Noble Hardwoods. This was recognized as a good starting point for Social Broadleaves as well. J. Turok will circulate this list to the participants **before 20 November 1997**. Comments should be sent directly to J.S. Jensen **by 1 March 1998**. The list will be discussed **at the next meeting** (circulated one month before the meeting). The objective is to provide a minimum common format for databases on gene conservation units at a national level. An international database may be set up later.

Public awareness

Awareness about the importance of the genetic resources of beech and oaks as cultural heritage will be promoted by the Network. Ioan Blada in collaboration with Jozef Turok will formulate a one-page draft about the importance of conserving genetic resources of oaks and beech and describing the role of the Network. J. Turok will send him the leaflet produced by Noble Hardwoods Network **by 10 November 1997**. The draft will be circulated by Ioan Blada **before 15 December 1997** and comments sent back to him by all participants **before 1 January 1998**. It will then be included in the Report of the meeting.

A collection of slides linked to the gene conservation of Social Broadleaves will be established. Dominique Jacques will prepare and circulate a letter with proposed topics to be covered by the collection. Ladislav Paule and S. de Vries will assist with organizing this Network's collection. It will be presented **at the next meeting** and completed afterwards.

Conclusion

The participants of the meeting elected A. Kremer as Chair of the Network. T. Geburek and L. Paule were elected to act as Vice-chairs. The host of the meeting, M. Arbez, INRA Station de Recherches Forestières in Cestas, was commended for the excellent organization of the meeting. Following several offers, it was agreed to hold the next meeting in Switzerland, in February-March 1999. The final dates will be announced.

Country Reports

Beech and oak genetic resources in Romania

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Occurrence and origin

According to the Romanian Forest Inventory (Anonymous 1984) the total forest area was 6 341 472 ha, including 6 223 416 ha of forests and 118 056 ha not covered by forested stands. The major broadleaved species are beech and oaks.

Fagus sylvatica is the most widespread broadleaved species, naturally distributed from low hills to mountains, i.e. between about 400 and 1400 m (Negulescu and Savulescu 1957). It covers 1 915 657 ha, or 30.8% of the forest area (Table 1). It grows mostly in pure stands of large extent, but is also mixed with other native species such as *Abies alba, Picea abies, Quercus petraea, Ulmus glabra, Acer pseudoplatanus*, etc. (Blada 1995). The species is characteristic with very good natural regeneration and therefore possesses a high genetic variability. It must be emphasized that Romania still has many virgin populations that should be protected for future generations.

Fagus orientalis has a sporadic distribution at low elevations, mostly in the southern part of the country but also in southern Transylvania (Stanescu *et al.* 1997).

Oaks (*Quercus* spp.) are widely distributed throughout the country, covering 1 339 065 ha, i.e. 18.5%.

The genus *Quercus* is represented by seven native species: *Quercus petraea, Q. robur, Q. pedunculiflora, Q. frainetto, Q. cerris, Q. pubescens* and *Q. virgiliana* (Georgescu and Moraru 1948; Stanescu *et al.* 1997).

Quercus petraea is the most widespread oak in Romania, covering 670 319 ha or 10% of the total forest area (Table 1). It is a native species distributed throughout the country, from low hills up to the lower part of the mountains. Its upper limit is 800 m in the eastern Carpathians, 1000 m in the southern Carpathians and 900 m in the western Carpathians (Negulescu and Savulescu 1957). It grows in pure and mixed stands together with *Fagus sylvatica, Quercus robur, Carpinus betulus* and several Noble Hardwoods.

Quercus robur is naturally distributed in lowlands but also in low hills, covering 139 856 ha. *Quercus pedunculiflora, Q. frainetto, Q. cerris, Q. pubescens* and *Q. virgiliana* cover 332 325 ha or 5.3% of the total forest area.

Table 1. Beech and oaks in Romania

Species	Total area: ha	Total area: %
Total forests	6 223 416	100.0
Fagus sylvatica	1 915 657	30.8
Quercus petraea	670 319	10.8
Quercus robur	139 856	2.3
Other *Quercus* spp.[†]	332 325	5.3
Total beech	**6 223 416**	**30.8**
Total oaks	**1 339 065**	**18.5**

† *Q. pedunculiflora, Q. frainetto, Q. cerris, Q. pubescens, Q. virgiliana.*

Economic importance

Beech and oaks are very important in several industries. They also play a major role in reforestation. Details are given in Table 2.

Table 2. Economic importance of beech and oaks in Romania

Use	Beech	Oaks
Silviculture for reforestation	+	+
Furniture industry (with or without veneer)	+	+
Paper industry	+	–
Leather industry (tanning)	–	+
Chemical industry (acetic acid, methylic alcohol, tar)	+	–
House, boat, vehicle manufacture	–	+
Flooring and interior finishes	+	+
Handicrafts and woodwork goods	+	+
Fuel	+	+
Landscaping	+	+
Cooperage (barrel/butt), railway sleepers manufacture	+	+
Woodwheel manufacture	–	+
Plywood	+	–

Silvicultural approaches used

- Exclusively natural regeneration for beech.
- Natural regeneration combined with artificial regeneration (planting but no coppice) for oaks.

Health state of the stands and threats to their genetic diversity

According to Patrascoiu *et al.* (1985), the present health state of beech and oaks is as follows.

Beech has a good to very good health state and there is no threat to diversity.

The situation is different for oaks:

- not very good health state for *Q. petraea*, poor for *Q. robur* and *Q. pedunculiflora* and very poor for *Q. cerris*, *Q. frainetto*, *Q. pubescens* and *Q. virgiliana*
- negative factors: drought, pollution, defoliating insects, vascular diseases, seed predators, unsuitable silvicultural approaches (coppice) used in the past
- negative effects: slow growth, lack of fructification, decline in health state, death of some populations (Blada, unpublished)
- genetic diversity threatened at population level for all oaks but mainly *Q. cerris*, *Q. frainetto*, *Q. pubescens* and *Q. virgiliana*.

Research activities and tree improvement

The following research activities are under way:

- Research on natural regeneration in both beech and oaks to maintain the genetic diversity of ancestral populations.
- Research on genetic variation at population level. Thirteen provenance trials were laid out about 20 years ago, five in *Quercus petraea* and eight in *Q. robur*. Two international beech trials were planted in 1996 (Table 3).

The aim of these studies was to detect the best provenance for reforestation and to determine what transfer between regions is possible without loss of adaptability, resistance, yield and quality.

Needs for better research in the future:

- More comprehensive provenance trials, for all regions of provenance, in both beech and oaks.
- Besides field testing, new and modern techniques should be applied (isoenzyme and DNA analyses) to describe genetic diversity; at present the necessary equipment is not available.

Tree-improvement activities consist of the phenotypical selection of plus trees and establishment of seed orchards.

Table 3. Provenance trials

Species	Number of: Trials	Provenances	Area (ha)
Quercus petraea	5	33	4.5
Quercus robur	8	27	7.7
Fagus sylvatica[†]	2	44	4.0[‡]
Total			16.2

[†] International trials. [‡] Approximately.

Conservation of genetic resources

According to the Romanian Forestry Law (Anonymous 1996) all forests are to be managed according to the following principles:

- sustainable, close-to-nature and multifunctional forest management, for dynamic gene conservation
- active protection and conservation of the biological diversity of forests
- support of the biological and economic stability and continuity of forests, by promoting natural regeneration and improving the planting stock
- natural regeneration supported in all forests, where possible. If seedlings are used, they should derive from adequate seed sources, and only suitable species/ provenances can be used.

Upon this basis the Forest Research and Management Institute in Bucharest initiated a national programme devoted to the conservation of genetic diversity in forests. The main objective of the programme was the conservation and utilization of the genetic adaptability of forest tree populations. According to the OECD regulations, Romania was divided into regions of provenance, and consequently, the transfer of the reproductive material between these regions must be done according to OECD rules (Enescu *et al.* 1988).

In situ *conservation*

The goal of *in situ* conservation in beech and oaks is to maintain the evolutionary genetic adaptability of populations over generations. For beech, most of the original natural populations are still present in Romania, but it is not the case in oaks where many populations were lost for various causes.

According to Koski (1997) a successful *in situ* gene conservation must fulfil certain fundamental prerequisites:

- a network of gene conservation stands is to be created with sufficient coverage of the spatial genetic variation of the species
- the number of individual genotypes per population must be large enough to include most of the genepool existing in the respective population
- the system of regeneration must maintain the population, and the regeneration stock should predominantly originate from matings within the respective population.

All the following activities of gene conservation in beech, and partially in oaks, took into consideration the above prerequisites.

Selected seed stands

To be considered for conservation, a forest stand had to be representative of the natural populations, and regenerated naturally. These requirements were fully met for beech and in most cases for oaks.

According to the national register (Enescu 1986), to date 1085 *in situ* conservation (i.e. seed) stands are declared as forest genetic resources, comprising a total area of 34 179 ha (Table 4). Taking into consideration beech and oaks separately, it can be noted that:

- out of the 1085 seed stands, 871 were oaks and and 214 beech
- out of a total area of 34 179 ha, 26 057.8 ha (76%) represent oak while 8 121.2 ha (24%) represent beech
- out of a total area of 26 057.8 ha of oak, 25 077.7 ha (96%) represent natural populations and only 980.1 ha (4%) represent artificial ones
- no artificial beech population was selected.

It must be stressed that a new inventory of the seed stands is under way and will be finished in 1999.

Table 4. Selected seed stands

Species	Total stands (no.)	Total area (ha) *In situ*	Total area (ha) *Ex situ*	Total (ha)
Fagus sylvatica	214	8 121.2	0	8 121.2
Quercus petraea	498	17 056.8	352.6	17 409.4
Quercus robur	211	4 658.8	535.7	5194.5
Quercus cerris	69	705.1	6.7	711.8
Quercus frainetto	46	1 851.9	0	1 851.9
Quercus pedunculiflora	41	785.3	85.1	870.4
Quercus pubescens	6	19.8	0	19.8
Total *Fagus*	214	8 121.2	0	8 121.2
Total *Quercus*	871	25 077.7	980.1	26 057.8
Total	**1085**	**33 198.9**	**980.1**	**34 179.0**

National parks and biosphere reserves

In addition to seed stands, beech and oak genetic resources are also conserved in 13 national parks and biosphere reserves covering 397 761 ha or 2.3% of the total forest area (Table 5). These forests are allowed to develop with almost no human interference, leaving the trees to reach their natural age and leaving dead wood in the forest. The forests serve as nature reserves and research populations. The structure and development of such forests are being analyzed and results from these studies used to establish guidelines for close-to-nature silviculture. It must be stressed that because of their large areas, national parks and biosphere reserves include almost all native species; therefore they represent significant reserves.

Table 5. National parks and biosphere reserves

Local name of the park	Area (ha)
Retezat (Biosphere Reserve)	54 400
Rodna (Biosphere Reserve)	56 700
Domogled - Valea Cernei (National Park)	60 100
Cheile Nerei - Beusnita (National Park)	45 561
Apuseni (National Park)	37 900
Bucegi (National Park)	35 700
Semenic - Cheile Carasului (National Park)	30 400
Ceahlau (National Park)	17 200
Cozia (National Park)	17 100
Calimani (National Park)	15 300
Piatra Craiului (National Park)	14 800
Cheile Bicazului (National Park)	11 600
Gradistea de Munte (National Park)	1 000
Total	**397 761**

Conservation units

The areas covered by gene reserves are supposed to be large enough to conserve the genetic structures and allow evolution of the population to continue. Since pollen contamination from outside sources is undesirable, the core area should be surrounded by a wide buffer zone.

An inventory of this category started in 1993 and will be finished in 1998. By the end of 1996 the following results were available (Lalu and Nicolescu 1996):

- 347 units were selected in 42 counties, each unit consisting of a core area and a surrounding buffer zone
- the total core area, at the country level, was 11 304 ha, with an average of 33 ha per core area
- genetic reserves represented 0.17% of the total national forest area
- the total buffer zone was 25 805 ha.

The major criteria for selecting these units were origin, timber production and quality, health state and adaptability to environment. Such gene reserves contain the principal forest tree species including beech, oaks and Noble Hardwoods.

Ex situ *conservation*

According to Enescu *et al.* (1989), 1004 ha of clonal and seedling orchards of selected plus trees were established in Romania.

Out of the 1004 ha, 87 ha belong to oak species. No seed orchards were established for beech, because in this country it is regenerated only naturally.

Provenance trials represent another method of *ex situ* conservation. As mentioned earlier, 16.2 ha were established (12.2 ha of oaks and 4 ha of beech) (Table 3).

Beech and oak trials are not sufficient, and more trials should be established.

Use of reproductive material

Reproductive material is used according to the Romanian Forestry Law 'Codul Silvic' and the OECD rules. According to these regulations, the reproductive material must be collected from selected seed stands and seed orchards, taking into consideration that:

- seed collecting must be done only in years of good fructification, where more than 50% of the trees have a good crop
- the number of individuals chosen for seed collecting should be more than 100
- seed collecting must be overseen by a specialist
- all significant details about the population from which the seed was collected must be recorded.

Institutions involved in genetic resources activities

The following institutions are currently involved in the conservation and utilization of forest genetic resources:

- the Ministry of Waters, Forests and Environment Protection, through its Department of Forests
- ROMSILVA - The Romanian National Company of the Forests
- Forest Research and Management Institute
- The Romanian Academy of Sciences.

Country priorities and capacities

- Restoration of genetic diversity in oaks, mainly in the southern part of the country, where many populations disappeared or are in decline.
- Stimulation of fructification in oaks, in both seed stands and seed orchards – the constraint is lack of 'know-how'.
- Long-term *ex situ* conservation or storage of oak acorns – the constraint is no facilities.
- *In situ* and *ex situ* conservation of the most representative oak populations.
- Creation of artificial mixed stands of oaks with other species, preferably Noble Hardwoods; also, re-introduction of shrubs should be supported.
- Description of genetic diversity within populations of the main species by using modern techniques (genetic markers).

Current international collaboration

The following collaborations are under way:

1. Project 'Genetics and improvement of forest trees', cooperation between INRA (France) and the Forest Research and Management Institute, Bucharest.
2. Project INCO-COPERNICUS 'Geographic map of oak gene diversity at an European scale for conservation and utilization of genetic resources'.
3. Project 'Genetic resources of broadleaved forest tree species in southern Europe', cooperation between IPGRI, Luxembourg, Bulgaria, Moldova and Romania.

Needs for international collaboration

Without international support, the Forest Research and Management Institute from Bucharest cannot solve the following:

1. Conservation/storage of oak acorns for at least 2 years; lack of know-how and facilities.
2. Genetic inventories based on genetic markers (isoenzymes, DNA), because there are no specialists and facilities and because the financial situation of our Institute is very difficult.
3. Construction of geographic maps based on the genetic differences (chloroplast DNA analyses).

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Present status of the conservation and use of broadleaved forest genetic resources in Moldova

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The total forest fund occupies 11.7% of Moldova's territory (394 400 ha), including 325 400 ha covered by forests (9.6% of the territory). The total growing stock is 35.14 million m^3 constituting only 8.1 m^3 of timber stock and 0.075 ha of forest land per capita.

The state forest organizations manage 345 600 ha or 87.5% of the total area, of which 295 300 ha (or 85.6%) are covered with forests. The rest of the area, which is made up of 48 800 ha or 12.4% of the territory, is managed by municipalities and agricultural farms.

The principal species in the natural forest are oaks, which occupy 140 500 ha. Three species of oaks occur: *Quercus petraea* (Matt.) Liebl., *Q. robur* L. and *Q. pubescens* Willd. Forest types are distributed according to the zonal and vertical division of the territory. Forest associations of *Q. petraea* occupy watersheds and slopes of different expositions in the central part of Moldova (180-400 m). *Quercus robur* occupies sites of low relief. In the northern part of the country natural forests predominate. Forest associations of *Q. pubescens* are widespread in the south. European beech (*Fagus sylvatica)* grows only in the central part of Moldova.

Thus, in spite of the small territory occupied by forests, the forest vegetation is rather diversified. Twelve 'zonal' and six 'azonal' types of forests were recognized (Gheideman *et al.* 1964; Postolache 1995).

According to the forest planning inventory (1985) the area of forest stands, which do not correspond to the ecological site conditions, constitutes around 40% of all the forests. Ninety-five percent of this area is covered by species such as *Robinia pseudo-acacia* (52%), ash (15%) and hornbeam (8%).

A tendency to invasion by the introduced maple tree (*Acer negundo)* was noticed in the meadow forests in the valleys of the Nistru and Prut rivers. This maple species invades mainly willows and poplar stands. Reconstruction and careful silvicultural management are now carried out with the aim of re-establishing the original stands (including native oaks).

The health condition of many forest stands worsened considerably recently. The average annual surface of forests damaged by defoliating insects constitutes 50 000-70 000 ha (16-22% of the area occupied by forests); this area has to be subjected to some active measures of control every year.

Droughts, frosts and reduced biological resistance of some forest plots lead to the further spreading of pathogens and overall decline.

The natural regeneration of most oak stands is satisfactory (Ivanov 1962), and most stands were regenerated in this way. Natural regeneration is very difficult in the damaged or declining stands.

In the application of natural regeneration, priority is given to stands which consist of native species, thus contributing to gene conservation. Artificial regeneration methods were applied after clear-cutting, successive logging, etc. The application of different methods of regeneration aims at achieving a structure similar to that of natural forests.

Forest plantations have been created during the last 50 years on a total area of 171 000 ha. Forest stands (113 000 ha) and forest belts (21 000 ha) have been planted.

The concept of creating stands similar to the natural ecosystems through the use of the native species was established. The origin of forest reproductive material for the creation of more productive and resistant forest plantations in extreme ecological conditions was recognized and controlled. That is why conservation of the forest genetic resources is one of the principal objectives of our silviculture.

Other measures of forest gene conservation were initiated:

- designation and conservation of most valuable forest stands
- identification and conservation of some rare species
- conservation of trees with exceptional qualities
- creation of genetic collections of valuable species, subspecies, clones, etc.
- conservation of seeds, pollen, meristem, etc. of valuable genotypes.

Three forest reserves, five nature reserves, 10 protected natural landscapes and 22 'natural monuments' were designated by the Government of Moldova with the aim of conserving valuable forest stands, rare species and their populations.

Most valuable stands of beech and oak (*Q. petraea*, *Q. robur*) are conserved within three reserves: Codrii, Plaiul Fagului and Pădurea Domnească.

Local valuable populations which were not contained within the reserves were distinguished as an independent protected category of stands. These are represented by valuable populations from the standpoint of timber production, genetic properties, etc.

The reserves with large surfaces give the possibility to protect and conserve species in different types of forests.

The establishment of forest plantations on the basis of ecological genetics is a central issue in creating new forests. Great attention is being paid to this issue.

The old trees are a particular category of conservation of forest resources. Owing to favourable ecological conditions and their valuable genotype, old trees are distinguished by vitality and resistance to extreme conditions. They are characterized by a larger size, height and diameter. The total of 372 old trees identified in the Republic of Moldova included 265 *Quercus robur*, 10 *Q. petraea* and 10 *Fagus sylvatica*.

The creation of clonal archives and collections of some valuable tree species is another form of conservation of the forest genetic resources. Clonal archives of some valuable forms of oak trees were created in the forest enterprises of Bender and Străşenni.

Until now, the species forming natural populations – beech, *Fagus sylvatica* (Istrati 1975); oak, *Quercus robur* (Cuza 1994; Gumeniucm *et al.* 1994) and cherry tree, *Prunus avium* (Gumeniuc 1987) – have been studied. Following from this research, recommendations were formulated for division of the forest into seed districts for oak, and for the creation of a forest 'seed base'.

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Conservation of genetic resources of Social Broadleaves in Ukraine

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Occurrence and origin of oaks and beech

Ukraine is not very rich in forests. Only 14.2% of its territory is covered by forests, with a total forest area of 8.6 million ha. Because of the diversity of climatic conditions, the distribution of the forests over the country's territory is quite irregular. Usually, five natural zones are differentiated: mixed forests, forest-steppe, steppe, and the mountain regions of the Carpathians and the Crimea. The major part of the forests is concentrated in the Carpathians and the mixed forests zone where they occupy 37.5 and 29.8% of the territory, respectively. In the relatively small territory of the Crimea, 28.7% is forests. Only small forest areas can be found in the forest-steppe and steppe zones. In these zones the land covered by forest amounts only to 12 and 4%, respectively.

The species composition of Ukrainian forests is diverse. The forests with predominance of Social Broadleaves occupy just above 2 million ha, of which 1.69 million ha are forests with a predominance of oaks.

The range of *Quercus robur* covers almost all the plain territory of Ukraine. The forests with predominance of this species occupy 27% of the total forest area (1.57 million ha). In the Carpathian region *Q. robur* grows on foothills and reaches the altitude of 500 m asl.

The forests with predominance of *Quercus petraea* are concentrated in the southwestern regions and in the Crimea. They reach the altitude of 700 m in the Carpathians, some stands reaching 1000 m. *Quercus petraea* grows on poorer soils, where *Q. robur* and *Fagus sylvatica* cannot compete. *Quercus petraea* stands occupy 20 000 ha in the Carpathians.

The forests with predominance of *F. sylvatica* occupy 560 000 ha. They are situated in the mountain regions of the Carpathians and the Crimea. Most beech forests (524 000 ha) are concentrated in the western regions of Ukraine. About 80% of the beech forests grow in the mountain regions of the Carpathians (420 000 ha, 38.3% of all forests of this region). Beech is the principal forest tree there. It grows from 150 to 1300 m asl.

It should be pointed out that the taxonomic position of the Crimean beech has not been explained until now. Poplavskaja (1928, 1936) described this beech as a distinct species – *Fagus taurica* Popl. Some time later the beech populations from the lower zone of the Crimean mountains were more frequently described as *Fagus orientalis* Lipsky and from the upper one as *F. taurica* (Molotkov 1966; Milescu *et al.* 1967). Sometimes the Crimean beech stands are described as a mixture of individuals of *F. sylvatica* and *F. orientalis* with the occurrence of several hybrid forms (Wulff and Tsyrina 1925) or as stands formed predominantly by *F. orientalis* with an admixture of *F. sylvatica* (Privalova 1958). Several authors consider it to be a transitional form between *F. sylvatica* and *F. orientalis*, which is morphologically closer to *F. orientalis* (Czeczott 1932, 1933), or as a subspecies identical to the Balkan beech *Fagus sylvatica* subsp. *moesiaca* (Maly) Cerny. (Didukh 1992, 1997). It should be noted that all the authors based their classifications exclusively upon morphological characters.

Current economic importance for the forestry sector

The wood of *Q. robur*, *Q. petraea* and *F. sylvatica* is widely used in furniture, aircraft, shipbuilding, the chemical industry, buildings, etc. because of its high mechanical and aesthetic characteristics.

Presently the wood of oak and beech is widely exported, particularly to countries of western Europe (some 25% of the total export of forestry production).

Silvicultural approaches used

The forests of Ukraine are subdivided into two groups. The forests of the first group (I) represent 50.1% of the forests and they perform protective functions. These are forests of green zones around the cities, water-protective forests, soil-protective forests, roadside belts and reserves. The management carried out in these forests aims at their conservation and enhancing their protective role. The commercial forests, which are the main source of wood, comprise the second group (II).

Oaks and beech are the principal tree species. They predominate in natural stands in the forests of groups I and II. These species are widely used for the establishment of artificial stands in suitable soil and climate conditions.

Health state of the forest stands and threats to genetic diversity

An important part of oak stands has low resistance to biotic and abiotic factors at present. Climatic factors, particularly droughts, play a major role in the weakening of 45.9% of oak stands affected by decline. Unsuitable forest management measures were the cause of decline in 6.5% of oak stands. The majority of these stands originated from vegetative reproduction.

Diseases cause weakening of 15.6% of declined oak stands, and 17% of declined stands were affected by defoliating insects, which are the main factor of damage in Ukrainian forests.

The considerable extent of forest harvesting in mountainous conditions reflected on the state of Social Broadleaves forests of the Carpathian region. Many high-quality beech stands were replaced by pure spruce stands regularly subjected to wind and snow breakage, diseases and insect pests. This resulted in disequilibrium of the forest ecosystems.

Research activities and capacities related to genetic resources/diversity

The Laboratory of Forest Tree Breeding, Research Stations and Carpathians branch of the Ukrainian Research Institute of Forestry and Forest Melioration have worked for a long time on the problem of conservation and rational use of the forest genetic resources. In the 1960s some research on the selection of plus trees was carried out under the guidance of Prof. Piatnitsky. Subsequently the investigations were oriented toward the creation of a constant seed-production base for the principal forest species under the guidance of Prof. Molotkov. All this research covered all regions of Ukraine and included programmes for gene conservation *in situ* and *ex situ*:

- surveys of natural forest and selection of gene reserves, plus trees and seed stands, including research on population structures, genetic diversity and the dynamics of taxation indexes
- creation of clonal archives of plus trees at experimental stations
- creation of seedling and clonal seed orchards
- creation and study of progeny tests of the best-performing trees and stands.

Social Broadleaves hold a prominent place in this research.

Current genetic conservation activities *in situ* and *ex situ*

Since the early 1980s, gene reserves have been designated as follows: 6789.1 ha for *Q. robur*, 265.2 ha for *Q. petraea* and 2820.4 ha for *F. sylvatica*. The distribution of gene reserves in Ukraine is given in Table 1. The largest reserve areas are concentrated in forest regions.

Presently the inventory of gene reserves is being undertaken. This will provide the opportunity to estimate the current situation of genetic resources.

For several years, studies on European beech diversity in the Carpathian region and adjacent territories have been carried out by the Ukrainian State University of Forestry and Wood Technology (Lviv), together with Technical University in Zvolen, Slovakia. Genetic diversity and differentiation of beech populations (20 European beech and 7 Crimean beech) have been studied by electrophoresis.

Genetic differentiation was estimated on the basis of genetic distances. The results confirm a low degree of differentiation within *F. sylvatica* compared with *F. orientalis*, the values of subpopulation differentiation of European beech populations being only approximately 30% of the differentiation among *F. orientalis* populations. Within European beech populations from western Ukraine a slight differentiation between populations from the southwestern and northeastern macroslopes of the Carpathians, and plain populations from the northeastern limit of beech distribution range was observed. Crimean beech is also much more differentiated than Carpathian beech. Crimean beech occupies an eccentric position between both beech species; however, it is much more similar to *F. orientalis* than to *F. sylvatica* (Paule *et al.* 1993; Vyšný *et al.* 1995; Gömöry *et al.* 1998a, 1998b).

The intensity of reproduction in beech root meristem cells was examined in cytological studies by the University together with the Institute of Forestry and Forest Melioration. The results led to the conclusion that some differences exist in the mitotic activity of root meristem cells of beech seedlings from different populations. Since the mitotic kinetics of the meristematic cells of all plants depend not only on external factors but also on internal factors, it is quite possible that the results reflect the genetic diversity between populations (Kyrychenko *et al.* 1995).

Clonal propagation of European beech and sessile oak is studied at the Laboratory of Tissue Culture. For this purpose explants were taken from different vegetative and generative plant parts of beech (buds of different-aged trees, hypocotyls, cotyledons) (Bazyuk and Fedyaj 1995).

Relevant nature protection policies and activities

Among the legislative acts related to conservation of genetic resources, the Law on Natural Reserves of Ukraine (of 5 May 1993) is in force. According to this law any activity which might affect negatively the state of protected areas is forbidden. The Committee of Environmental Protection is the administrative unit specialized in this field. The protection is implemented by the institutions on the territory in which they are situated. Protection of forest areas is carried out by regional forest offices.

Table 1. Gene reserves of Social Broadleaves in Ukraine

	Quercus robur		*Quercus petraea*		*Fagus sylvatica*	
Natural zone	**Area (ha)**	**Number**	**Area (ha)**	**Number**	**Area (ha)**	**Number**
Mixed forest	2526.3	80	52.4	1	2.0	1
Forest-steppe	3935.8	160	29.0	2	1789.8	60
Steppe	269.0	1	128.0	7	0.0	0
Carpathians	58.0	1	22.1	2	1028.6	7
Crimea	0.0	0	33.7	4	0.0	0
Total	6789.1	257	265.2	16	2820.4	68

Tree-improvement activities

Research activities on the conservation of genetic resources are usually associated with tree breeding. Conservation of genetic resources aims at the reproduction of genetic diversity in the most valuable trees and stands on a broad scale for the creation of productive and stable forests.

The phenotypically best-performing and most productive stands were classified as seed stands. Plus stands of Social Broadleaves occupy 1758.6 ha. Among them *Q. robur* is represented by 1588.6 ha, *Q. petraea* by 30.2 ha and *F. sylvatica* by 139.8 ha (Table 2). By now 1564 plus trees of Social Broadleaves have been selected in the stands of Ukraine. Among them *Q. robur* is represented by 1212 trees, *Q. petraea* by 165 trees and *F. sylvatica* by 181 trees. Forest management in these stands should be carried out in such a way to ensure the conservation of the genetic information.

Clonal archives were created for the conservation and study of the plus trees. There are 23.1 ha of clonal archives of *Q. robur* and 0.6 ha of *Q. petraea* in Ukraine. The seedling and clonal seed orchards were created on large areas to provide forestry with seeds. Another objective of the creation of seed orchards is gene conservation. The distribution of the seed orchards over the territory of Ukraine is given in Table 2. The total area of clonal seed orchards of *Q. robur* amounts to 492.8 ha, the seedling seed orchards to 60.2 ha. Seed orchards of *Q. petraea* and *F. sylvatica* are small, and need to be extended.

Research on the inheritance of useful traits of Social Broadleaves is carried out through progeny tests. The areas and numbers of the progenies in the progeny tests are shown in Table 2. Progeny tests of *Q. robur* occupy an area of 32.05 ha where 852 progenies are tested. Progeny tests of *Q.petraea* are limited (6.4 ha, 134 progenies). The trees and stands whose progeny had the best growth performance and high adaptability were selected.

From the beginning of the century to the present, 12 plots of provenance tests of *Q. robur* were established in Ukraine on a surface of 69.3 ha (323 provenances). The bulk of the area is concentrated in the forest-steppe region (Table 2). As for *F. sylvatica* there is only one provenance trial zone (1.2 ha) in the Carpathians, where 45 provenances of this species are represented. The delimitation of seed zones is developed on the basis of the provenance tests and altitudinal-ecological studies. In 1995, on the territory of an experimental training forest of the Ukrainian State University of Forestry and Wood Technology, a provenance test of European beech were established on an area of 2.4 ha, where 70 provenances of the species were represented from western, central, southern and eastern Europe. These studies are carried out within the framework of the European Network on the Evaluation of Genetic Resources of Beech, and are coordinated by the Institute for Forest Genetics and Forest Tree Breeding in Grosshansdorf (Germany) (see von Wuehlisch *et al.*, this volume).

The Laboratory of Forest Tree Breeding carries out similar studies. We study the growth, morphology, phenology and reproduction of *Q. robur* in the clonal seed orchards and in progeny tests. A compilation of morphological descriptors for *Q. robur* is under way. Differences between clones are studied by using biochemical analyses of the phenolic compounds. A test for selection of biotypes in different seed zones and technologies for collecting, storage and grafting have been developed. Seed orchards have also been established.

Use of reproductive material

The reproductive material from valuable stands is used for natural regeneration and for establishment of artificial stands. Artificial plantations are created for the conservation of the most valuable stands and trees. The main part of seeds in these cases is produced in seed orchards (see section on Tree improvement). The clonal seed orchards of oak begin to produce seed when 15-30 years old, and beech at 20-50 years old. The average seed crop of the *Q. robur* seed orchard is almost 300 kg/ha. In the majority of cases the seedlings are grown in nurseries for 2 years and then are planted out. Vegetative material is used for creation of the clonal seed orchards.

Table 2. Tree improvement activities of Social Broadleaves in Ukraine

Species and natural zone	Seed stands (ha)	Plus trees (no.)	Clonal archives (ha)	Clonal seed orchard (ha)	Seedling seed orchard (ha)	Progeny tests: Area (ha)	Progeny tests: No. of progenies	Provenance tests: Area (ha)	Provenance tests: No. of progenies
Quercus robur									
Mixed Forest	330.3	294	11.0	76.9	15.0	1.5	52	0.0	0
Forest-Steppe	1224.7	459	18.2	382.0	35.2	27.1	634	47.4	215
Steppe	30.3	323	5.6	28.6	10.0	3.5	119	9.5	60
Carpathians	3.3	138	0.0	5.3	0.0	0.0	0	12.4	48
Total	**1588.6**	**1214**	**34.8**	**492.8**	**60.2**	**32.1**	**805**	**69.3**	**323**
Quercus petraea									
Mixed Forest	27.0	4	0.0	0.0	0.0	0.0	0	0.0	0
Forest-Steppe	0.0	35	0.0	0.0	0.0	0.0	0	0.0	0
Steppe	2.6	1	0.6	0.0	0.0	0.0	0	0.0	0
Carpathians	0.6	59	0.0	1.2	0.0	1.0	14	0.0	0
Crimea	0.0	99	0.0	0.0	0.0	5.4	120	0.0	0
Total	**30.2**	**198**	**0.6**	**1.2**	**0.0**	**6.4**	**134**	**0.0**	**0**
Fagus sylvatica									
Mixed Forest	0.0	0	0.0	0.0	0.0	0.0	0	0.0	0
Forest-Steppe	87.6	134	0.0	2.0	16.0	0.0	0	0.0	0
Carpathians	52.2	41	0.0	1.2	0.0	0.0	0	1.2	45
Crimea	0.0	12	0.0	0.0	0.0	0.0	0	0.0	0
Total	**139.8**	**187**	**0.0**	**3.2**	**16.0**	**0.0**	**0**	**1.2**	**45**

Institutions involved in genetic resources activities in Ukraine

The Ukrainian Institute of Forestry and Forest Melioration (Kharkiv) is the leading research institution working on the conservation of forest genetic resources in Ukraine. This Institute has a network of Research Stations covering the whole country. The regional Ukrainian Research Institute of Mountain Forestry (URIMF, Ivano-Frankivsk) was created on the basis of the Institute's Carpathian branch in 1993. In the Carpathians, related investigations are also carried out by the Ukrainian State University of Forestry and Wood Technology (Lviv).

Summary of country capacities and priorities

The forests of Ukraine have a valuable genepool of Social Broadleaves which needs to be studied, conserved and reproduced. The best-performing natural stands were selected and a network of clonal archives, seed orchards, provenance and progeny tests established in previous years. On the other hand, the activity of the mentioned institutions in the field of conservation of genetic resources is considerably limited by the lack of funds.

Since in the past more emphasis was placed on the conservation and study of plus trees, now it is necessary to focus on study and conservation of the most valuable populations. The majority of gene reserves was selected in the early 1980s; thus it needs repeated inventory with biochemical, cytological and molecular genetic methods. Unfortunately, the lack of financial support resulted in a decrease in research activities and in the impossibility of applying modern methods requiring expensive equipment.

Needs for international collaboration

Undoubtedly the mentioned institutions need international collaboration related to the conservation of genetic resources. In addition to exchange of information and participation in meetings, the scientific potential of Ukraine should be drawn upon and utilized within the framework of European programmes and projects. The following measures are needed for the consolidation of international cooperation:

- exchange of databases
- exchange of information on research activities and legislation
- exchange of reproductive material
- establishment of an international network of provenance tests and altitudinal-ecological studies
- establishment of an international network for the monitoring of genetic resources
- development of fellowship programmes in the field of molecular genetics.

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Conservation of genetic resources of white oaks and beech in Hungary

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Introduction

Hungary is situated in the central, lowest part of the Carpathian basin. Out of the total area of 93 000 km^2, only slightly more than 2% of the country's area is above 400 m altitude. Hills of low elevation, and medium-high mountains between 200 and 400 m occur on 14% of the territory. The two lowlands bear a certain similarity of appearance with the loess-covered Sarmatian plains of eastern Europe. The topographical regions and natural zones of the country are the Great Plain (S and E), the Small Plain (NW), the Subalpine region (W), the Transdanubian Hills (SW), the Transdanubian Central Mountains (mid-W) and the Northern Central Mountains (NE).

The country lies in the temperate zone, at the meeting point of three large climatic regions. The continental climate of the eastern European plains is characterized by extremes such as hot summers, cold winters and medium precipitation; the well-balanced, cool Atlantic climate has cool summers and mild winters; and finally the Mediterranean climate is characterized by hot, dry summers and mild, rainy winters. The Hungarian climate is therefore very diverse.

The natural plant cover of Hungary is extremely variable and rich in species.

Origin and occurrence of oaks and beech in Hungary

Introduction to Hungarian oak taxa

Although oaks are still the most widespread tree species in Hungary, their taxonomy and genetics are not yet sufficiently known. Oaks can be found under a great variety of site conditions and tend to form different races. Transitional forms between species are very common too. This is partly because, except for *Quercus cerris*, oaks hybridize among themselves. In addition, variability of important traits, such as early flowering and bud burst, is similarly observable.

It is generally recognized that the Hungarian oak taxa belong to the white oaks in a broader sense (subgenus *Quercus s. lat.*), in particular to two groups, usually designated as section *Cerris* (here *Q. cerris* only) and section *Quercus s. str.* (here *Q. robur*, *Q. petraea*, *Q. pubescens* and rare species of *Q. frainetto*). Within *Q. petraea* and *Q. pubescens* further taxonomic subdivision has been advocated by numerous botanists, but is not yet accepted by forestry practice.

Accordingly, *Q. petraea s. lat.* is divided into *Q. dalechampii* Ten., *Q. polycarpa* Schur and *Q. petraea s. str.*; and *Q. pubescens s. str.* is differentiated from *Q. virgiliana* Ten.

Pedunculate oak

The species has been exposed to very intense human effects (seed transfer, artificial regeneration, selective logging). In central Europe, and first of all in Hungary, pedunculate oak of Slavonian origin has been extensively planted since the end of the last century. Although the Slavonian populations can be easily distinguished by their exceptionally straight stem, relatively regular crown and upward pointing branches, recent genetic investigations do not justify the separation of this provenance from other populations in central Europe.

Sessile oak

Three small species belong to the classical sessile oak species.

- *Quercus petraea s.str.* is an Atlantic species occurring jointly with hornbeam and thriving on cooler mountain slopes with seeping water supply.
- *Quercus dalechampii* is the species of the southern slopes, often associated with *Q. cerris*. This species reaches the northern limit of its distribution in Hungary.
- *Quercus polycarpa* is also a southern-type species. Its ecological features resemble those of pubescent oak, and it often grows mixed and intercrosses with other oaks.

Pubescent oak

Pubescent oaks inhabit the extremely dry, calcareous mountain slopes. These sites have been mostly planted with Austrian pine in recent decades. *Quercus pubescens* and the less known *Quercus virgiliana* are, however, very valuable because of their tolerance to arid conditions, and should therefore be conserved and promoted.

Beech

European beech (*Fagus sylvatica* L.) is one of the most important and widespread native forest tree species in Hungary. It is distributed in the hills and mountains of Transdanubia and in the Northern Central Mountains. Beech is mainly regenerated naturally.

Within its area of distribution, beech grows under diverse climatic, geological and soil conditions. The Hungarian beech populations are isolated from each other. They show different growth and morphological traits (for example, stem form, bark colour, crown structure, timing of bud burst of these populations are easily distinguishable). However, the hereditary character of these traits has not been proved yet.

Economic importance and silviculture of oaks and beech

The total forest area in Hungary is 1 586 000 ha, which represents approximately 17% of the total land area. Roughly 35% of the forest area is composed of stands of oak species (*Q. robur, Q. petraea, Q. pubescens, Q. cerris* and a negligible proportion of *Q. frainetto* as well as introduced oak species), while 7% of the Hungarian forests are composed of beech stands (Table 1). It is worth mentioning that, whereas almost all pedunculate oak forests are planted artificially, most sessile oak stands and about 80% of beech stands are regenerated naturally. Since Turkey oak is considered less valuable, it is planned to replace 40% of its stands with sessile and pedunculate oak species on the appropriate sites.

Health state of the forest stands and threats to their genetic diversity

Sessile oak

Oak decline has caused considerable losses in the Hungarian forest recently. The health state of sessile oak has been assessed on 65 plots in Hungary for 10 years. Data for all observed trees from 1989 to 1994 are given in Table 2. It can be noted that 12.2% of the observed trees have died to date, and that mostly forests in the subalpine region are damaged. Oak decline is also shown to cause growth losses (Somogyi and Standovár 1995). Preliminary results suggest that possible causes of sessile oak decline are the following:

- permanent drought (lack of precipitation, as well as dry air)
- outbreaks of defoliating insects
- outbreaks of oak death-watch beetle (*Scolytus intricatus*)
- multiplication of xylophagous insects
- multiplication of bud- and shoot-destroying insects
- increase of the pathological effect of *Armillaria* spp.
- faulty silvicultural practices, e.g. lack of thinning
- air pollution.

Table 1. Economic importance of oaks and beech (Source: Forest Research Institute, 1991)

Species	Area (ha)	%	Natural regeneration (%)	Growing stock (1000 m³)	%	Annual allowable cut (1000 m³)	%
Q. robur	144 326	9.2	10	28 993	10.2	635	7.0
Q. petraea high forest	91 222	5.8		16 304	5.7	371	4.1
Q. petraea coppice	94 658	6.1		24 571	8.6	537	6.0
Q. petraea total†	185 880	11.9	60	40 875	14.4	908	10.1
Q. pubescens‡	15 657	1.0	100	1 878	0.7	54	0.6
Q. cerris high forest	107 000	6.9		21 621	7.6	606	6.7
Q. cerris coppice	68 585	4.3		15 182	5.3	442	4.9
Q. cerris total	175 585	11.2	10	36 803	12.9	1048	11.6
F. sylvatica	102 457	6.6	80	38 952	13.7	799	8.9
Total forest area	1586 760	100	15	284 556	100	8997	100

† Data are for the sessile oak aggregate.
‡ Including *Q. virgiliana.*

Table 2. Health state of sessile oak (Source: Varga *et al.* 1995)

Region	No. trees observed	Dead trees No.	Dead trees %	Height class 1+2+3: Total trees (No.)	Height class 1+2+3: Dead trees No.	Height class 1+2+3: Dead trees %	Height class 4: Total trees (No.)	Height class 4: Dead trees No.	Height class 4: Dead trees %
Northern Central Mountains	9505	961	10.1	8124	537	6.6	1385	424	30.6
Transdanubian Central Mountains	2183	289	13.2	1917	183	9.5	266	106	39.8
Transdanubian Hills	2487	354	14.3	2148	189	8.8	339	165	48.7
West-Transdanubia	1689	336	19.9	1307	114	8.7	382	221	57.9
Total	15868	1940	12.2	13496	1023	7.6	2372	916	38.9

Height classes: 1 – dominant; 2 – codominant; 3 – intermediate; 4 – overtopped.

Pedunculate oak

Relevant data for pedunculate oak for the years 1990-94 are summarized in Table 3.

Table 3. Health state of pedunculate oak (Source: Varga *et al.* 1995)

Region	No. trees observed	Dead trees No.	Dead trees %	Height class 1+2+3: Total trees (No.)	Height class 1+2+3: Dead trees No.	Height class 1+2+3: Dead trees %	Height class 4: Total trees (No.)	Height class 4: Dead trees No.	Height class 4: Dead trees %
Great Plain 1	1586	303	19.1	1434	165	11.5	152	138	90.8
Great Plain 2	863	125	14.5	786	88	11.2	74	37	50.0
Transdanubian Hills	1888	159	8.4	1830	128	7.0	58	31	53.4
Transdanubian Central Mtns.	651	128	19.6	581	82	14.1	70	46	65.7
Mezoföld	1555	312	20.1	1262	163	12.9	293	147	50.2
West-Transdanubia	929	34	3.7	923	31	3.4	6	3	50.0
Total	7472	1061	14.2	6816	657	9.6	653	402	61.6

Height classes: 1 – dominant; 2 – codominant; 3 – intermediate; 4 – overtopped.

The causes of pedunculate oak decline are partly similar and partly different from those of sessile oak. They are as follows:

- outbreaks of defoliating insects
- too much gley and slack water, as well as chalk formation in compacted soils
- mildew
- disequilibrium in the water balance within the tree
- appearance of parasites (*Armillaria* spp.)
- outbreaks of scale insects and xylophagous insects.

Pedunculate oak decline is a periodical phenomenon. Intensive drying of trees occurred when the outbreaks of *Lymantria dispar* followed periods with a rainfall higher than average. This happened in 1907-08, 1914-17, 1924, 1962-65 and 1972-74.

Beech

The health state of beech stands has declined in recent years, but problems are less serious than for oaks (Table 4). The most common cause associated with damaged beech trees is drought. Air pollution or acid rains are not considered an important damaging agent in the Carpathian basin.

Table 4. Percentage of healthy stems in beech

Region	1992	1993	Difference (1993 – 1992)	1994	Difference (1994 – 1993)
Northern Central Mtns. 1	67.9	59.6	–8.3	55.7	–3.9
Northern Central Mtns. 2	45.4	32.0	–13.4	35.5	+1.5
Transdanubian Central Mtns.	73.2	69.1	–1.4	71.4	+2.3
Transdanubian Hills 1	74.4	67.1	–7.3	63.1	–4.0
Transdanubian Hills 2	73.3	69.1	–4.2	71.6	+2.5
West-Transdanubia	87.7	82.7	–5.1	86	+3.3

Source: Tóth *et al.* 1995.

Research activities related to genetic resources/diversity

We have hardly any information about the genetic variation of the Hungarian oak and beech populations. In collaboration with other countries, we could only conduct a few investigations including:

- Genetic differentiation by RAPD markers of oak species in Hungary (see Bordács and Burg 1997).
  The genetic differentiation of four oak taxa in Hungary was investigated by RAPD analysis. In total, 99 trees were sampled to compare levels of genetic diversity and to identify the taxa. Among 26 single decamer primers screened, the four resulting profiles showed significant differences among the four taxa.
- Genetic variation in beech populations along the Alpine chain and the Hungarian Basin (Comps *et al.* 1998):
  Seventy-eight European beech population from the Alp Chain and the Hungarian Basin were analyzed using eleven alloenzymatic loci. Four pools of populations could be discriminated.

Experiments are under way in the following fields:

- inter- and intraspecific variation of *Q. robur* and *Q. petraea*, and within the *Q. petraea* aggregate for morphological traits
- controlled crossing among native oak species
- provenance tests.

Some of the respective results are as follows:
The status of oak species within the oak aggregate is still very doubtful. To try to separate these species taxonomically, numerical methods were applied. The frequency distribution of discriminant scores, calculated from leaf morphological characteristics of pedunculate and sessile oak *s. lat.*, shows that the two oaks can be separated according to these characteristics. Similarly, multigroup discriminant analysis of the three minor species of sessile oak resulted in three distinguishable groups based on the same morphological characteristics (Fig. 1).

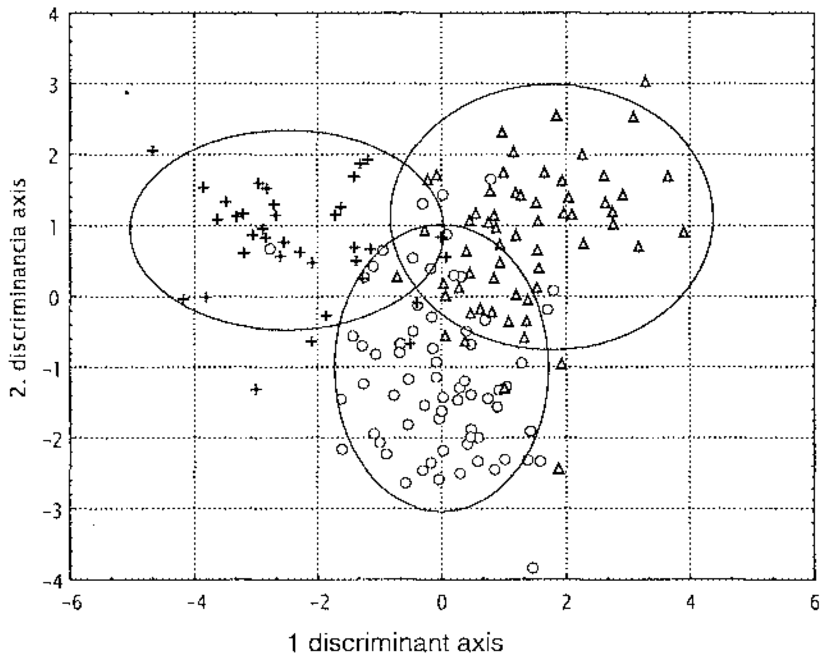

Fig. 1. Multigroup discriminant analysis of three sessile oak taxa: O = *Q. petraea;* Δ= *Q. dalechampii;* + = *Q. polycarpa.*

In the second research field mentioned above, we carried out controlled crossing trials with native oaks. In general, intraspecific crossings were more successful than interspecific ones, with *Q. frainetto* showing the highest success rate (Fig. 2).

It is worth noting that, when grown, combinations of *Q. petraea* female parents with *Q. robur* male parents were equally successful as the reciprocal combinations. The opinion that reciprocal combinations give different success rates may arise from the fact that most combinations are made under field conditions where the microclimate within the isolation bags may differ considerably. It must be mentioned that the timing of male and female flowering can also be synchronized easily in a greenhouse. Another noteworthy result of our research so far is that the combination of *Q. robur* × *Q. pubescens* showed transient morphological characters (for example in density of pilosity, form of lobe, etc.), and that pollinated flowers of the *Q. robur* × *Q. cerris* combination rapidly aborted around a month after pollination (Borovics, unpublished).

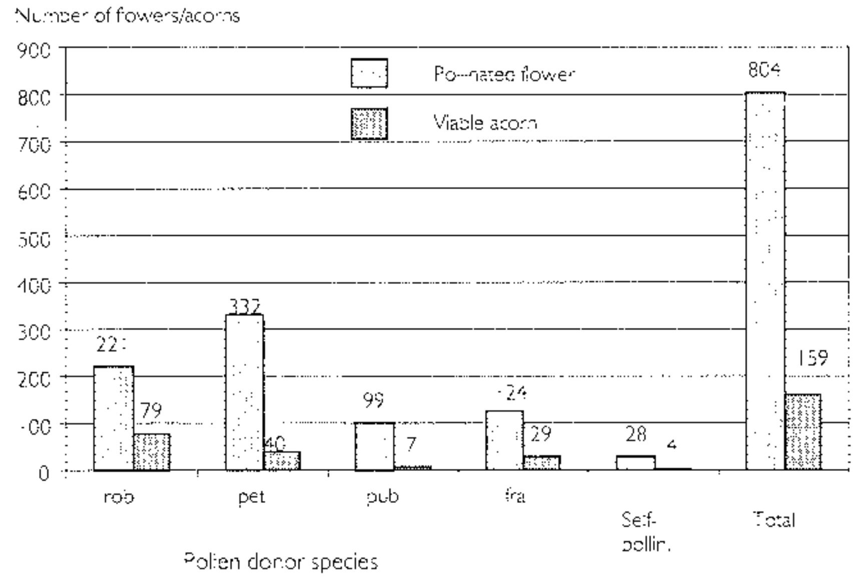

Fig. 2. Total number of pollinated flowers and viable acorns in a controlled crossing with *Q. robur* female individuals in the Bejcgyertyános seed orchard in 1995.

Current genetic conservation activities

Seed stands represent a general basis for genetic conservation (Table 5). No *ex situ* conservation measures for oaks and beech have been taken yet.

Table 5. Area of seed stands in Hungary

Species	Area (ha)
Quercus robur	1590.4
Q. petraea	583.8
Q. frainetto	12.1
Q. cerris	308.6
Fagus sylvatica	308.6

Source: National Institute for Agricultural Quality Control, 1996.

The forest reserves system has recently been established in Hungary. The proportion of beech stands in these reserves is higher than that in the country, while oak is under-represented. This is clearly shown in Figure 3, where the area of forests is compared in the reserves and the country mean according to the forest climate zones defined in Hungary.

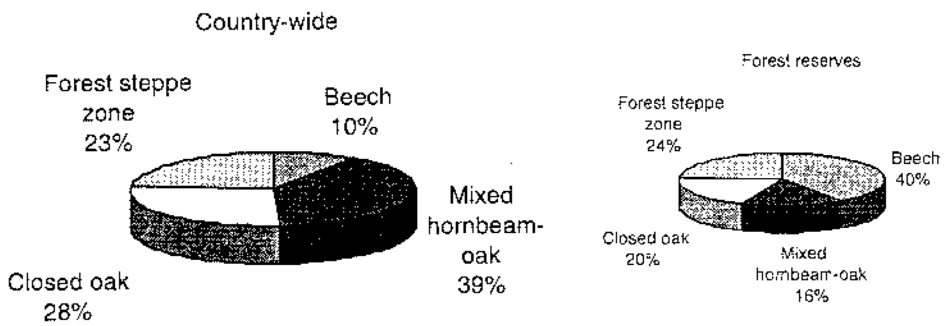

Fig. 3. Area of forest reserves. Riparian and other wetland forests are grouped in the forest steppe climate zone, whereas all types of plantations (hybrid poplar, pine, etc.) are excluded from these statistics.

Relevant nature protection policies and activities

Neither oaks (except for pubescent oak) nor beech are endangered species, from a nature conservation viewpoint. However, there are many endangered plant or animal species in several stands of these indigenous trees; therefore, some of these stands are protected. In the case of pubescent oaks, a research programme will be launched next year, which will be supported by the Ministry of Environment, and which will focus on the conservation of genetic variability.

Tree-improvement activities and use of reproductive material

Tree improvement

The Carpathian basin was once inhabited by a rich and well-adapted oak flora. Human activity (clearing of forests, selective logging, coppicing) greatly affected these forests and their ecological conditions were severely damaged by the deterioration of the water regime of the sites. The excessive planting practice, disregarding the ecological demands of the species and the importance of provenance compatibility, resulted in a mixture of valuable stands of local provenance and stands of unknown or unsuitable origin, these often occurring side by side. Conservation and natural regeneration of ecotypes that are well adapted to a particular site must be given high priority in the future. This underlines the importance of seed stands.

There is no tree improvement programme for beech in Hungary, because it is mainly regenerated naturally. It is the silvicultural practice that may improve relevant features of the populations.

The establishment of Hungarian seed stands of oak and beech was initiated by Mátyás in the 1950s. These stands were continuously observed and classified from the points of view of quality of morphological characteristics, species identity and state of health. Systematic provenance testing with oaks started in 1985 at the Forest Research Institute. There are provenance tests with stands established over 5 years and approximately 60 populations (in a random block design with four repetitions).

Oak plus tree selection in Hungary was initiated by Harkai in the late 1960s. The plus trees were generally selected in seed stands. These plus trees were grafted and planted in seed orchards established in several locations in recent years: three for *Quercus robur* and two for *Q. petraea*. One of the biggest, situated in Bogdasa (southwest Hungary), was established jointly by the Forest Research Institute and the Mecsek State Forest Company in 1989. In this orchard, trees of *Q. robur* subsp. *slavonica* were planted. The total area of the orchard is approximately 16 ha, and the 2186 grafts are found in six simple random blocks. The grafts are clones of 40 plus trees selected in local seed stands along the Drava river. Clones were tested for flowering capacity and fertility by the National Institute for Agricultural Quality Control (Bordács 1997).

Reproductive material

Seed production of oaks and beech is rather irregular. Therefore, there have always been problems with the availability of their reproductive material. Oaks and beech in Hungary produce a sufficient quantity of acorns only once every 6-8 years.

There was an exceptionally large acorn production in 1995 and therefore, a considerable surplus of seedlings is available at the moment. In future years, however, a shortage of seeds that may amount to 10-90% of demand is expected. Unfortunately, only a negligible part of the reproductive material is produced from seeds collected in stands (Fig. 4).

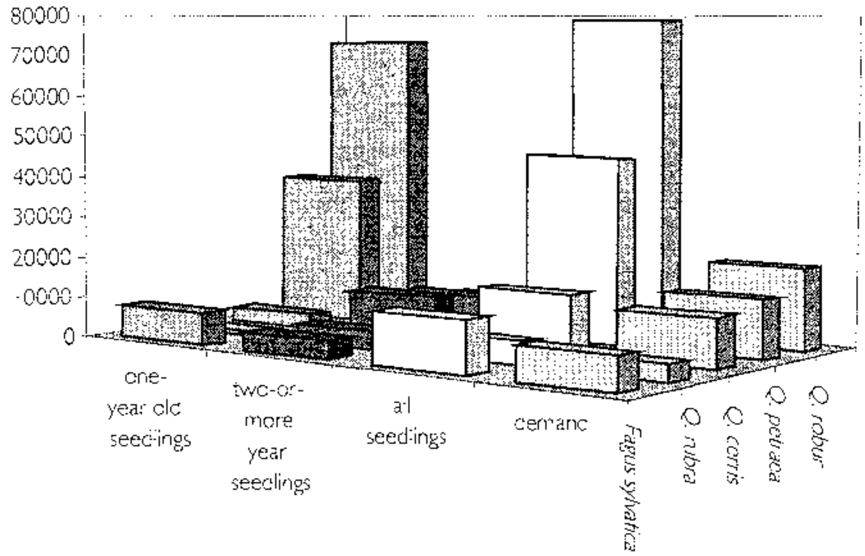

Fig. 4. Supply and demand of seedlings in the planting season 1996/97 (Source: National Institute for Agricultural Quality Control, 1996).

Institutions involved in activities related to genetic resources

- Forest Research Institute (Department of Breeding)
  Morphological variability, provenance experiments and species hybridization.
- National Institute for Agricultural Quality Control (Department of Forestry)
  Gene diversity in natural populations of oaks, clone tests, seed orchards.
- University Sopron (Faculty of Forestry)
  Morphological diversity and ecology of pubescent oaks (Department of Botany).
- Gene diversity of beech populations (Department of Environmental Sciences).

Summary of country capacities and priorities

1. Genetic information about the variation of the oak and beech populations in Hungary is lacking.
2. There are some results in the following fields:
   - inter- and intraspecific variation between *Q. robur* and *Q. petraea* (within the *Q. petraea* aggregate) concerning morphological traits
   - controlled crossings among native oak species
   - provenance tests.
3. The recent planting practice, disregarding ecological demands of the species and the importance of compatibility of provenances, resulted in a mixture of valuable stands of local provenance and stands of unknown origin, these often occurring side by side. Therefore, conservation and natural regeneration of ecotypes that are well adapted to a particular site must be given high priority.
4. There are many seed stands of both oaks and beech. The use of reproductive material from these stands – within the appropriate provenance zones (regions of provenance) – must be promoted.

Needs for international cooperation

- Investigations on the genetic structure of the species (DNA, isoenzyme analysis).
- Establishment and evaluation of provenance tests.
- Investigations on the mating system.
- Standardization of numerical taxonomic investigation procedures: establishment of taxonomic keys.

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Conservation of beech and oak genetic resources in Slovakia

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Introduction

Forest land in Slovakia represents about 1.9 million ha, of which 90% are in the Carpathians. Approximately 40% of the forest land is covered by beech and oak stands. Basic information on the gene conservation units for both species is given and gene conservation programmes are outlined for both species.

Occurrence, origin and distribution of beech and oak species

The forest area in Slovakia covers 1 904 339 ha in total (Table 1). The proportion of beech is 29.6% and of oak species (*Quercus robur* and *Q. petraea*) 11.26% . The proportion of Turkey oak (*Quercus cerris*) is 2.45%. The present proportion of beech and oaks is lower than the original one (Hančinský 1972). During the last century, beech was replaced in some places by Norway spruce and oak stands by Scots pine.

Natural distribution of the beech forests in Slovakia is in altitudes between 330 and 1200 m. It forms pure forest stands in the beech optimum and mixed stands with oak, or mixed stands with conifers (silver fir and Norway spruce). The natural distribution of beech covers all Slovakia except the Western and Eastern Lowlands and the Southern Slovakian Karst region. It is also missing in the highest mountains.

Natural distribution of *Q. petraea* is in the hills of western, central and eastern Slovakia. It forms forest stands up to 700 m, although there are several occurrences even in higher altitudes, e.g. Sitno up to 900 m. Natural distribution of *Q. robur* is on loamy soils and in wet lowlands. It is a tree species of lowlands and lower hills up to 450 m. In several parts of Slovakia the natural ranges of both species overlap and they form mixed populations.

One of the classifications of forest vegetation cover was elaborated by Prof. A. Zlatník who, on the basis of intensive investigation of Carpathian forests in Slovakia and in Transcarpathian Ukraine, described the natural forest cover in eight vegetation zones which could be defined as the climax geobiocenoses determined by geography and macro- and mesoclimate in given altitudes. The vertical forest vegetation zones are usually named according to prevailing tree species and they correspond with the altitudinal zones usually applied in geobotany (planar, colline, submontane, montane, boreal, subalpine, alpine and nival):

- Oak forest vegetation zone
- Oak-beech forest vegetation zone
- Beech-oak forest vegetation zone
- Beech forest vegetation zone
- Beech-fir forest vegetation zone
- Beech-fir-spruce forest vegetation zone
- Spruce forest vegetation zone
- Mountain pine forest vegetation zone.

The principal characteristics of forest vegetation zones were given in a previous paper (Paule 1995).

Table 1. Forest area, economic importance and breeding activities in beech and oaks in Slovakia

Forest land [†]	Beech	Sessile + pedunculate oak	Turkey oak	Broadleaves
Actual area (ha)	563453	214506	46732	1083440
%	29.60	11.26	2.45	56.89
Growing stock (1000 m^3)	107678	38587	8050	182877
%	29.41	10.54	2.20	49.97
Annual allowable cut (1000 m^3)				
Final logging	1366	191	59	
%	36.69	5.15	1.60	
Thinnings	363	92	23	
%	33.40	8.42	2.05	
Total	1729	283	82	
Seed stands [‡]				
A-category	2471	745	–	
B-category	14642	3971	–	
Plus trees	38	262	–	
Seed orchards	–	7.00	–	
Seed plantations	149	110	–	
Gene reserves	1200	1119		7300 (mixed)

[†] As of 1 January 1994. [‡] As of 31 December 1997.

Oak species in Slovakia

Except for the two principal white oak species – *Q. petraea* and *Q. robur* – the forestry practice also recognizes Turkey oak (*Q. cerris*) and *Quercus pubescens*. These two species reach their northern limit of distribution in Slovakia. The fifth, introduced oak species is *Q. rubra* which grows in several 60- to 70-year-old plantations and numerous younger ones.

Besides the four indigenous species, taxonomists (Magic 1974, 1975) differentiated another five oaks (may be of hybrid origin) with a lower but indigenous occurrence in Slovak forests: *Quercus dalechampii*, *Q. polycarpa* (both from the section *Roburoides*), *Q. pedunculiflora* (section *Robur*) and *Q. virgiliana* and *Q. frainetto* (section *Dascia*). They can be found in the inner Carpathians as a continuation of their more abundant occurrence in the Hungarian lowlands and hills.

The significance of these minor oak species for the forestry practice is questionable, since it uses only the two principal oak species (*Q. petraea* and *Q. robur*) and does not include the others in forest management plans and forestry statistics. Their occurrence is, however, known and might be interesting from the point of view of gene conservation, independently of their taxonomic status.

The northernmost occurrence of *Q. pubescens* has been proved in several nature reserves within the natural distribution range in Slovakia. *Quercus cerris* forms lower-quality forest stands usually mixed with hornbeam or other oak species.

Threats to beech and oak genetic resources

Several factors negatively affect genetic resources of oaks in Slovakia, e.g. grazing by game, improper silvicultural practices, lack of natural regeneration, and recently the oak dieback. Originally this was considered as a bark beetle outbreak (*Scolytus intricatus*) and subsequently tracheomycosis, but later the scientists proved the complex disease was caused by abiotic (drought) and biotic factors combined with human activities (summer logging of oak).

Beech has mostly been regenerated naturally. Most changes in genetic composition, even in the case of natural regeneration, are due to the improper forestry and silvicultural practices which led to failure of natural regeneration. Part of the beech stands was converted in the past to Norway spruce stands or mixed beech-spruce stands, frequently on inadequate sites.

Conservation aims and current state of conservation activities

On the territory of Slovakia the first regulation aimed at seed procurement from approved stands was adopted in 1938. In keeping with this legal regulation, the seeds of conifers (Norway spruce, silver fir, Scots pine and European larch) could be collected only in approved stands (A and B category) and seed transfer was allowed only within 'silvicultural' seed zones. The silvicultural zones were defined according to their geographical distribution and the length of vegetation period.

Subsequently these regulations were updated in 1965 and again in 1985 and 1988. The last one also includes seed procurement from the approved seed stands and the seed transfer within seed zones for pedunculate and sessile oak and beech.

Oaks and beech were absent from the first regulations because these tree species were mainly regenerated naturally. In oaks the artificial regeneration by seeding and planting was more common than in beech. At present the proportion of beech reforestation in Slovakia is rather high. Beech is frequently a component of combined regenerations to establish mixed forest stands.

For beech there are four seed zones within the natural range (Sub-Tatra, Eastern Slovakia, Central Slovakia and Little Carpathians) and two zones outside the natural range (Tatra and Southern Slovakia), for sessile oak there are three zones within the natural range (Eastern Slovakia, Central Slovakia and Southern Slovakia) and three seed zones outside the natural range (Northern Slovakia, Western Slovakia and Southeastern Slovakia). For pedunculate oak there are three zones within its natural range (Western Slovakia, Southeasern Slovakia and Southern Slovakia) and three zones outside the natural range (Northern Slovakia, Eastern Slovakia and Central Slovakia). Vertical transfer of seeds is allowed within ±200 m for beech and ±150 m for oaks from the altitude of approved stands where the seed was collected.

At present, 111 gene reserves are defined for all tree species in Slovakia, five (1200 ha) and six of them (1119 ha) are established only for beech and oaks, respectively, seven of them (3637 ha) for mixed stands composed of oaks and beech, and seven gene reserves (3663 ha) for mixed stands composed of tree species other than beech and oaks. They occur mainly in central Slovakia and some in western and eastern Slovakia.

Facilities for long-term conservation of acorns and beech nuts have been built up in Liptovský Hrádok. In these facilities the storage of acorns and beech nuts can be maintained up to 5 years to cover the time gaps between the seed years.

Four provenance trials have been established with beech. Those established in 1968-1972 and 1982 comprise the Slovak and Czech provenances (20 and 27, respectively) (Červenka and Paule 1982; Paule 1982). The latter two are a part of international provenance experiments coordinated by the Federal Forestry Research Center in Grosshansdorf, Germany, containing 100 and 31 provenances, respectively. Trials were established in 1996 and 1998.

At present there are 74 forest reserves, of which 5% are in the oak forest vegetation zone, 2.42 and 3.78% are in the beech-oak and oak-beech forest vegetation zones, respectively, and 9.19% in the beech forest vegetation zone. For comparison, the proportion of nature reserves in the first four forest vegetation zones (20.39%) is about one-third of the total proportion (69.41%) in the forests in Slovakia. It means that there is a lower proportion of virgin and natural forests with oaks and beech than would be expected according to the general occurrence (Vološčuk 1993).

Nevertheless, there are also some natural oak forests with *Q. robur* (Palárikovo) or *Q. petraea* (Kašivárová, Bujanov, Sitno) as well as numerous beech virgin forests in eastern Slovakia (e.g. Vihorlat, Stužica, Rožok,) whose size ranges from 16 ha (Kašivárová) to 600 ha (Stužica) (Korpel' 1993). The forest reserves are in most cases a part of gene reserves, although the legal status of both categories is defined by two different Acts (Nature Protection Act and Forestry Act and accompanying regulations). The most common occurrence of beech forests in Slovakia (and also the forest reserves) is in eastern Slovakia where conifers are missing in the natural composition (Carpathian disjunction). The Carpathian disjunction is on the southern side of the Carpathians about 200 km wide (from Khust in Transcarpathian to Košice in Eastern Slovakia) due to climate.

Relevant research activities and needs

Genetic diversity of indigenous populations was investigated not only from the territory of Slovakia but also on the adjacent regions of the Western Carpathians (Czech Republic, Poland, Ukraine and Romania) (Gömöry *et al.* 1992, 1995, 1998; Paule *et al.* 1995; see Paule and Gömöry, this volume).

There is, however, a lack of information on genetic diversity and differentiation of oak populations from Slovakia, although some material has been used for broader genetic investigations on DNA polymorphisms by Kremer *et al.* Studies of genetic diversity and differentiation of oak populations are planned for the coming years. Further research is needed on the taxonomy and genetic structures of forest stands with the occurrence of minor species as well as on the genetic composition of the forest stands with the occurrence of the principal oak species, *Q. petraea* and *Q. robur*.

The geographic variation has been investigated in beech in provenance trials and significant differences were found between eastern Slovakian provenances and the remainder of Slovakia, although in western and central Slovakia some good-performing provenances were also found along with slow-growing ones. Beech provenances have also performed well in the international provenance trials (Červenka and Paule 1982; Paule 1982).

There is only a single open-pollinated progeny test of beech, established in Slovakia in 1961 (Červenka and Paule 1979).

Significant differences among beech populations concerning the crown shape and quality and stem quality (including forking) among individual regions were observed (Veselý 1977).

Oak provenance trials are few, established by the Forest Research Institute in Zvolen but these were not inventoried systematically (Korenek 1980). We have little information on the geographic variation of oak populations.

The occurrence of minor oak species was also studied and a comparative trial established. Unfortunately this trial, owing to a restricted number of parent trees of each species, did not give sufficient information on the intraspecific variation of oak species involved. There is also a lack of information concerning the spatial distribution of individual oak species. Further investigations of population structure based on morphological traits as well as on genetic markers and provenance trials are needed for these species.

Beech, in contrast with other tree species of economic importance, is in a favourable situation. Owing to its ecological features it has seldom been regenerated artificially, and the common silvicultural practice has always relied on natural regeneration. In eastern Europe there are, however, also traces of improper forest management of beech stands. Coppice stands, mainly in mixtures with oak, are characteristic for the contact zone with agricultural land in lower altitudes. There were many cases when deforestation and replacement of beech stands by more productive coniferous ones took place. Artificially regenerated beech stands were established during the last two centuries.

Natural regeneration will remain the best way for gene conservation of indigenous beech populations. The significance of gene conservation is emphasized by the prognosis of climate changes. If, in the case of climate change, the necessity to replace local populations by more southern ones occurs, genetic resources should be available.

Science is already partially prepared for this event. The provenance trial with European beech has been established which includes 155 provenances in two series, established in 20 sites (incomplete provenance numbers); the previous series contained over 150 provenances planted on 10 sites (see von Wuehlish *et al.*, this volume). The main aim of these provenance experiments is to test the adaptation potential of individual provenances to changed environmental conditions.

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Social Broadleaves in the Czech Republic

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Introduction

Forest land covers about 2 630 000 ha in the Czech Republic. The composition of forest tree species was considerably changed in the past two and a half centuries of intensive forest management. Plantation of coniferous tree species was recommended since the 18th century.

The natural species composition is as follows: beech (about 40%), oaks (about 18%), fir (16%), spruce (15%) and pine (3%). The present species composition is different. The proportions of spruce (55%) and pine (18%) are higher. Oaks (6%), beech (5.6%) and fir (<1%) are underrepresented with regard to the original situation. Most of the beech stands were harvested and used in glass manufactories and for charcoal production. Mixed beech stands were replaced by Norway spruce monocultures and oak stands by pure plantations of pine.

The territory of the Czech Republic is divided into 41 Natural Forest Regions (NFRs, see Fig. 1 and Table 1), delimited by geographic, geomorphological and climatic conditions. Ecological conditions affect the representation and rise of regional populations which are adapted to local conditions.

Within these NFRs, populations are merged into seed zones. The tree seed zones are proposed for the following reasons:

- current regional populations should not be mixed with regard to the use of forest reproductive material
- there is insufficient knowledge on their variability (in contrast to coniferous species – spruce, pine and larch – which are better known), and their contamination by other, not well-adapted populations or species should be avoided.

Unfortunately, it seems that some representatives of the forestry practice prefer not to have seed zones, with the possibility to handle reproductive material arbitrarily.

Beech grows naturally in all 41 NFRs, oaks grow naturally in 37 NFRs.

Occurrence and origin of oaks and beech in the Czech Republic

In the Czech Republic there are eight forest vegetation belts (FVB) (Table 2). Pedunculate oak occurs naturally from FVB 1 to 3, and up to FVB 5 if artificially planted. Sessile oak occurs naturally from FVB 1 to 4. Beech occurs naturally from FVB 2 to 7.

Pedunculate oak stands survived, especially on humid sites. Sessile oak survived on extremely shallow soil as coppice forest. Beech stands survived in extremely steep areas, where it was impossible to carry out artificial regeneration with spruce. In these localities beech regenerates in a natural way.

Pedunculate oak was artificially distributed, for example, around dams and ponds (especially in southern Bohemia and southern Moravia). Many stands with pedunculate oak are situated in floodplain forest after stream regulation. Important were imports of pedunculate oak from Croatia, specially from Slavonia. Populations of oaks from Slavonia are more productive and have better wood quality than local oaks.

Sessile oak was not regenerated artificially as well as the pedunculate oak. Generally in the past foresters did not respect site requirements of these two species. In oak forest stands, both species often mixed.

Artificial regeneration of beech started at the beginning of the 20th century. In the last 40 years, beech reproductive material from Slovakia and western Ukraine has been used more than beech of local origin.

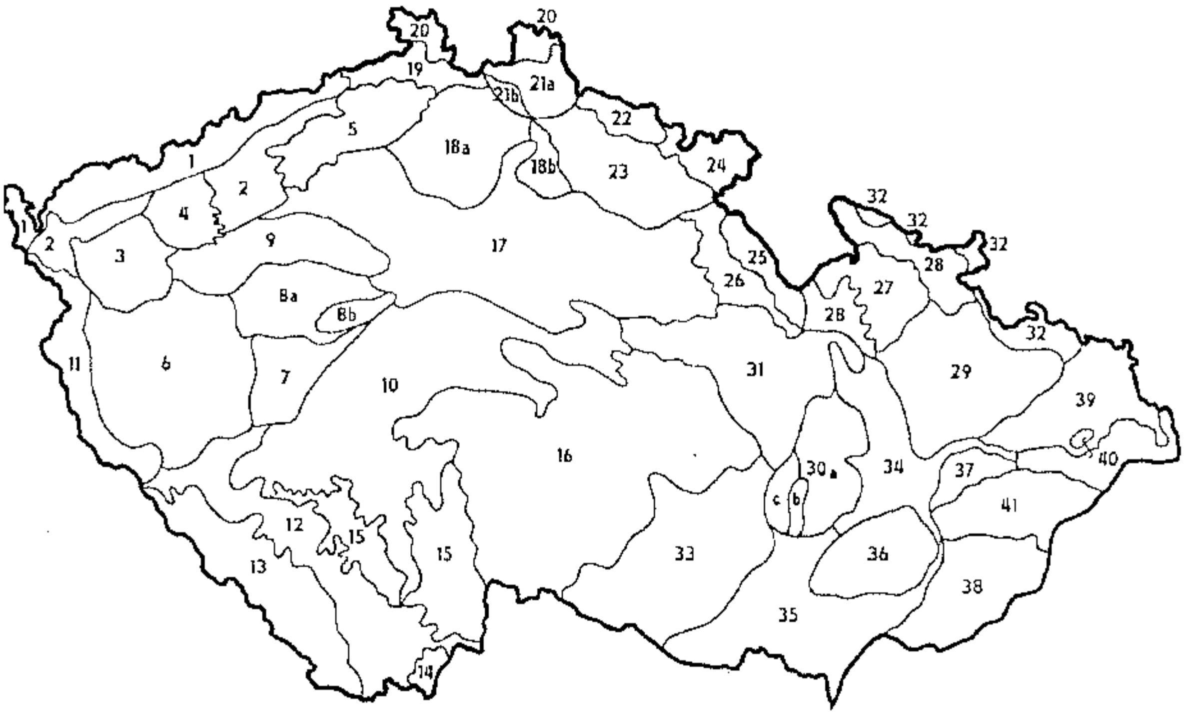

Fig. 1. Natural forest regions of the Czech Republic.

Current economic importance for the forestry sector

Oak wood is used in the furniture industry, and beech wood is used for example for railway sleepers and in the building industry. Spruce and pine are still more important economically. It depends on the level of wood industry. According to the new Forest Law from 1995, a minimum of 30% of 'melioration' species has to be used, which increases the resistance of newly established stands. Oaks and beech are often used as the 'melioration' species.

Silvicultural approaches

Mixed forest stands which contain native broadleaved species such as oaks and beech are more stable and resistant to air pollution. Air pollution in the Czech Republic is one of the highest in all European countries. Most of the forest stands are artificial with a majority of monoculture of spruce and pine. An increase in the percentage of broadleaved tree species increases the stability and resistance to other abiotic and biotic factors.

Therefore, the current forest law prescribes the raising of the proportion of broadleaved species.

Health state of the forest stands and threats to their genetic diversity

Oaks

At the moment oaks are the second most endangered genus in the Czech Republic after elms. This situation is a result of the tracheomycosis disease and repeated damages by an oak leaf roller moth (*Tortrix viridana* L.). In forest stands without chemical protection no acorn has been found for several years. The seed crop is not a problem nationally but regionally. To conform with the new Forest Law (30% of 'melioration' species), practical forestry needs to import reproductive material from foreign countries. This practice decreases the native oaks genepool in the Czech Republic and also contaminates with untested genetic material. From all the imported oaks material, Slavonic oak (pedunculate oak) has good practical results, but the imports from Croatia are practically nonexistent.

Table 1. Forest vegetation zones in natural forest belts regions of the Czech Republic

FVZ	1	2a/b	3	4	5	6	7	8a/b	9	10	11	12	13	15	16	17	18a/b	19
9	0.9		0.2										0.9					
8	9.9		0.5								0.2		12.5					
7	28.9	+	11.7				0.1				3.7	+	26.9		1.0			2.9
6	27.2	1.0	21.0		0.1	0.2	19.6				30.8	6.2	55.8		23.6			22.9
5	27.9	14.0	55.8	28.4	6.5	2.4	37.3			1.5	64.0	65.7	3.5	4.3	63.7			24.5
4	0.1	8.2	0.6	39.7	5.0	9.2	17.6		3.1	21.2	0.3	13.8		38.8	7.0	0.2		0.7
3	4.6		6.6	26.7	47.8	49.9	23.5		35.8	49.8	0.6	12.8		17.8	4.0	2.2		9.9
2	0.1		0.4	3.6	27.6	20.4	1.5		47.0	23.5		1.2		5.6	0.3	22		+
1	0.1		0.2	1.4	11.7	1.8	0.3		2.8	3.6	0.4	0.1		1.6	0.1	73.8		0.1
0	0.3		3.0	0.2	1.3	16.1	0.1		11.3	0.4	+	0.2	0.4	31.9	0.3	1.8		39.0

FVZ	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
9		0.2	10.3					1.3														
8		12.9	25.5	+		?		12.0													0.1	
7		10.9	19.3	+	0.1	16.3		21.8	0.7		+	+									1.9	
6	18.4	41.3	41.3	4.1	17.2	48.9	0.3	36.8	11.6	9.6	0.7	1.0									8.4	0.4
5	52.8	26.8	3.6	43.8	73.0	32.5	35.8	27.4	54.8	37.6	14.5	31.8		0.1					8.4	1.1	87.9	70.0
4	0.2			0.9	0.8		2.1		7.7	9.9	27.2	33.3		29.4			7.3		20.7	15.9	0.2	8.7
3	24.0	7.6		42.1	3.9	0.3	48.7	0.6	23.7	39.6	40.3	27.7	90.6	27.1		0.3	55.8	69.7	50.5	72.7	1.5	19.4
2	0.2		+	6.1			10.1		1.2	3.2	14.8	4.7	7.5	28.5	26.5	7.8	33.6	30.3	19.7	3.2		1.5
1	0.6			0.3	+		3.0		0.3	0.1	2.3	0.6	1.9	14.2	73.5	91.9	3.3		0.7	7.1		+
0	3.8	0.3		2.7	5.0	+	+	0.1	+		0.2	0.9		0.7		+	+					+

Table 2. Characteristics of the forest vegetation belts in the Czech Republic

Vegetation belt	% of total forest area	Altitude (m asl)	Mean annual temp. (°C)	Annual precip. (mm)	Vegetation period (days)
0. Pine	3.73				
1. Oak	8.31	<350	>8.0	<600	>165
2. Beech-oak	14.89	350-400	7.5-8.5	600-650	160-165
3. Oak-beech	18.41	400-550	6.5-7.5	650-700	150-160
4. Beech	5.69	550-600	6.0-6.5	700-800	140-150
5. Fir-beech	30.04	600-700	5.5-6.0	800-900	130-140
6. Spruce-beech	11.95	700-900	4.5-5.5	900-1050	115-130
7. Beech-spruce	5.00	900-1050	4.0-4.5	1050-1200	100-115
8. Spruce	1.69	1050-1350	2.5-4.0	1200-1500	60-100
9. Mountain pine	0.29	>1350	<2.5	>1500	<60

Beech

The health situation of beech stands is better. The absence of seed years was supposed to be the result of air pollution. But in the most polluted regions, such as the Ore Mountains, natural regeneration was observed. The long period of seedless years ended in 1992. The next seed year was in 1995. The native genepool of beech was influenced by imports mainly from Slovakia and Ukraine. Until now beech has been artificially regenerated from imported material even when it was possible to use local material.

Research activities and capacities related to genetic resources/diversity

Research projects and breeding of broadleaved species began later than for coniferous species. The first provenance trial of beech was established in 1972. In this trial, populations from the whole Czecho-Slovakia are being tested. Other series of provenance tests were established in 1984, 1988 and 1995. We are now preparing a new series which should be established in 1999. Phenotypic variability of adult stands was evaluated in the 1980s, separately for the Hercynian region and the Carpathians (the eastern part of Moravia around the border with Slovakia). On the basis of provenance results, new proposals were prepared for seed zones of beech. First results of isoenzyme analyses (Gömöry *et al.*, unpublished) confirm most of these proposals (see Fig. 2).

In 1984 the first provenance test of oaks was established (10 different sites). The acorns used were from the seed year 1982. Provenances of two species – pedunculate oak and sessile oak – from the Czech Republic were used. At the same time we performed phenotypic evaluation of adult oaks stands. On the basis of this it was reported that sessile oaks dominated in most of the Czech Republic (see Fig. 3). Pedunculate oak dominated in Natural Forest Regions 2, 15, 17, 32, 34 and 35 (see Fig. 4). According to the authors of this project on oaks, this is the native area of pedunculate oak. In the Czech Republic only one seed orchard of pedunculate oak was established in southern Moravia.

In the last 20 years we have been concerned with the vegetative reproduction of oaks and beech. Cuttings, grafting and *in vitro* tissue culture were used. From the point of view of the maintenance of diversity it is very important to be able to reproduce adult oak trees from buds (*in vitro*). Results of oaks and beech cuttings are very promising. The majority of this work is being done at the Forestry and Game Management Research Institute. Vegetative methods are used in the breeding programmes which are concerned with reproduction of the rest of the native populations, unable to reproduce in a natural way (influenced by the age of stands, by animals and, in the case of oaks, by *Tortrix viridana* L.).

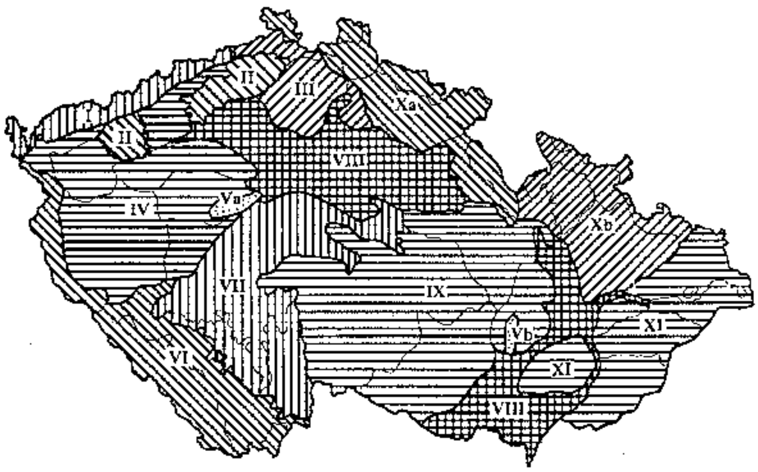

Fig. 2. Map of tree seed zones proposed for *Fagus sylvatica* L.

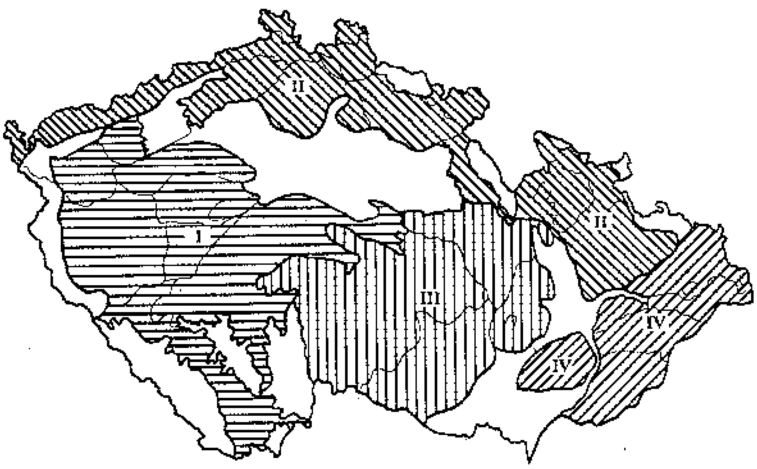

Fig. 3. Map of tree seed zones proposed for *Quercus petraea*.

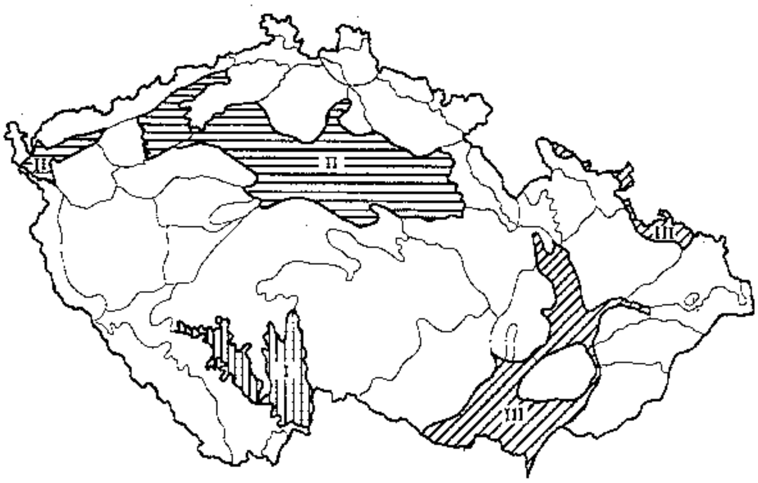

Fig. 4. Map of tree seed zones proposed for *Quercus robur*.

Current genetic conservation activities *in situ* and *ex situ*

In situ

Passive gene conservation of oaks and beech populations *in situ* takes the form of state reserves. The gene reserves (bases) are considered as an active way of gene conservation and reproduction. Gene reserves are groups of stands with a minimum surface area of 100 ha of forest land. Regeneration is usually natural. If natural regeneration is not successful, it is possible to use artificial reproductive material but only with origins from these gene reserves. Suggestions for management methods in gene reserves are elaborated by the Institute.

Ex situ

The most important activities on *ex situ* gene conservation are grafting and establishment of clonal archives and seed orchards. This method is not used often for oak propagation, because of incompatibility problems. Only one seed orchard has been established and no others are planned. This method of conservation is more important for beech. We established clonal archives of beech from the seven forest vegetation belts only in the most polluted areas (Ore Mountains). Another method of *ex situ* conservation is the establishment of special plantations for obtaining secondary cuttings. Genebanks are used within the existing seed banks and tissue culture banks.

Relevant nature protection policies and activities

In 1992, a Law on Nature Protection was issued, and later in 1995 a new Forest Law (No. 289). Both aim to conserve the remaining natural forest tree genepool.

Tree-improvement activities

Tree-improvement activities are carried out on the basis of provenance tests. Practical implications of the provenance tests include rules for effective transfer of reproductive material, delimitation of seed zones, preparation and implementation of breeding programmes including different methods of vegetative reproduction (grafting, cuttings and *in vitro* methods).

Use of reproductive material

In the Czech Republic it is allowed to use reproductive material of spruce, pine and larch only from approved sources (approved seed stands, seed orchards, clonal archives). For all forest trees (including oaks and beech) a rule regarding the limitation of vertical transport of reproductive material is in force. This limit is plus or minus one forest vegetation belt (FVB). Beech origins from the seven FVBs are suggested as special climatic ecotypes.

The proposed seed zones for oaks and beech (also for beech originating from the seven FVBs) have not been approved yet.

Import of reproductive material of all forest tree species (including oaks and beech) from foreign countries is regulated by the Ministry of Agriculture. The Ministry also defined the areas where this reproductive material can be used.

Institutions involved in genetic resources activities

Most of the work is done by the Forestry and Game Management Research Institute. The central seed bank is managed by the state forest company and situated in the town Týniště, Orlicí. Both Forestry faculties (University Brno and University Prague), the Academy of Science and the other state and private institutes and organizations are concerned with the problems of oaks and beech genetic resources to a limited extent. The Ministry of Environment and its organizations are interested in the conservation of oaks and beech in state nature reserves and national parks.

Summary of country capacities and priorities

In the Forestry and Game Management Research Institute there are only four scientists involved in research on oaks and beech (breeding, vegetative propagation, breeding programmes concerned with conservation and reproduction of the genepool).

The main priority is to conserve the remaining natural and good-quality populations of pedunculate and sessile oaks and beech by means of natural regeneration.

Needs for international collaboration

The proportion of oaks should increase from 6 to 9% and beech from 5.5 to 12-18%. Considering these goals, the local sources of reproductive material will not be sufficient.

Testing of new provenances, establishment of new series of provenance tests for both oak species are very important to increase the variability of newly established forest stands. In the case of beech a sufficient number of provenance tests in the framework of the international series (von Wuehlisch *et al.*, this volume) will be established.

To collect enough information on the genetic variability of populations of forest trees, international projects concerned with DNA and isoenzyme studies should be carried out. A laboratory in the Forestry and Game Management Research Institute has just been established, and accordingly started work.

Selection on resistance to tracheomycosis and *Tortrix viridana* L. would also be interesting.

Conservation of genetic resources of oaks and beech in Austria

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Introduction

Austria is densely forested, with 46.2% of its surface covered by forests. Owing to the predominantly mountainous terrain, the proportion of conifers is high (77.3%), whereas broadleaved tree species and shrubs cover 22.7% of the total land (3 877 000 ha) (BMLF 1995). Since more than two-thirds of the forest area is located in the Alps, besides their economic importance forests play a very important role in the protection from erosion, torrents and avalanches. These reasons led the Federal Forestry Research Centre (Vienna) to start a national programme on the conservation of genetic diversity in forests. Launched in 1986 and implemented through cooperative actions of the Institute of Silviculture and the Institute of Forest Genetics, the programme aims at the conservation of the genetic adaptability of forest tree populations.

Distribution of beech and oaks

Beech is the second most widespread forest tree species in Austria (9.8%), while oaks represent only 2.2%. A meticulous description of the natural range of *Fagus sylvatica* was published in the late 1920s by Tschermak (1929). The following remarks are based on his work and on the Austrian Forest Inventory (Schadauer 1994).

With the exception of major parts of the Central Alps, beech is found in the other areas of Austria, although at highly variable densities. In the Weinviertel, northern parts of the Waldviertel in Lower Austria, and in the Mühlviertel, beech is scarce. Further west and south of the river Danube, beech is more frequent in the Hausruck and the Kobernausserwald. In the Northern Limestone Alps, it is distributed from the Bregenzerwald close to the Bodensee to the northeastern edge of the Wienerwald.

In the Allgäuer Alps and in the northern parts of the Tyrolean Alps, beech is commonly found in mixed stands. In the province of Salzburg, mixed beech forests are typical on slaty sites and at high altitudes of the Northern Limestone Alps. Widespread pure stands are common in the foothills of the Salzkammergut. In the Northern Limestone Alps of Upper and Lower Austria, extensive pure beech stands are also frequently found, especially on sediments of the Cretaceous and Tertiary period. Pure *Fagus sylvatica* stands are also typical of the Wienerwald, whereas foothills of the eastern Alps (Northern Limestone and Central Alps) are only partly covered by beech in mixed forests. Disjunct beech stands are further found in the hills of the Geschriebestein close to the Neusiedler Lake.

Beech is also found in the Southern Limestone Alps, namely in the Karawanken, the Carnic Alps, and the Gailtaler Alps. However, pure stands are more common in the Karawanken than in the rest of the Southern Limestone Alps. As a scattered forest tree species it is indigenous at the southern foothills of the Central Alps, in the Lavantal at the eastern edge of Carinthia, and on elevations of the Klagenfurter Becken. In the Central Alps beech is nearly completely absent (see also Tschermak 1958). There is a good coincidence of the natural range of beech with the occurrence of limestone (Geburek and Thurner 1993). The altitudinal range varies from 170 to 1700 m. A mixed beech stand is located at 170 m close to the river Danube, at Greifenstein in Lower Austria. Pure stands are found in this area above 225 m. At the Gapfahler Falben in the province of Vorarlberg, shrubby forms were found close to 1700 m. The upper limit within the Northern Limestone Alps rises from east to west. Within the Southern Limestone Alps, the upper tree line of beech is generally higher than in the northern Alpine range.

Quercus petraea and *Q. robur* are found on (moderately) fresh mollisol and interceptisol types. Both species most commonly occur in mixed forest stands in the Weinviertel, Marchfeld, Wiener Becken, Burgenland and Oststeirisches Hügelland. In the northeastern part of its range the climate is Pannonian-subcontinentally influenced with high summer temperatures and low annual precipitation ranging from 450 mm in the north to 700 mm in the south. In the southeastern part precipitation is much higher. At lower elevations up to 350 m *Quercetum petraea-cerris*, pure *Quercus pubescens* stands on sunny, dry and calcareous sites or the *Quercus petraea-Carpinus betulus* forest type are typical, while at higher elevations up to 500 m *Quercus petraea-robur* is associated with beech and hornbeam. Scattered stands are also found in the foothills of the Northern and Southern Limestone Alps (e.g. Klagenfurter Becken). In this region *Quercus* is found in the *Quercus robur-Carpinus betulus* forest type at low elevations or in association with beech at the submontane level (Kilian *et al.* 1994).

Economic importance of beech and oaks

Beech is the most important hardwood economically and yields approximately 1 600 000 m^3/year. Less than 2% of the wood is of veneer quality. On average 75 ECU/m^3 can be expected for beech timber, while only 30 ECU/m^3 are paid on average for poor-quality wood by the pulp and paper industry. In the past, beech forests have been mainly harvested for fuel wood. Low profits and low yield of beech in comparison with conifers have caused conversion of beech forest into coniferous stands. More recently, the demand for fuel wood and beech lumber has increased and consciousness of a close-to-nature forest management is more pronounced. This has commonly resulted in new planting of beech forests. Forest enterprises based on beech logging face a fairly stable economic situation, while returns of softwood have been diminishing in the last decade. Oak species account for approximately 450 000 m^3 (2.3% of the total). On average 100 ECU/m^3 can be expected for oak timber, whereas prices for veneer quality are much higher (1000-5000 ECU/m^3).

Silviculture

Oaks and beech are mainly managed in high forests. Beech is predominantly regenerated naturally in different shelterwood systems. Oaks are also managed in high forest, but the coppice with standards system still plays an important role locally. Oaks are regenerated artificially more often than beech.

Reproductive material

In beech, 760 000 plants are produced annually and 470 000 plants are imported. This accounts for 1.3% of the 57 million plants produced and 23% of the total import (some 2 million plants). In oaks, 1.1 million plants are produced per year and 350 000 plants, i.e. 18%, are imported. Thus, domestic plant production is low, while Austrian import of plants of both genera is fairly high (roughly 40% of the total plant imports). According to the Austrian Forest Reproductive Material Act (Anonymous 1996), beech and oak seeds have to be harvested in selected stands. In line with this regulation, some 840 ha of beech stands, 231 ha of sessile oak and 238 ha of pedunculate oak have been selected and registered.

Health and threats

Early loss of leaves and the resulting crown sparseness indicate a state of individual damage. Usually the health status of beech is much better than that of oaks in Austria. Less than 1% of the beech trees and more than 4% of oaks monitored exceed 60% defoliation. Beech accounts for approximately 4% of the trees in the defoliation class 25-60%, oaks for more than 16%. More than 50% of beech trees and 35% of oaks are (nearly) unaffected. Damage by browsing of game and livestock is negligible for both genera.

Gene conservation

Genetic resources of both genera are mainly conserved by *in situ* measures, to secure the unknown genetic variability, guarantee evolutionary development, and thus conserve adaptability to changing environmental conditions. Since Austrian virgin forests are low in numbers and small in size, conservation is practised in managed forests which are integrated into the economic cycle (Müller 1996). *In situ* management plans are developed that comprise gene reserves, each covering a minimum area of 30 ha. This size is assumed to be large enough to conserve the genetic structure and to allow an evolutionary change of the resource population. As pollen contamination from outside sources is unwanted, the core area ought to be framed by a 300-500 m wide buffering zone. A suitable forest stand is declared an *in situ* gene conservation stand by a voluntary agreement of the owner. Unfortunately the Austrian forest ownership structure is unfavourable to declaration of genetic resources. Of the total forest area, 36.3% is cultivated by small forest enterprises (productive area under 50 ha). There is no means to declare forest genetic resources by law.

Since beech and oaks are often found in mixed forest types, preference is laid on so-called large-scale gene reserves that exceed 30 ha in size to ensure a sufficient effective population size (see Table 1).

The pragmatic approach chosen is based on the assumption that different site conditions determine the forest communities and shape genetic structures of the forest tree species. The following main criteria are considered for declaration of a gene conservation stand:

- representative of a natural forest community
- conform to nature with regard to the plant community
- autochthonous or at least well adapted (high vitality, no damage by biotic and/or abiotic factors, economically important phenotypical traits (e.g. straight stem forms) not regarded)
- naturally regenerated, at least potentially.

Silvicultural measures are taken in the gene conservation stands. However, forest managers must aim to achieve a sustainable balance by permanent stocking, all-aged stand structure, heterogeneous stand development, long natural regeneration with overlapping reproductive periods, and self-differentiation processes during all growth phases (for more details see Müller 1996).

Breeding

The Institute of Forest Genetics of the Federal Forestry Research Centre currently contributes to the International Beech Provenance Trial (see von Wuehlisch *et al.*, this volume), but there are no breeding activities in a strict sense for either *Quercus* or *Fagus*.

Table 1. Large-scale gene reserves (>30 ha) with beech and oaks in Austria

	Beech		Oak	
Province	**No.**	**Average size (ha)**	**No.**	**Average size (ha)**
Burgenland	2	32.6	–	–
Carinthia	15	66.3	1	103.0
Lower Austria	7	48.5	1	59.8
Salzburg	1	35.0	–	–
Styria	5	43.9	–	–
Tyrol	6	170.0	–	–
Vorarlberg	1	52.6	–	–
Total	**37**		**2**	

Research and capacities

Three institutions conduct genetic studies on beech and oak in Austria:

- the Austrian Research Centre, Seibersdorf
- the Centre of Applied Genetics of the University of Agriculture, Vienna
- the Federal Forestry Research Centre.

At present these institutions perform provenance, isoenzyme and DNA marker studies (e.g. Steinkellner *et al.* 1997; Comps *et al.* 1998).

Institutions

The Federal Forestry Research Centre with its Institute of Forest Genetics and Institute of Silviculture acts to put forest gene conservation into action. However, the cooperative programme to conserve forest genetic resources relies on the support of forest owners and managers.

Needs and perspectives

Gaps in the knowledge related to the conservation of genetic resources of beech and oaks are as follows:

- within- and among-population variation for morphological and genetic traits
- links between adaptive traits and genetic markers
- cryopreservation
- Multiple Population Breeding System (MPBS) vs. unmanaged *in situ* populations
- required number and size of *in situ* populations
- silviculturally managed vs. unmanaged *in situ* populations.

Answers to the above-mentioned questions would strongly contribute to the national conservation strategy.

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Conservation of Social Broadleaves genetic resources in Switzerland

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Occurrence and origin of beech and oaks in Switzerland

Switzerland is commonly divided into five different geographic regions: the Jura Mountains, the Central Plateau, the Lower Alps, the Alps and the Southern Alps (Fig. 1). These regions are characterized by specific ecological conditions. Overall, a great variety of different site types can be found, ranging from basic to acid soils and from atlantic to continental climates.

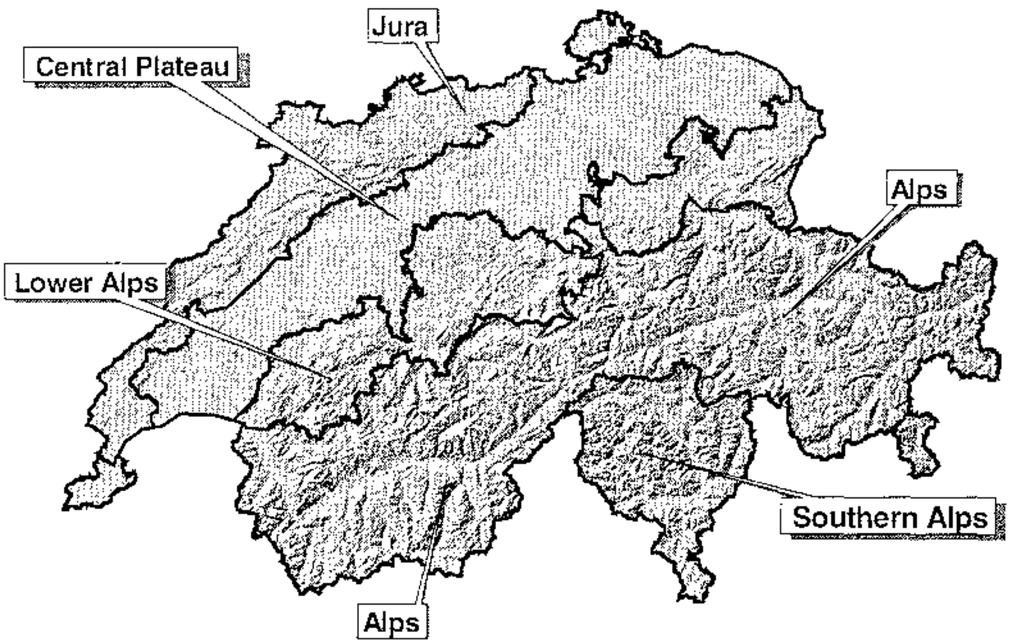

Fig. 1. The five geographic regions of Switzerland: Jura Mountains, Central Plateau, Lower Alps, Alps and Southern Alps.

Beech

Fagus sylvatica is mainly found in the Jura Mountains and the Central Plateau. It is not present in the dry and continental climates of the Alpine region (Fig. 2). In the subatlantic climate regions of Switzerland, beech forests form a broad vegetation belt between the subalpine vegetation zone dominated by Norway spruce and the lowland vegetation zone which is characterized by mixed deciduous forests. Beech occurs in almost all forest communities except those from subalpine mountain forests (Leibundgut 1984). Beech appears commonly as a species of mixed forests and only in 20% of the stands is its abundance higher than 66%. It is often associated with Norway spruce and silver fir, but also with sycamore maple, ash, oak and Scots pine (Brändli 1996). Fresh deep fertile soils, high humidity and high precipitation (>750 mm/year) are beneficial to beech (ETH-Zürich 1993). Beech requires a cooler climate than oak but a slightly warmer one than silver fir (Leibundgut 1984).

In the past, forest stands were considerably affected by human activities. Destruction of beech forests started in Roman times and continued throughout the Middle Ages. A significant proportion of beech stands disappeared as a result of clearing. Large areas were converted to agricultural land, especially in the Central Plateau. Today this region is the most populated part of Switzerland. Remaining beech forests were often replaced by Norway spruce, which is not native to the Central Plateau.

Oaks

Four different oak species occur in Switzerland: pedunculate oak (*Q. robur* L.), sessile oak (*Q. petraea* (Matt.) Liebl.), pubescent oak (*Q. pubescens* Willd.) and Turkey oak (*Q. cerris* L.). This report focuses on the two most abundant oak species, *Q. petraea* and *Q. robur*.

Pedunculate oak

The main range of pedunculate oak is in the Central Plateau and the eastern Jura Mountains. It is abundant in the western part of the country. It is rarely found or is even absent in areas of the more continental alpine regions. Pedunculate oak is most frequently found in forests below 400 m whereas solitary trees are encountered up to 1400 m in the upper montane vegetation zone (Brändli 1996). Although it has no specific demands on soil, it is often found on heavy clay and loam soils with high nutrient content and high water supply. Pedunculate oak is moderately heat-demanding during summer and sensitive to winter cold (less than sessile oak).

Sessile oak

Sessile oak is common and widespread in the Central Plateau, the Jura Mountains and the Southern Alps. It is most frequently found in the western part of the Central Plateau. Three-quarters of the sessile oaks grow in the lowland and submontane vegetation zones. Its main range is 400 to 600 m. Solitary trees are found above 1400 m (Brändli 1996). The demands for site conditions are different from those of pedunculate oak. Sessile oak is less nutrient-demanding and grows also on drier sites (Schweingruber 1990). On heavy soils it is replaced by pedunculate oak. Its demand for summer heat as well as its sensitivity to winter cold are higher than that of pedunculate oak (ETH-Zürich 1993).

Sessile oak is estimated to be twice as abundant as pedunculate oak. Pedunculate oak occurs mainly in hardwood riparian forests and mixed ash woodlands, whereas sessile oak dominates on very dry sites in acidophilous mixed oak forests. In a great number of forest communities (especially beech forests) both oak species are present in varying proportions. The most common associated species is beech. Norway spruce, silver fir, ash and sycamore maple are also often found in mixture with oak, owing to the impact of forest management. Pure oak forests (approximately 12 000 ha) are found only on 12% of the oak area, either on very dry sites or as artificial plantations (Brändli 1996). Natural oak forests are not found on fertile sites (Leibundgut 1984).

In the past, sessile and pedunculate oaks used to be more common in the Central Plateau and the Jura Mountains. In the former coppice with standards system, oaks were not only valued for their wood production but also for the acorns which were used for pig feed. The importance of oak species decreased with the introduction of potato starting in 1740. Oaks became less attractive than other species (e.g. Norway spruce) owing to the transformation of the coppice with standards into high forests. Since 1850 the construction and maintenance of the railway also devoured huge amounts of oak wood (Brändli 1996).

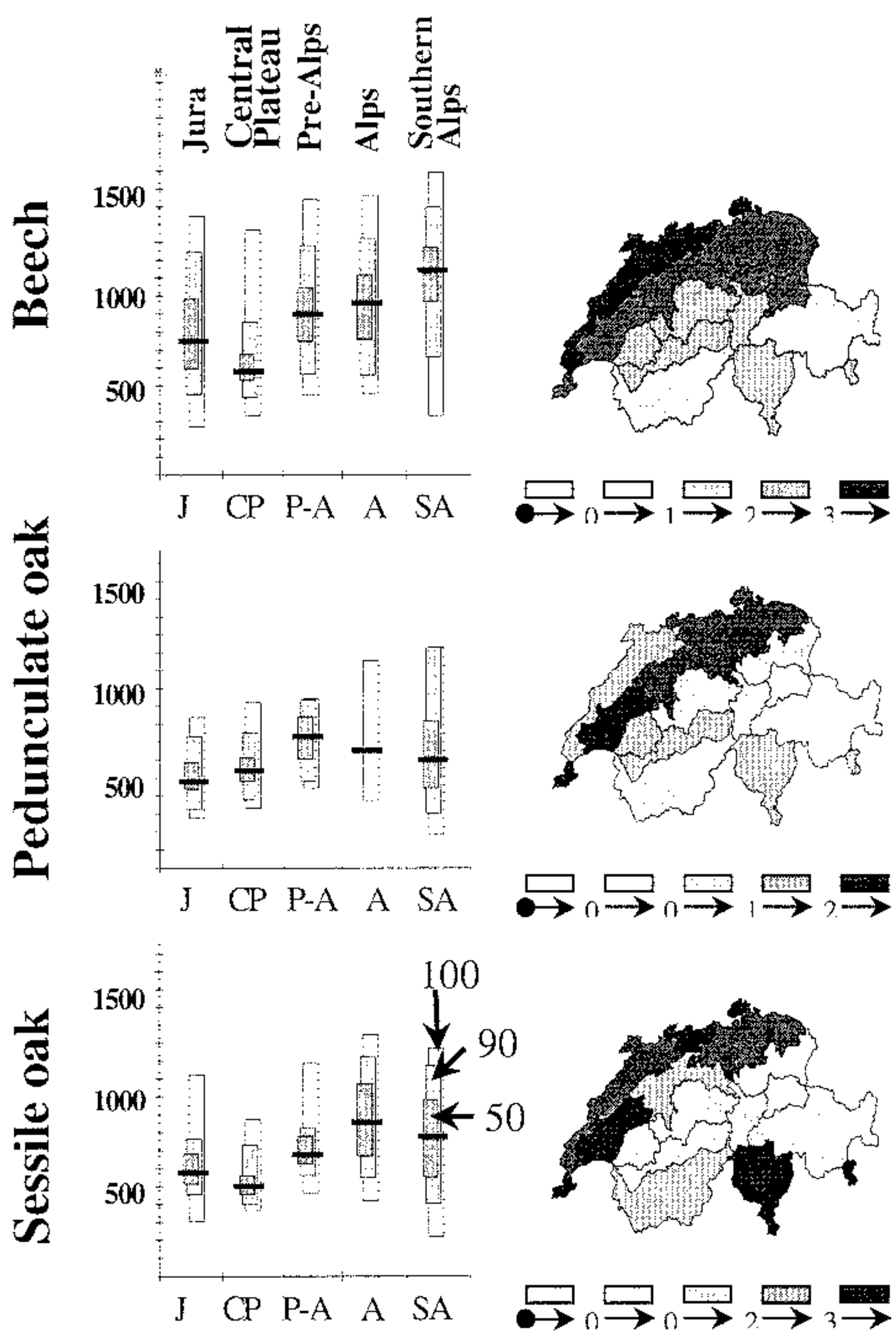

Fig. 2. Altitudinal and geographic distribution of beech, pedunculate oak and sessile oak.

Growing stock

Beech is the most important broadleaved tree species in terms of growing stock (approximately 59 million m^3) and after Norway spruce (179 million m^3) the second most important species in total (Table 1). Both oak species together represent approximately 2% of the total growing stock in Switzerland (EAFV 1988).

Table 1. Percentage of the total growing stock of beech and oak in different regions of Switzerland (EAFV 1988)

Species	Jura	Central Plateau	Lower-Alps	Alps	Southern Alps	Switzerland
Fagus sylvatica	30.0	20.4	13.3	6.6	13.1	16.2
Picea abies	31.2	42.9	57.3	62.6	35.2	49.1
Quercus petraea	2.0	2.3	0.1	0.2	1.7	1.1
Quercus robur	1.2	2.3	0.2	0.1	0.5	0.9
Others	35.6	32.1	29.1	30.5	49.5	32.7
Total in 1000 m^3	63 574	92 785	88 139	97 481	23 148	365 128

Ice age refugia

Fossil pollen maps of Europe indicate that oak survived the last maximum glaciation in refugia in southeastern Europe (Greece/Turkey), southern Europe (Italy) and southwestern Europe (Iberian Peninsula) (Huntley and Birks 1983). Analyses of genetic variation in chloroplast DNA (cpDNA) suggest that oaks recolonized Switzerland from at least two refugia (Dumolin-Lapègue *et al.* 1997; Ferris *et al.* 1997).

Beech populations north of the Alps are likely to originate from southeastern Europe (Balkan). Beech from an additional refugium in southern Italy may have expanded to south of the Alps (Burga and Perret 1998).

Current economic importance for the forestry sector

The economic value of oaks and beech remains limited because of their low abundance. The demand of Swiss non-coniferous wood for paper and cellulose industry has been stagnant for 20 years (Anonymous 1997). The use of steel, concrete and synthetic products is often preferred in construction and interior design industries. For railway construction, wooden sleepers have also been replaced by concrete and steel.

Beech and oaks, however, can be locally important especially for the production of veneer. During the last eight years, the average selling price for beech stem wood increased by approximately 6% (Anonymous 1997).

Silvicultural approaches used

Regeneration

Swiss forestry has a long tradition of close-to-nature silviculture and thus of enhancing natural regeneration. Almost 90% of the beech forests are regenerated naturally (Table 2) without major problems. Beech can be regenerated in small patches because of its shade tolerance. In association with Norway spruce and silver fir, beech is an important component in selection system forests. In other silvicultural systems it is usually regenerated with the shelterwood or strip-shelterwood method.

Artificial regeneration is much more important for oaks than for beech. Especially pedunculate oak is often planted as shown in Table 2. Both oak species are rarely sown. Natural regeneration is carried out in the shelterwood system and has to be fenced to avoid damage caused by game. The area of regeneration is usually at least 0.3 ha to minimize the

Table 2. Mode of regeneration used in Switzerland for beech and oak (Brändli 1996)

	Regeneration (%)			
	Natural	Natural and artificial	Artificial	No information
Beech	85.5	6.1	1.5	6.9
Pedunculate oak	54.8	18.4	17.3	9.5
Sessile oak	70.7	4.9	4.1	20.3

number of bent growing trees due to phototropic reaction (especially for *Q. robur*). Forest tending at the thicket and the early pole stages aims to homogenize quality and density of the trees. The growth in pure stands is considered to be an essential prerequisite for the production of good-quality wood. The cultivation of oaks is quite difficult and cost-intensive. Foresters are currently evaluating alternative silvicultural systems (e.g. planting in final distance - wide spacing) in order to lower costs.

Exploitation

The rotation period for beech is approximately 120 years, whereas oak is harvested after 120-200 years for sawn timber and after 240 years for veneer.

Health condition of the forest stands

Forest condition

In Switzerland a systematic monitoring of forest condition has been carried out since 1984 by evaluating the defoliation of crowns. The long-term trend suggests that the proportion of trees with unexplained defoliation higher than 25% is increasing (Fig. 3). Oak species seem to be more affected than beech (BUWAL/WSL 1992).

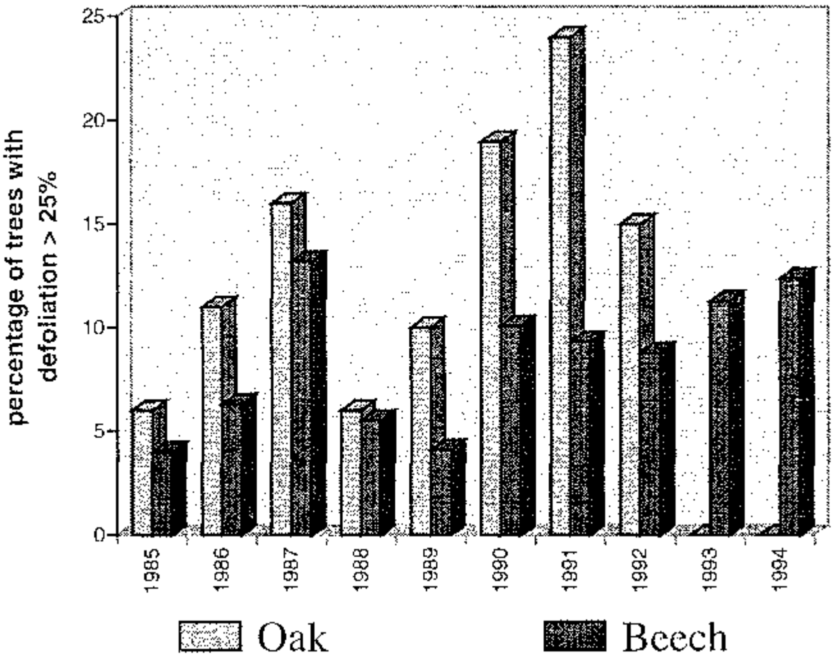

Fig. 3. Forest condition in Switzerland: unexplained defoliation >25%. Data for oak are only available up to 1992 (WSL 1995).

Tree diseases

The Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) publishes a periodical bulletin of relevant forest pathology problems based on a survey of all forest districts (Meier *et al.* 1996). In 1995 the following observations were made.

Oaks

Three different kinds of damage were observed in oaks.

First, in the development stages from saplings up to pole stage, signs of dieback of the crown were observed. The cause for this phenomenon was infestation by different cortical fungi. These damages were without exception caused by secondary pests, which affected the bark of weakened oaks.

Second, clear yellowing of leaves was observed. All age groups were affected. Often all the leaves on a branch or a bough were affected whereas the neighbouring leaf material of the same tree showed no signs of damage. In extreme cases the entire tree was affected.

Third, old oaks often showed a high percentage of dry branches with crown thinning. In advanced stages the root-infecting fungus *Armillaria mellea* was found to speed up the process of dying.

Although the health condition of older oaks in Switzerland has worsened, it does not seem that the observed symptoms and the damages point to an oak decline. The causes for the worsening health state of oak are probably the result of unfavourable weather (droughts, frost), pollution and to some extent also silvicultural activities (e.g. stress induction due to the transformation from coppice with standards into high forest) (Hämmerli and Stadler 1988). The ageing of certain oak stands could also be important.

Beech

In 1995 some cases of beech bark disease were registered. Various causes may explain this complex disease: disturbance of the hydrological regime of the soil, infestation with the canker fungus *Nectria coccinea* and attacks of the scale insect *Cryptococcus fagi*. Apart from beech bark disease, beech canker (*Nectria ditissima*) is locally important. Especially saplings can be affected (Meier *et al.* 1996). However, in Switzerland beech is not considered as seriously threatened by pathogens.

Research activities and capacities related to genetic resources/diversity

Various research activities are focused on the native oak species. Two projects are carried out at WSL. Within the project 'Conservation of Genetic Resources in Forests' the genetic diversity within and among oak populations is characterized. The second project 'Synthetic Maps of Gene Diversity and Provenance Performance for Utilisation of Oak Resources in Europe' is carried out within the frame of the EU-FAIR programme. A third project is carried out at the Swiss Federal Institute of Technology. This project aims at the characterization of genetic diversity of *Q. pubescens* within Switzerland. In the project 'Conservation of Genetic Resources in Forests' the variation of cpDNA was assessed in more than 600 individuals from 135 locations covering the natural range of the three native oak species (*Quercus robur*, *Q. petraea*, *Q. pubescens*) in Switzerland. Results from these analyses are expected to provide information on postglacial migration routes and transfer of seeds by humans. Assessment of genetic diversity within and among populations of oak species is also planned at nuclear marker gene loci, i.e. isoenzymes and microsatellites. Populations of all three native oak species will be included in the genetic inventory. Selection of populations for investigation will take into account the insights into the evolutionary history of oaks gained from chloroplast DNA studies. Geneflow and mating system will be investigated in some populations by observing the temporal dynamics of genetic structures in mature forests and progenies. Results will be used to identify valuable genetic resources of oaks for the designation of *in situ* gene reserves and to establish guidelines for the management of these reserves.

At present, no research activities are performed for beech.

Current genetic conservation activities *in situ*

Gene reserves

In 1988 the Conference of Cantonal Forest Services approved a programme for the conservation of genetic resources in gene reserves. As a result, the Federal Office of Environment, Forests and Landscape (BUWAL) financed various projects for the implementation of genetic conservation activities. Within the framework of the current project 'Conservation of Genetic Resources in Forests' (1996-99) several projects for gene reserves for Norway spruce and silver fir were initiated and are presently under negotiation with the local forest services and the forest owners. Projects for oak gene reserves will be started within the next 2 years. The objective is to enter into long-term contracts (50 years) for the special management of gene reserves. One gene reserve for oaks was established in 1993 in the Galm forest, canton Fribourg.

Gene reserves will be under strict forest management regulations (Bonfils 1995). Introduction of foreign genetic material is forbidden and natural regeneration has to be used as far as possible to ensure transmission of all genetic information to the subsequent tree generation. The gene reserves are divided into four zones (zones 0-3) and for each zone management regulations are defined. In zone 0 selective thinnings are forbidden. This zone covers a relatively small area (about 2 ha) but ensures a selection process close to nature. Zone 1 represents the main part of the gene reserve. This zone surrounds zone 0 and is 20-100 ha in size. Within this zone traditional close-to-nature silviculture is performed to enhance natural regeneration. If natural regeneration is not possible, artificial regeneration has to rely on reproductive material from the local source. Zone 2 is realized if trees of foreign origin grow within the gene reserve. These trees have to be eliminated at the latest by the end of the production period. Zone 3 is a buffer zone that prevents or reduces geneflow from trees of surrounding stands to the gene reserve. No particular silvicultural regulations are defined for this zone. Gene reserves will be incorporated in the general management plan of the forests. The Federal government jointly with the cantons will compensate the forest owner's expenditures that occur as a result of the special management of the gene reserves.

Seed stands

In Switzerland, the cantons are responsible for the supply of seed material. According to the Swiss forest law they determine the forest stands in which reproductive material may be collected. The Swiss Forest Agency is responsible for a national register of the seed stands and its registration according to OECD regulations. Currently the two categories 'Source-identified' and 'Selected' are available in Switzerland. The number and categories of seed stands for beech and oak species are shown in Table 3.

The minimum size of seed stands for beech and oak is as follows: 0.25 ha for seed stands providing source-identified reproductive material; 1 ha for stands providing selected reproductive material. The registered stands vary from 0.25 to 700 ha (Fürst, pers. comm.).

Table 3. Number of seed stands classified in the national register for beech and oak

Seed stands	'Source-identified'	'Selected'	Total
Beech	81	25	106
Pedunculate oak	46	18	64
Sessile oak	38	6	44

Relevant nature protection policies and activities

Close-to-nature silviculture

According to the 1991 Federal Forest Law the cantonal forest service has to perform close-to-nature silviculture. This is achieved by promoting natural regeneration and using natural growth patterns to obtain uneven-aged and well-structured stands. The resulting diversity in species, stand structures and age classes is important for sustainable benefits from forests and, furthermore, very valuable for nature protection. The use of natural regeneration is one of the key points of the concept of close-to-nature silviculture. In the context of *in situ* gene conservation this appears to be a prerequisite for successful management of gene reserves.

Forest reserves

According to the Federal Forest Law (1991) forest tending and exploitation are not compulsory for the total forest area. It is possible to renounce, partially or entirely, to silviculture activities. Forest reserves can be declared for the protection of a diversity of species. Currently the cantonal forest services are working on recommendations for such forest reserves with special management or even strict ban of management. However, strict forest reserves have existed in Switzerland since the beginning of this century. There are numerous reserves ranging in size in which human activities are forbidden. They make up approximately 0.5% (6000 ha) of the total forest area (FOEFL 1995).

Forest reserves can be integrated into gene reserves. When possible, it will be taken into consideration that in addition to these 'banned' areas there will also be areas in which an active genetic conservation policy is applied.

Use of reproductive material

Currently there are no ongoing tree improvement activities in Switzerland. The demand for reproductive material has clearly decreased during the past 20 years (Fig 4). From the mid-1980s to the beginning of the 1990s the total number of plants of broadleaved trees slightly increased. From 1991 on, the use of reproductive material decreased, showing the same trend as conifers had for 20 years. The annual demand for plants is currently estimated to be 200 000 for oaks and 380 000 for beech (Fürst, pers. comm.).

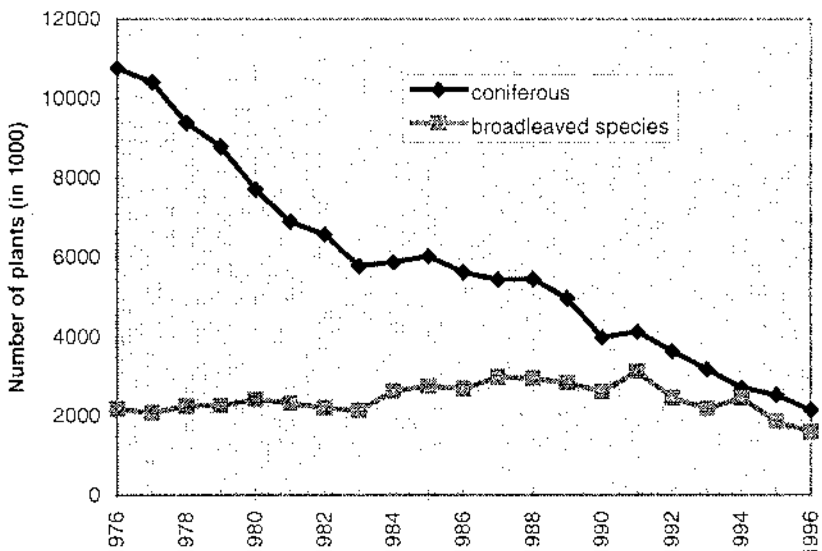

Fig. 4. Use of plants for artificial regeneration for conifers and broadleaved trees (Anonymous 1997).

Institutions involved in genetic resources activities

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Country capacities and priorities

Capacities for conservation and research activities in Switzerland are limited. Ongoing projects therefore are focused only on a few species. Oak is included in these programmes whereas beech is low priority.

Needs for international collaboration

The coordination of research projects and the collaboration of different groups could contribute to an overall reduction in costs and to an increase of the output on European level. Important factors for successful conservation of genetic resources is information flow among countries and availability of research results. Practical guidelines for the conservation of genetic resources should be discussed. In addition, research activities should be designed according to the needs of gene conservation.

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Fagus sylvatica, Quercus petraea and *Quercus robur* genetic resources in Italy

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Beech

Biogeographical range and origin of beech

In Italy, European beech (*Fagus sylvatica*) is a dominant species between 800 and 1500 m asl in part of the Alps and between 1000 m and the upper tree line in the Apennines (see Table 2 in Bucci 1997). It should be stressed that Italian forests in general are mountain forests, with only 17% of the total forest area located below 500 m.

Beech is the dominant species in 16% of Italian forests. Numerous populations exist outside the continuous biogeographical range, likely remnants of a wider coverage of the Italian peninsula that probably reached a maximum 5000-6000 years ago (Chiarugi 1939). In central Italy a number of fragmented populations (27) affected by various levels of isolation (marginal, remote-summit, remote-abyssal) have been studied to investigate the genetic effects of fragmentation (Leonardi *et al.*, unpublished). In southern Italy the largest beech forest separated from the continuum of the biogeographical range is the beech stand growing at relatively low altitude (500 m) in the Gargano peninsula, which extends to the Adriatic sea.

There is clear palynological evidence of a southern origin of Italian beech. A compilation of dates of the first appearance of beech after the last glaciation shows a clear geographic gradient from Sicily to the Alps (Leonardi and Menozzi 1995; Watson 1996). Not enough evidence exists to demonstrate the importance of refugia in the Illyrian Alps as a recolonization source of Italian beech.

The demonstrated presence of glacial refugia gives Italian beech populations a particular value for reconstructing the natural history of the species, and as a potential reservoir of the genetic variability associated with recolonization sources.

Current economic importance

Italy is the third largest importer of sawn lumber in the world, after the USA and the UK. This is not surprising given the large Italian furniture industry (almost US$40 billion in 1997). Against this background the economic relevance of beech production is dwarfed: between 1975 and 1985, 200 000 m^3 of sawn lumber (about 5% of the total production from all species) were produced annually, mainly from the Calabria and Campania regions (Bernetti 1995). Until about 30 years ago firewood used to be a much larger part of beech forest production (almost three times in the 1950s). In the last decades the increase in labour cost and the convenience of using other less bulky fuels has reduced the production of firewood to an amount equivalent to timber production. The conditions leading to an increased conversion of coppice to high forest seem to be present.

In this situation there is clearly a great potential for expanding the economic importance of beech wood.

Silvicultural approaches

In Italy, out of a total forest surface of 6.2 million ha, beech covers about 1 million ha: 240 000 ha of high forest, 330 000 ha of coppice (or coppice being converted to high forest), the rest in mixed types. High forest is mostly found in southern Italy (80%).

Silviculture followed a close-to-nature approach for a long time, producing a large (although difficult to quantify) proportion of beech forests with heterogeneous, uneven-aged structure with natural regeneration and overlapping production periods. These are some of the requirements necessary for establishing seed sources.

In general, beech forest ownership is mostly in private hands with only about one-third belonging to public institutions, although a large variation exists among regions. Forest management was transferred in the 1970s to regional authorities. The lack of coordination among regions has generated different policies and regulations in different regions and a different level of enforcement of such policies in different areas.

Health state of the forest stands

A critical reappraisal of previous work claiming widespread beech decline in Italy was published recently (Bussotti 1994). Forest damage seems within physiological limits for stands growing in favourable locations; ecologically marginal stands tend to show signs of decline from the combined effect of environmental stress and the associated secondary pest-related damage.

Research activities on genetic diversity

Recently, the genetics of Italian beech has been the object of a series of studies reported in the international literature.

The genetic variability of 21 Italian populations was studied assaying 10 (9 polymorphic) enzyme loci by starch gel electrophoresis (Leonardi and Menozzi 1995). The estimates obtained by different parameters (e.g. 16.8% average expected heterozygosity) were in line with the range of values (17.1-31.7) reported for European beech populations for the same parameter (Comps *et al.* 1990; Merzeau *et al.* 1994; Paule 1995). A closer match (24.5% for Italian populations compared with 23.1% for European ones) was obtained by recomputing the variability estimated using only the loci in common among the different studies. A value of 23.2% is reported for 11 stands from Piedmont region, northwestern Italy (Belletti and Lanteri 1996). A slightly higher variability estimate (30%) was obtained for a population from the Northern Apennines using I-SSR and RAPD markers (Troggio *et al.* 1996). This is not surprising given the well-known higher power of these DNA-based markers in detecting variability (Müller-Starck and Ziehe 1991).

The excess of homozygotes usually reported for European populations (Comps *et al.* 1990) was also found in most Italian populations (Leonardi and Menozzi 1995; Rossi *et al.* 1996). No definitive explanation was given for this observation. The discussion of this phenomenon touches upon the partitioning of variability among and within populations.

As with other forest tree species (all characterized by wind pollination, high outcrossing rates, large geographical range and long life cycles), beech populations carry most of the variability at the within-population level. A correspondingly low estimate of the among-population component was found in the survey of 21 Italian populations and in the 11 stands from Piedmont (F_{st}=0.046 and F_{st}=0.043). A very close estimate had been reported for a large survey of European populations (F_{st}=0.054) in Comps *et al.* (1990).

Inbreeding rates were estimated for two Italian populations between 2 and 4% values, in line with what is reported in the literature (Rossi *et al.* 1996). The paternity analysis of a set of open-pollinated sibships carried out using RAPD markers in a Northern Apennines population allowed a preliminary estimate of effective pollen migration (Troggio *et al.* 1996). The mean average distance between sibships (mother tree) and potential father trees (31 m) was larger than the mean distance from incompatible ones (29 m). Distance effects have to be investigated at greater spatial scales.

A large study of the spatial distribution of genetic variability within populations confirmed limited structuring at the microgeographical level (Leonardi and Menozzi 1996a). An autocorrelation study at 11 enzyme loci in 14 populations over the Italian biogeographical range of the species found significant spatial structuring for only 11.5% of all genotypes. No correlation between the amount of spatial structuring and environmental (latitude, longitude, altitude), structural (mean and standard deviation of tree size) and genetic characteristics (mean expected heterozygosity, mean F_{is}) of the population was found. No significant differences seem to exist among loci if low heterozygosity loci are excluded from the analysis.

In spite of the low genetic differentiation among populations and the low level of spatial structuring at the microgeographical scale, a clear pattern of variation was observed at the regional level: using multivariate statistics (principal components) southern and northern populations clustered in separate groups. Moreover the values of the synthetic multivariate statistics from Sicily to the Alps showed a gradient strikingly similar to the sequence of dates (obtained from palynological records) tracking the postglacial recolonization of the Italian peninsula (Leonardi and Menozzi 1995). The principal component gradient was found significant by a test based on resampling techniques (bootstrap) (Leonardi and Menozzi 1996b).

At a different scale, using different markers, a high variability was found in southern populations in a survey of European populations to investigate variability of chloroplast DNA by PCR-RFLP markers: the two populations from southern Italy included in the study (Pollino (Calabria) and Sicily) were, along with other southern stands from Crimea and to a lesser extent from the Pyrénées, among the most variable in Europe (Demesure *et al.* 1996).

No correlations between allele frequencies and soil type or altitude were found (Leonardi and Menozzi 1995). In the Piedmontese populations a slightly higher genetic variation was observed in north-facing (cooler and wetter microclimates) populations than in more stressed southern exposures (Belletti and Lanteri 1996). Provenance studies revealed differences in bud flushing (Borghetti and Giannini 1982), chilling needs (Bagni *et al.* 1980), xylem embolism, growth parameters and phenology (Borghetti *et al.* 1993) and drought resistance (Tognetti *et al.* 1995).

A complete diallelic cross (4×4) produced a progeny of more than 800 viable plants, ideal material for developing a deeper understanding of the genetics of the species using modern molecular tools (Ceroni *et al.* 1996).

Genetic conservation in situ *and* ex situ

In Italy genetic conservation for most species of forest trees is usually limited to seed stands. An official Register of seed stands for all principal forest tree species containing about 150 seed stands selected according to OECD/EEC regulations has been set up at the national level.

For beech a biogenetic reserve of the European Council was established for one stand (Cansiglio forest, Veneto region) in recognition of the outstanding features of this locality. Biogenetic reserves have been established for a long time for other high-quality stands (Vallombrosa in Tuscany and Sassofratino on a watershed between Tuscany and Romagna). Recently (July 1997) the status of Biogenetic Reserve has been granted to all the seed stands of the official Register. Beech is represented in the Register by a total of seven stands belonging to six different regions (Table 1). The seed stands are representative of the whole biogeographical range of beech in Italy.

There is very limited replanting in Italian forests in general (see below) and it is basically nonexistent for beech. Seed collecting can be seen as a form of *ex situ* conservation. The state seed company in Peri (Verona) maintains a sizable seed bank from the seed stands and from other locations. In total, 3590 kg of beech seeds are available.

Essentially no other *ex situ* conservation initiative has been taken in Italy. Although the availability of genetic material in controlled *ex situ* situations would be useful for other purposes (see below) the complex of nature conservation initiatives seems to protect the genetic resources of beech to such an extent to make *ex situ* conservation programmes unnecessary.

Table 1. *Fagus sylvatica* seed stands in Italy

Locality	Region	Area (ha)
Molveno	Trento	16
Cansiglio	Veneto	243
Alta Bormida	Liguria	78
Abetone	Tuscany	590
Amiata	Tuscany	4
Campo Ceraso	Abruzzo	270
Cinquemiglia	Calabria	174

Source: Ministry for Agricultural Policies. Libro nazionale dei Boschi da Seme 1976.

It is interesting to stress that the population genetic investigations carried out on the spatial structuring of genetic variability in Italian stands can help in designing rationally the form of genetic reserves for the species. The low spatial structuring of genetic variability, with patches of significant clustering of less than 100 m and paternity not attributable to the nearest trees, calls for a complex design of reserves that guarantee the conservation of the genetic variability present in the population.

Relevant nature protection policies and activities

A great conservation effort is being programmed in Italy. The total area of the national territory designated to be under some degree of protection in the near future is quite large for a highly densely populated country like Italy (3 041 000 ha, 10.09% of the whole country). At the moment 508 areas (18 national parks, 147 state natural reserves, 71 regional parks and 171 regional natural reserves, 101 protected biotopes, 7 marine reserves) cover a total of 2 000 232 ha (7.4% of the country). This is a great increase from just 10 years ago (in 1987 only 3.3% of the national territory was under some form of protection).

Many of these areas located in all parts of the country, mostly in mountain areas, contain beech forests (for details, connect to the National Forest Service Web site at **http://www.corpoforestale.it/home.htm**). Although in general not designed with the specific purpose of conserving genetic resources, the system of Italian protected areas with its latitudinal span from Sicily to the Alps guarantees a vast source of beech genetic resources.

Tree-improvement activities

No large-scale tree improvement is carried out in Italy for beech. Provenance trials have been established for ecological research purposes. For instance the Institute for Forest Tree Breeding (IMGPF-CNR, Florence) maintains the following provenances in three localities in Tuscany:

- in Vallombrosa, provenances from Liguria (2), Abruzzi (4), Calabria (4)
- in Rincine, provenances from Emilia (1), Tuscany (1), Abruzzo (2), Puglia (1), Basilicata (9), Calabria (3), Campania (2)
- in Pisanino, provenances from Emilia (1), Tuscany (1), Abruzzo (2), Puglia (1), Basilicata (8), Calabria (2), Campania (2).

Use of reproductive material

According to data of the Statistical Institute, artificial reforestation covered on average approximately 10 000 ha/year during the decade 1979-88 (60% broadleaves and 40% coniferous trees). From 1989, the afforestation activities have been supported by the EU (EEC 1094/80, 'set aside') related to 2500 ha in 1989, 7000 ha in 1990 and 10 500 ha in 1991.

Given the silvicultural practices used in Italy for beech, it not surprising that no sizable planting is carried out.

Institutions involved in genetic resources activities

As previously illustrated, with the exception of the state seed company, there is no institution specifically dedicated to genetic resources activities: many share responsibility for their management and protection, from the Ministry of Agricultural Policies (MIPA) with its National Forest Service, to the regional Forest Services, the Parks and protected areas at various levels. Research activities on genetic resources are carried out in Universities (about 20 of them offer a programme in Forestry) and in other research institutions: CNR (National Research Council), MIPA, and other public and private concerns.

Summary of country capacities and priorities

Italy has great potential for contributing to the conservation of beech genetic resources. The ecological variety of the biogeographical range that hosted glacial refugia makes Italian forests very rich in genetic resources. The numerous institutions involved in the management of forest resources, the political initiatives for nature conservation and the potentially sound research capacities all contribute to a favourable scenario for successful action in genetic resources conservation. A coordination capable of focusing all this potential on clear goals seems necessary to achieve factual results.

International collaboration and participation in multinational programmes could play a very important role in overcoming the multiplicity of objectives of the different actors, and foster the shaping of an effective national policy in genetic conservation of beech natural resources.

Oaks

***Biogeographical range and origin of* Quercus robur *and* Quercus petraea**

In Italy, 12 species of deciduous oaks exist, but only five have a non-negligible presence (Bernetti 1995). The taxonomy of oak species is an open question, and is attracting a lot of attention in Italy. In this paper, information on the distribution of the species most frequently found in Italy is given only to evaluate the relevance of the two species of interest for the EUFORGEN Social Broadleaves Network: *Q. robur* and *Q. petraea*.

Out of a total of almost 1 million ha of forest prevalently made up of deciduous oaks, *Quercus pubescens* is the most frequent, followed by *Q. cerris* (Table 2). *Quercus frainetto* is found in the peninsular part of Italy from south of Tuscany to Calabria.

Table 2. Deciduous oaks in Italy

Species (Italian name)	Area (ha)	
Quercus pubescens (roverella)	150 000 ha (high forest)	540 000 ha (coppice)
Quercus cerris (cerro)	70 000 ha (high forest)	200 000 ha (coppice)
Quercus robur (*pedunculata*) (farnia)	a few thousand ha	
Quercus petraea (*sessiliflora*) (rovere)	sporadic	
Quercus frainetto (farnetto)	in mixed fomations with *Q. cerris*, area difficult to quantify	

The two species of interest for the Network (*Q. robur* and *Q. petraea*) are scarcely represented. The biogeographical range for *Q. petraea* is reported to extend as far south as the Abruzzi region (east of Rome), although stands of the species have been reported from the whole peninsula and Sicily.

There is clear palynological evidence of a southern origin of Italian oaks. Italian populations of *Q. robur* and *Q. petraea* are at the southern margin of the European biogeographic range and their study is of great interest for the understanding of the recolonization process and to investigate the effects of fragmentation on the genetic structure of the species.

The natural plain forests hardly exist in Italy, having been replaced long ago by crops of larger agricultural value. The ecological preferences of *Q. robur* for this kind of environment severely limit its presence in the country. Although exhaustive quantitative data on its distribution are not yet available, one could say with caution that the species is in a status warranting some protective measures. We will see that this statement will have to be validated in light of the new evidence that is being collected.

Quercus petraea, relatively more tolerant of environmental conditions less desirable for agricultural use, is found in a more important extent.

Current economic importance

Timber production from most oak species is mainly used as firewood (1.8 million m^3 in 1989) while production of sawn timber is limited (70 000 m^3 in the same year) (Bernetti 1995).

Quercus robur and *Q. petraea*, given their scarce presence in Italian oak forests, are at present of marginal economic interest. Given the high quality of their wood, the increasing availability of land made available by European Union agricultural policies, and the importance of the Italian wood manufacturing industry (see part on beech), a great potential can be seen for expansion of the two species.

Silvicultural approaches and health state of the forest stands

Quercus petraea is managed like the much more frequent *Q. pubescens* with which it can easily produce hybrids. *Quercus petraea* has been found to be more abundant than expected in central Italy, while little information exists on its presence in southern Italy (Buresti *et al.* 1995). The largest population of *Q. petraea* in central Italy (10 ha) has been coppiced in the past (Cutini and Mercurio 1995).

The sparse distribution of *Q. robur* makes it hard to formulate meaningful generalizations. The small *Q. robur* Policoro population (Basilicata region, Fineschi, pers. comm.; Dumolin-Lapègue *et al.* 1997), part of a small protected area, is made up by a group of old trees in poor health with almost no natural regeneration.

Research activities on genetic diversity

Given the limited distribution of the two species in Italy, the amount of research carried out on them is almost surprising. The potential practical use of a genetic characterization of the existing populations makes such activities of special interest. Five *Q. robur* and five *Q. petraea* populations from Piedmont have been investigated using 11 enzyme loci (Belletti and Leonardi 1997). Variability is mostly found between populations (G_{st}=0.023 for *Q. robur* and G_{st}=0.056 for *Q. petraea*). Sicilian populations of *Q. petraea* and *Q. pubescens* have been investigated using chloroplast DNA markers (Fineschi *et al.* 1997). Populations of *Q. petraea* from several Italian locations are included in a Europe-wide investigation carried out using chloroplast DNA markers (Dumolin-Lapègue *et al.* 1997).

Research on the genetic variability of oaks using microsatellites is being carried out at Florence University (PhD thesis of P. Bruschi, under the supervision of Prof. Grossing).

Genetic conservation in situ *and* ex situ, *tree improvement activities and use of reproductive material*

The national Register lists only three stands for *Quercus:* one of *Q. robur* (70 ha in Piedmont), two of *Q. cerris* in the Lazio and Molise regions. The official availability of seeds is not negligible and of diversified origin (Tables 3 and 4).

According to data of the Italian Statistical Institute, artificially reforested surfaces were on average approximately 10 000 ha/year during the decade 1979-88 (see information given for beech).

Table 3. Seed availability (kg) for *Quercus robur*

	Seed provenance (province)†												
Total weight (kg)	BL	SO	MN	BO	VE	UD	RO	BG	VR	CN	PR	VI	TN
8459	41	342	1105	633	447	181	325	4538	270	88	72	189	228

† BL=Belluno, SO=Sondrio, MN=Mantova, BO=Bologna, VE=Venezia, UD=Udine, RO=Rovigo, BG=Bergamo, VR=Verona, CN=Cuneo, PR=Parma, VI=Vicenza, TN=Trento.
Source: Ministry for Agricultural Policy, Uficio Amministrazione Produzione Sementi Forestali di Peri (Verona).

Table 4. Seed availability for *Quercus petraea*

	Seed provenance (province)†								
Total weight (kg)	PR	TS	BO	PD	VI	TN+VR	VC	TO	CN
5136	1657	407	5	199	176	238	570	219	1665

† BO=Bologna, VR=Verona, CN=Cuneo, PD=Padova, PR=Parma, VI=Vicenza, TN=Trento, TS=Trieste, TO=Torino.
Source: Ministry for Agricultural Policies, Uficio Amministrazione Produzione Sementi Forestali di Peri (Verona).

In response to the demand for reproductive material for afforestation of agricultural land freed by the 'set aside' European Union policy, a great deal of interest has been dedicated to the evaluation of possible sources of genetic material. These efforts are still in their initial phase. For instance, reproductive material was sampled from about 70 natural stands for both species in northern and central Italy. An *ex situ* collection of nine provenances was established by the Forest Research Institute of Arezzo in collaboration with regional authorities. A 4-ha plot has been established for the production of reproductive material.

These initial efforts reflect the awareness of the importance of inventorying, evaluating and developing the genetic resources of the country, which are potentially very rich for the above-mentioned reasons.

Relevant nature protection policies and activities

The general information given for beech on this topic also applies to oaks. In addition, given their economic importance and sparse distribution, there is an obvious need for a complete mapping of the extant populations of *Q. robur* and *Q. petraea*. As is the case for beech, the populations most valuable for genetic conservation are probably already under some kind of protection. But it is likely that given the small size of the remaining populations, many of those still have to be identified. Their evaluation through appropriate procedures is necessary so that they can be granted the protection they deserve.

Institutions involved in genetic resources activities

The same institutions involved in genetic resources activities of beech are also involved in the handling of genetic resources of *Q. robur* and *Q. petraea*.

Summary of country capacities and priorities

Italy has a great potential for contributing to the conservation of *Q. robur* and *Q. petraea* genetic resources. Owing to the ecological variety of the biogeographical range that has hosted glacial refugia and to the fragmentation and reduction in size of the populations of both species, the study of their genetic resources present in Italy is very interesting. Their potential economic importance should be able to stimulate the numerous institutions involved in forest resources management to coordinate their action to achieve factual results.

International collaboration and participation in multinational programmes is even more necessary for *Q. robur* and *Q. petraea* than for beech, to overcome the organizational difficulties and to acquire the standard of scientific knowledge necessary for effective conservation of their genetic resources.

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Beech and oak genetic resources in Slovenia

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Introduction

Forests cover 53% of Slovenia. Because of the mountainous and karstic character of the country, which makes access to many forests difficult, the degree of human intervention has been lower than in most central European countries. In addition, owing to highly diverse ecological conditions, forest sites and their tree species are characterized by a high diversity. Because of the traditional close-to-nature forestry management for sustainable and multifunctional use, the species composition in 87% of the Slovenian forests is equal to or very similar to the potential one. Only in 9% of all forests has the species composition been changed significantly, and in 4% the species composition is completely different from the natural one (Grecs and Kraigher 1997). The potential forest types are presented in Table 1. However, the proportion of the most important tree species in the growing stock of Slovenian forests is different (Table 2).

Occurrence, origin and current economic importance of beech and oaks for the forestry sector

European beech (*Fagus sylvatica* L.) is an indigenous tree species in Slovenia. It represents 29% of the total growing stock but in the potential natural vegetation its share would be as high as 58%. A great majority of the beech forests are natural, for in the past practically no beech was planted in Slovenia. During the glacial period the majority of beech populations survived in the refugia of southern Italy, southern France and on the Balkans peninsula. In the postglacial period, approximately 8000 BP, beech started to spread into the territory of Slovenia again. The so-called beech stage, following the *Quercus-Corylus* stage, starts in the period before Boreal and is subdivided into a *Fagus-Abies* substage, when fir and alder prevailed, a pure Subboreal *Fagus* stage, when beech increased due to a warmer and drier climate, and another *Fagus-Abies* stage in which the living space of beech was reduced and which lasts up to the present (Šercelj 1972; Horvat-Marolt 1992).

Table 1. Forest sites in Slovenia (The Forest Development Programme of Slovenia, 1996)

Forest sites	Area (ha)	%
Beech forests on carbonate ground rock	286 074	27
Acidophilous beech forests	179 451	17
Forests of beech and silver fir	163 581	15
Forests of beech and oak	115 166	11
Forests of oak and hornbeam	87 373	8
Thermophilic broadleaved forests	57 936	5
Silver fir forests	49 228	4
Alpine forests	41 525	4
Pine forests	39 394	4
Oak forests	33 769	3
Norway spruce forests	15 471	1
Forests of willow and alder	7 508	1
Total	1 076 474	100

Table 2. Proportion of the most important tree species in the growing stock of Slovenian forests (The Forest Development Programme of Slovenia, 1996)

Vegetation	European beech	Norway spruce	Silver fir	Oaks	Valuable broadleaved species	Other broadleaved species	Pine
Potential (%)	58	8	10	8	6	8	2
Current (%)	29	35	11	8	3	7	7

Lowland forests of **oaks** are the most changed forest ecosystems in Slovenia. As a result of agricultural activities and urbanization, they have been transformed into cultivated steppes and urban areas. Only a few remnants subsist and even these are affected by various disturbances like changes in water table, input of fertilizers, air pollution, etc. However, the species structure in these remnants is largely natural. There are seven indigenous oak species (Martinčič and Sušnik 1984; Azarov 1991; Batič *et al.* 1994; Batič *et al.* 1995) and two introduced oak species in Slovenia (Table 3).

Most of the **pedunculate oak** (*Quercus robur* L.) forests have been cleared in the past for agricultural use. The biggest residues of once widespread forests are in lowland, occasionally flooded areas of Krakovski gozd. This Krakovo Forest is also known because of the largest virgin oak forest reserve, formed predominantly by pedunculate oak. Other complex localities are sited north from Breice and along the rivers Mura and Ledava. Residual forest fragments are known from the valleys of Drava, Paka and Mislinja rivers, on the Ljubljana's moor and even on some carbonate soils in the Midlands (Notranjska).

Sessile oak (*Quercus petraea* (Matt.) Liebl.) is the most widespread oak species in Slovenia. It forms approximately 87% of all oak species in the growing stock, grows equally well on carbonate and silicate ground rock material, mainly up to 700 m asl, but also above 1000 m. The overview on the areas and growing stock in the forest management units (Slovenian Forest Service 1990) in Slovenia are presented in Table 4.

Silvicultural approaches

Silvicultural measures in Slovenia depend on the Forest Development Programme of Slovenia and the Forest Management Plans. On the basis of these, detailed silvicultural plans are prepared for each forest management unit (on average 50 ha of forest), belonging to districts (area from 3000 to 6000 ha), these being included in forestry regions (14 in Slovenia).

According to the Forestry Act (1993) the detailed silvicultural plans define:

- necessary cultivation work for regeneration and tending of the forests, including the first selective thinning (before the first commercial thinning)
- necessary protection work
- guidelines and time limits for carrying out tending and protective work
- quantity and structure of trees for the maximum allowable cut
- guidelines and conditions for felling and skidding timber.

On the basis of silvicultural plans and other operational projects or plans within the framework of the investment programme for forests, drawn up by the Slovenian Forest Service for the current year, the state subsidizes the following silvicultural and protective measures:

- measures for preventing or mitigating the disturbances in the functioning of the forest and forest work in protective forests and torrent watersheds
- measures for silvicultural protection and for the maintenance of wildlife habitats
- production of seeds and seedlings in a nursery and investments in forest tree nurseries
- restoration of forests if the party responsible for the damage is unknown
- reforestation after fires and natural disturbances
- thinning of pole stands and conversion into private forests.

Table 3. Beech and oak (Azarov 1991) species in Slovenia, their status (Wraber and Skoberne 1989) and the annual felling in 1996 (Zavod za gozdove Slovenije 1996)

Latin name	Common name	Status[†]	Annual felling in 1996 (m^3)
Fagus sylvatica L.	European beech	common	540 906
Quercus robur L.	pedunculate oak	7% of all oaks	10 913
Quercus petraea (Matt.) Liebl.	sessile oak	82% of all oaks	76 128
Quercus ilex L.	holm oak	EN, L	0
Quercus cerris L.	Turkey oak	8% of all oaks	6 260
Quercus pubescens Wild.	pubescent oak	2% of all oaks	328
Quercus crenata Lam.	false-cork oak	EN, L	0
Quercus virgiliana Ten.	Croatian oak	EN, L	0
Quercus palustris Muenchh.	swamp oak	I	134
Quercus rubra L.	red oak	I	101

[†] I = introduced species; EN = endangered species in terms of IUCN categories; L = the species being in its geographical borderline and occurring in limited numbers in Slovenia.

Table 4. Areas and growing stock in the forest management units for beech and commercially important oak species in Slovenia

Tree species	Area of units (ha)	Stock of tree sp. (m^3) Units	Stock of tree sp. (m^3) Units/ha	Total stock (m^3) Units	Total stock (m^3) Units/ha	% tree sp. in total stock	No. units
European beech	903 501	61 323 849	67.87	190 874 477	211.26	32.13	64 619
Sessile oak	528 266	12 297 359	23.28	94 169 135	178.26	13.06	39434
Pedunculate oak	30 379	1 010 362	33.26	5 209 483	171.48	19.39	2708
Turkey oak	84 446	1 257 606	14.89	10 265 231	121.56	12.25	4572
Pubescent oak	28 770	338 424	11.76	1 657 657	57.62	20.42	1394
Swamp oak	724	2 550	3.52	122 363	169.01	2.08	38
Red oak	2 261	14 953	6.61	371 877	164.47	4.02	161

Source: The Slovenian Forest Service, 1990.

Health state of the forest stands and threats to their genetic diversity

Forest decline monitoring activities started in Slovenia in 1985. A 4×4 km network was established, while a 16×16 km grid (part of the 4×4 km network) was used for a few more detailed studies (foliar nutrient analysis, etc.). The health state of beech and oaks is species-specific: beech shows a slight trend of decline (where it is necessary to mention extreme droughts as well as air-pollution effects), while oaks have shown high decline trends since 1990. The probable causes for oak decline are several: changed water table, air pollution, root pathogens, defoliating insects, etc. The results from forest decline monitoring for the last 10 years are shown in Figure 1.

In the three most air-polluted areas in Slovenia the genetic structure of beech populations has been studied and compared with the unpolluted populations. Significant differences of allelic frequencies between the groups of polluted and unpolluted populations on two isoenzyme loci were determined. A substantial change of allelic frequencies is indicated by the fact that genetic distances are highest when we compare polluted and unpolluted populations or polluted populations only. There are some indications that selection against some alleles is present, but this was not unambiguously confirmed. Only some small differences in genetic diversity between polluted and unpolluted groups were revealed (Brus 1996b).

Other disturbances which were very important in the last 15 years are extreme winters, extreme droughts, snow and ice-breaks in the last 2 years. The whole range of disturbances has resulted in high sanitary felling during this period (as presented in Tables 5 and 6).

In previous studies, oak decline has been studied on nine forest research plots (Golob 1991). These were followed by two small oak projects: on taxonomy, cytogenetics and isoenzyme studies of oaks (Batič 1996; Rogl *et al.* 1996), which included also several Diploma and MSc theses (Mavsar 1996; Breznikar 1997), the genetics of oaks in Slovenia (Benedik 1997), and on oak decline in Slovenia (Batič 1997).

Silvicultural studies and provenance trials with beech progressed well between 1951 and 1971, when the main Slovenian geneticist, M. Brinar, was active at the Institute. He partially described two beech races and mapped several interesting beech morphotypes. His work was largely forgotten until recently, when he offered collaboration with some young researchers.

At the Forestry Department of the Biotechnical Faculty studies on population genetics of beech in Slovenia have just started. The main goal is to compare the genetic characteristics of the Slovenian populations with the populations from other parts of Europe, study the existence of different races or types of beech in Slovenia and define the influence of ecological parameters on the genetic structure of populations. Reconstruction of potential postglacial migrations of beech will also be attempted, since the territory of Slovenia is supposed to be an important crossing of a number of tree species' routes.

Research activities and capacities related to genetic resources

Within the National Research Programme 'The Forest', lasting from 1995 to the end of 1999, one single project, financed at 50% by the Ministry for Agriculture, Forestry and Food and 50% by the Ministry for Science and Technology, with less than 1 FTE (full time equivalent) staff, was accepted for forest genetics, physiology, seeds and nursery studies. It is run by both research organizations, working in forestry in Slovenia, the Slovenian Forestry Institute and the Forestry Department of the Biotechnical Faculty. This project is enhanced by two young researchers' projects: on the role of phytic acid in physiology of acorns during storage, and on the genetic variability of Norway spruce (Table 7).

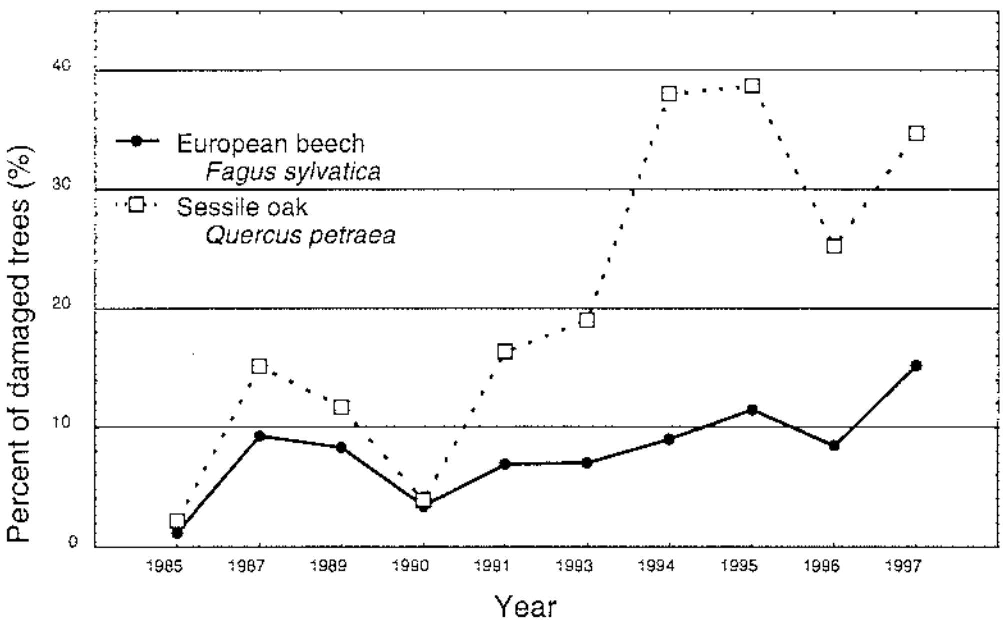

Fig. 1. Monitoring of beech and sessile oak decline in Slovenia: on 4x4 km network (on approximately 700 plots) for 1985, 1987, 1991 and 1995; on 16x16 km network (43 plots for all tree species) for 1989, 1990, 1993, 1994, 1996, 1997.

Table 5. Structure of felling of Slovenian beech and oaks in 1996 in % of total 635 000 m³ (for felling per tree species see Table 3), which represents 27% of total yearly felling of all tree species or 76% of all broadleaved tree species

Tree sp.	Selective thinning (%)	Artificial regeneration (%)	Sanitary felling (%)	Other felling (%)
Beech	80	0.1	13	7
Sessile oak	57	0.1	31	12
Pedunculate oak	37	10	43	10
Red oak	35	0	10	15
Swamp oak	84	0	15	1
Downy oak	50	0	49	1
Turkey oak	74	2	16	8

Source: Slovenian Forest Service, 1996.

Table 6. Silvicultural measures in Slovenian forests in 1996

	Individual protective measures	Tending of young growth	Tending of thickets	Selective thinning	Total tending
Programme 96 (ha)	2224	3575	6334	4077	16210
Realisation (ha)	1709	1329	2375	2091	7504
Real./Prog. 96 (%)	77	37	37	51	46

Source: Slovenian Forest Service, 1996.

Table 7. Current research activities† related to forest genetic resources

Programme	No. of projects	SFI (FTE)	BF For. (FTE)	Other (FTE)	Total (FTE)	Duration (years)
National Programme - Forest	1	0.5	0.3	0	0.8	1995-99
National research programme	1	0.8	0	0.2	1	1997-99
Bilateral projects (F, CRO)	1	visits	0	0	visits	1998-99
International projects	0	0	0	0	0	0
Young researchers (MSc, PhD)	2	2	0	0	2	1996-99
Students (BSc, MSc)	2	0	0	0	0	?
Public Forest Service	1	2	0	0	2	permanent

† FTE = Full Time Equivalent (1700 working hours per year per person); SFI = Slovenian Forestry Institute, BF For. = Forestry Department at the Biotechnical Faculty; the duties of the Public Forest Service are written in the Forestry Act and the Forest Development Programme of Slovenia and are performed mainly by the Slovenian Forest Service, while some aspects, such as The Seed Objects and The Forest Gene Bank, are done or led by law by the Slovenian Forestry Institute.

Current genetic conservation activities *in situ* and *ex situ*

According to the Slovenian Forestry Act of 1993 all forests are managed in a close-to-nature way, classified as Category VI of the IUCN management categories; 'protected area managed mainly for the sustainable use of natural ecosystems' (Wraber and Skoberne 1989).

Sustainable, close-to-nature and multifunctional forest management implies:

- small-scale flexible forest management, easily adapted to site conditions and natural development of forests
- active protection of natural populations of forest trees
- protection and conservation of biological diversity in forests
- support of the bio-ecological and economic stability of forests by improving the growing stock
- tending of all developmental stages and all forest forms for support of vital and high-quality forest trees, which could optimally fulfil all functions of forests

- natural regeneration is supported in all forests; if seedlings are used, they should be derived from adequate seed sources/provenances, and only adequate species can be used.

Additionally, about 135 000 ha of forests are protected under different IUCN categories (Table 8). The network of virgin forest reserves was established in the 1970s on all possible forest sites (Mlinšek *et al.* 1980). They take areas from 1.6 to 500 ha. Beech grows as the dominant tree species in 62% of them, in 30% it grows together with oaks, while oaks are dominant species in 4% of all reserves. Beech and oaks occur in 96% of forest reserve areas, while beech forms 50% and oaks 3% of the growing stock in these reserves.

Most forest stands are regenerated naturally, only one-tenth are regenerated from nursery seedling material, while seeds are mostly collected from acknowledged seed stands. Therefore, no special attention is given to *ex situ* conservation of forest genetic resources in Slovenia.

The use of reproductive material from selected seed stands started in Slovenia in the 1950s (Wraber 1951; Brinar 1961). Evaluation and selection of seed stands, the register of seed stands and the Slovenian forest gene conservation projects are run through the Public Forest Service, defined in the Act on Forestry (1993). The first revision of seed stands was done by 1987, the second has just been finished (Pavle 1987, 1997). The main change over the last 10 years is in the planned search for seed stands of broadleaved tree species, whereby the recorded number of these seed stands has risen from 68 in 1987 (Pavle 1987) to about 168 this year (Pavle 1997). The numbers and distribution of seed stands of oaks and beech in Slovenia are presented in Figures 3 and 4, their seed units in Tables 9 and 10.

Tree-improvement activities and the use of reproductive material

There are no tree breeding programmes for oaks or beech in Slovenia. However, for conservation of biodiversity and support of natural or site-adapted populations of forest trees, only seedlings derived from seeds collected in seed stands of the same seed unit from certain regions of provenance can be used for regeneration. Seed units are defined considering the potential forest type, bedrock and elevation (Pavle 1997). They are groups of similar potential forest types, among which exchange of seeds and seedlings is allowed. They belong to four altitudinal levels (0-400 m, 401-700 m, 701-1000 m, above 1000 m) and two groups based on bedrock material (carbonate, non-carbonate). The seed units are separately formed for each tree species. For beech and oaks there are eight seed units in Slovenia (on carbonate and silicate ground rock material and in four altitudinal zones). Each potential forest type can be included into one or more seed units, considering its altitude.

Plans for 1997 included natural regenetation of 2150 ha of forests and planting or sowing of 750 ha of forests. For this, about 3 million seedlings, 60% of which broadleaved, were needed.

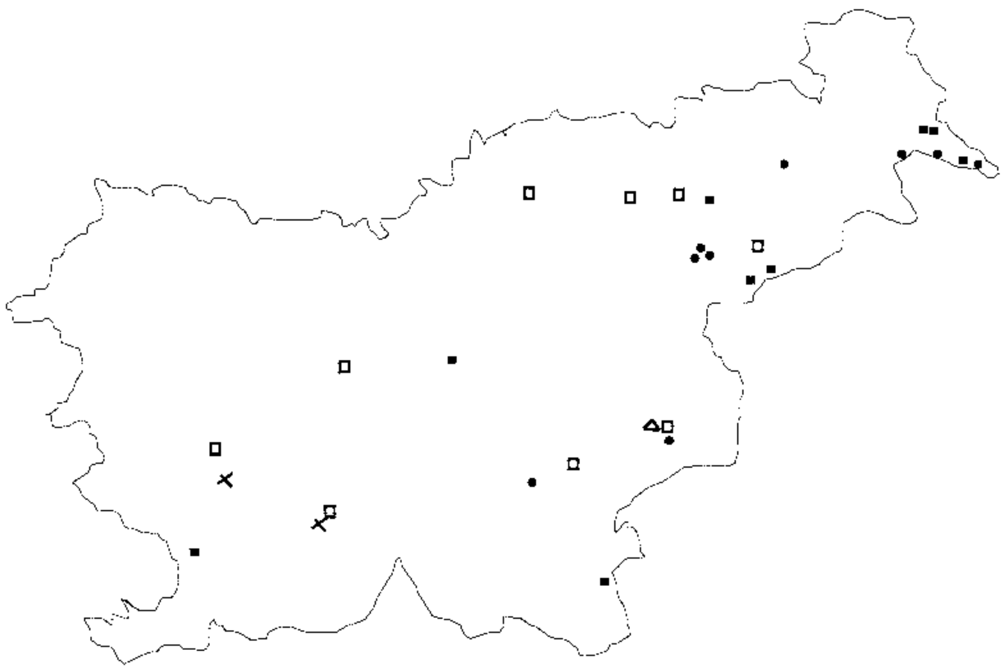

Fig. 3. Seed stands of different oak species in Slovenia: • *Q. robur* (9 seed stands); ■ *Q. petraea* (10 seed stands); □ *Q. rubra* (9 seed stands); × *Q. cerris* (2 seed stands); Δ *Q. palustris* (1 seed stand).

Fig. 4. Seed stands of beech in Slovenia (65 seed stands).

Table 8. Protected forest areas

Protected forests	IUCN category	Area of forests (ha)	Protected since
Triglav National Park	II / V	36 240	1924, 1981
36 regional parks	V, one III	30 045	most from 1984 or later
173 forest reserves	I	10 421	some from 1887, 1973
Protection forests	I / V	55 400	most from 1852
Seed stands	IV / VI	2 313	1955, updated in 1997

Sources: modifed from Kraigher *et al.* 1996; Pavle 1997.

Table 9. Beech seed stands in different seed units in Slovenia

Seed unit	Altitude (m asl)	Area (ha)	No. of seed stands
B-1k	<400	6.50	4
B-2k	400-700	51.30	11
B-3k	700-1000	41.20	17
B-4k	>1000	85.87	13
B-5s	<400	16.32	7
B-6s	400-700	15.60	6
B-7s	700-1000	0.50	1
B-8s	>1000	25.08	6
B-total		242.37	65

Table 10. Seed stands of different oak species in Slovenia

		Q. robur		*Q. petraea*		*Q. cerris*		*Q. palustris*		*Q. rubra*	
Seed unit	Altitude (m asl)	Area (ha)	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)	No.
H-1k	<400	1.00	1	7.05	2	5.81	1	0	0	2.18	3
H-2k	400-700	0	0	0	0	3.49	1	0	0	0	2
H-3k	700-1000	0	0	0	0	0	0	0	0	0	0
H-4k	>1000	0	0	0	0	0	0	0	0	0	0
H-5s	<400	37.69	8	11.10	4	0	0	1.05	1	0.50	2
H-6s	400-700	0	0	17.13	3	0	0	0	0	1.40	2
H-7s	700-1000	0	0	0.50	1	0	0	0	0	0	0
H-8s	>1000	0	0	0	0	0	0	0	0	0	0

Relevant nature protection policies and activities

The Forestry Act, which also regulates the management of forest genetic resources, was adopted in 1993. The Act on Plant Protection was adopted in 1994, while all regulations on seed testing, seed stands and seedlings date from the 1960s. The Act on Seeds and Seedlings was adopted in 1973. This is being dealt with at the moment and will be prepared in a thoroughly revised version, according to the Directives of the European Commission and as much as possible including the OECD scheme.

The most important other laws and regulations concerning forest genetic resources are the Act on the Protection of the Environment (1993), the Regulation on protection of endangered plant species, the Decree on financing and cofinancing investments in forests (1994) and the Forest Development Programme of Slovenia (FDP) (1996). FDP suggests that all protection and nature conservation activities in forests should be the responsibility of the Slovenian Forest Service. However, the new proposal for the Act on the Protection of Nature (Ministry for Landscape and Environment, draft version from September 1997), suggests the establishment of the Slovenian Nature Protection Service. We might expect a long discussion among different political tendencies in the distribution of tasks on the 53% of Slovenia covered by the forests.

The activities in preparation of the National strategy for conservation and protection of biodiversity (after the ratification of the Convention on Biological Diversity, the pan-European strategy biological and landscape diversity and the resolutions from Strasbourg, Helsinki and Lisbon) have also just been initiated at the Board for the Protection of Nature by the Ministry for Landscape and Environment. In these, the forestry sector is coordinating two of the 18 working groups (Forest ecosystems and Forest genebanks).

Institutions involved in genetic resources activities

Information on *in situ* forest genetic resources is dealt with by the Slovenian Forest Service under the expert guidance by the Slovenian Forestry Institute and in collaboration with the Board for the Protection of Nature. Annual certificates for seed stands and seeds are issued by the Slovenian Forestry Institute. All scientific studies and the development of strategies for management of forest genetic resources are dealt with by staff from the Slovenian Forestry Institute and the Forestry Department of the Biotechnical Faculty in Ljubljana.

Summary of country capacities and priorities

In Slovenia, 53% of the country is covered by forests, which have been grown in a close-to-nature and sustainable way for almost 150 years. The highly diverse ecological conditions have supported the high biodiversity at the ecosystem, species and genetic levels, which have all been well conserved. European beech is the most naturally widespread tree species in Slovenia. It presents 29% of the current growing stock. Of the seven indigenous oak species, three are at their geographical borderlines and occur in limited numbers. The other four and the two introduced oak species (of minor importance) form 8% of the current growing stock in Slovenia, of which 82% represents the sessile oak. The silvicultural approaches in Slovenia depend on the Forest Development Programme and the Forest Management Plans, used as a basis for preparation of detailed silvicultural plans according to the Forestry Act. The majority of felling is by selective thinning, while in the last few years heavy snow and ice damage have increased sanitary felling. The health state of beech shows a slight decline in the last 10 years, while the health state of oaks has worsened remarkably since 1990. However, a single study of air pollution impacts on genetic diversity of beech populations did not show significant differences. Research activities comprise a small project on oak decline, an MSc project on water stress, another one on acorn physiology during storage and a PhD project on population genetics of beech.

Within the framework of 173 forest reserves, beech grows as the dominant species in 62%, in 30% it grows together with oaks, while oaks grow as dominant species in 4% of them. The use of forest reproductive material deriving from selected seed stands has been applied since 1951. At the moment there are 65 beech seed stands in eight seed units, defined after the phytocenological associations, the groundrock material and altitudinal levels; and 31 seed stands for five oak species. However, seed collecting and distribution need a better control system. This should be done through acceptance of a new Act on forest reproductive material, which is being prepared, following as much as possible the directives of the EU. International collaboration is needed for the above-mentioned research and legislation-related activities.

Needs for international collaboration

Collaboration in research projects:

- Genetic studies of beech: international collaboration is essential. The sampling has been planned to include beech populations from Slovenia, Italy, Croatia, Bosnia and Herzegovina and a few other countries. The laboratory part of the studies with isoenzyme markers has been carried out at the Forestry Faculty of the Technical University in Zvolen, Slovakia.
- The studies of the role of phytic acid in long-term storage and physiology of acorns are done in collaboration with the Department of Plant Sciences, University of Cambridge, UK. Also a bilateral project has just started to enable collaboration with the Forestry Research Center at INRA, Nancy, France.

Collaboration in preparation of the new legislation on forest reproductive material:

- In order to prepare the new act on forest reproductive material as close to the EU directives as possible, an unofficial collaboration has started through the bilateral DAAD visits scheme with the Institute for Forest Genetics and Tree Breeding, Grosshansdorf, Germany. More visits, also to different institutions and possibly to the EU officials from this field, would be needed.
- Inclusion of the Slovenian strategies for sustainable use and support of the high biodiversity at all levels in the Slovenian forests into the European strategies might help in further harmonizing our legislation.

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Oak genetic resources in Malta

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Introduction

Oaks in Maltese are called 'ballut', whilst the acorns are referred to as 'gandar'. Only one species is known to be native, namely *Quercus ilex* subsp. *ilex*, the holm or evergreen oak, which is locally very rare and also listed in the Red Data Book for the Maltese Islands (Lanfranco 1989).

Quercus robur subsp. *robur*, the pedunculate oak (or English oak), occurs as a rare planted street tree but also as a very rare naturalized alien species (Borg 1927; Haslam *et al.* 1977). It was introduced by the British, as the Maltese Islands formed a colony. Thus, *Q. robur* is referred to in Maltese as Balluta Ngliza, literally English Oak, but also as Sigra tar-Ruvlu, Oak-Wood Tree.

Other species occur – *Quercus cerris* and *Quercus infectoria* subsp. *veneris* – but these are very rare planted ornamentals, occurring in few public gardens or public areas.

With respect to habitat, the few *Q. robur* occur planted in public gardens and forest remnants, or as street trees. *Quercus robur* is naturalized in the semi-natural woodland of Buskett.

Uses

At present, no local uses of *Q. robur* are known. Acorns used to be fed to goats, pigs and other domesticated animals, but these were most probably acorns of *Q. ilex* (Lanfranco 1993).

Conservation and silviculture

Few *ex situ* conservation measures for *Q. robur* are undertaken in the Maltese Islands. However, acorns of this oak are collected at the beginning of autumn, and sown in normal calcareous soil immediately after collecting. They are usually planted out 2-3 years after germination, or at a size of about 50 cm.

With respect to *in situ* conservation measures, all oaks at an age of more than 200 years are fully legally protected via the Antiquities Act of 1925. Apart from this, legal protection of both *Q. robur* and *Q. ilex* has been proposed in the Tree and Forest Protection Regulations 1998; analogously, all trees occurring in the holm oak forest remnants (four in all) and Buskett have been proposed as Woodland Nature Reserves in the same regulations.

Departments and agencies responsible for genetic resources

The following departments are involved. Work relevant to genetic resources conservation and utilization is included.

Environment Protection Department

- Environmental legislation and its enforcement.
- Production of environmental education material.
- Formulation of management plans for protected areas.
- Monitoring of local flora and fauna, including oaks.
- Producing strategic countryside policies and guidelines.
- Providing expert advice on conservation issues.

Environmental Management Unit (EMU)
Within the Planning Directorate in the Planning Authority (PA)
- Countryside and nature conservation.
- Scheduling of areas or sites of ecological and/or scientific importance.
- Issuing of Conservation Orders and Tree Preservation Orders.
- Providing expert advice on conservation issues.
- Processing applications related to development in rural areas.
- Coordinating the environment impact assessment process associated with development applications.

Departments of Agriculture and Fisheries
- Soil conservation, afforestation and landscaping.
- Issuing of phytosanitary, veterinary and other certificates in connection with importation and exportation of flora and fauna.

Department of Works
- Cleaning of valleys, building sites and other sites of heavy rubble.

Police
- Enforcement of legislation relating to the environment and to trade.

Customs Department
- Control of importation of flora and fauna and enforcement of trade regulations.

Local Councils
- Each Local Council has its own jurisdiction including some environmental aspects.

At the moment, no legislation prohibits introduction of foreign genetic stock; *Q. robur* is, however, rarely imported for afforestation and ornamental purposes, since it is rarely used as such. The few pedunculate oaks which are employed are usually grown from the local existing stock.

Priorities

In general, priority for *in situ* and *ex situ* conservation projects is given to indigenous (autochthonous) species, and in this sense *Q. robur* is not native. However, as stated previously, legal protection of this species has been proposed, also because some old trees (probably not older than 100 years, but no dating has been carried out) occur in the Maltese Islands.

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Management and conservation of beech (*Fagus sylvatica* L.) and oak (*Quercus petraea* (Matt.) Liebl., *Q. robur* L.) genetic resources in France

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Occurrence and origin

France has seven native oak species. The main species are pedunculate oak (2.1 million ha) and sessile oak (1.51 million ha), which represent about 30% of the total forest area. Temperate oak forests have a very large ecological niche from podzolic to calcareous soils, and occur from sea level to 1750 m. They are very common in France except in the Mediterranean region and Corsica.

In French forests, beech is a native species in the major part of its range. It is the second most important broadleaved species after oaks. It covers (in pure and mixed stands) over 1.7 million ha (12% of the total forest area). It is a species of low to high elevation (0-1600 m) as long as the water supply is at least 800 mm rainfall per year.

Economic importance

The average annual timber production is 2.25 m^3/ha for pedunculate oak and 2.4 m^3/ha for sessile oak. The total felling of oak wood is 3 215 000 m^3/year. Prices vary according to quality and diameter from 70 to 2600 FRF/m^3 (10-400 ECU).

Annual production of beech varies from 2 to 7 m^3/ha according to site fertility. A recent forecast shows that beech should remain one of the most attractive broadleaves for timber production with current prices easily reaching 800 FRF per standard quality cubic meter wood under bark (120 ECU).

Stand management

Oaks

About 50% of the regeneration is natural and 50% artificial. The system of registered seed stands and regions of provenance is applied only for sessile and pedunculate oaks. French foresters plant about 20 million oak seedlings per year. Even with a conversion to high forest started in 1830, this treatment represents only 22% (Table 1). The main types are coppice with standards and coppice.

Table 1. Types of white oak forest in France

Types	Area (ha)	Percentage
High forest	921 236	22
Coppice with standard	2 672 175	64
Coppice	423 170	11
Miscellaneous	140 270	3
Total	4 156 851	100

Beech

Most of the regeneration is natural with a variety of silvicultural treatments including high forest (majority), uneven-aged forest, and coppice with standards under conversion to high forest. These treatments also vary according to regions, topography, elevation, history and of course, of the stands: timber production, soil conservation, protection of stands at the upper tree line, amenity, etc. But part of the regeneration has been, and still is, done by artificial regeneration. Up to 3000 ha/year were planted in the mid-1970s, when beech was highly ranked among species used for reforestation for its relative ecological plasticity and when foresters had to face severe failures in natural regeneration.

Threats to oaks and beech genetic diversity

Oaks

The genetic resources of oaks are not endangered in France but marginal situations exist such as in the Mediterranean region and Corsica, or in extreme ecological situations (sand dune, peat bogs). In these cases, the populations of sessile and pedunculate oaks are very scattered and very small. They very often have only a few tens of individuals. The other threatening factor is the introduction of foreign origins.

Beech

In spite of a decline in certain regions (Teissier du Cros *et al.* 1993) beech resources are not endangered in France. Unfortunately several mistakes were made during the 1970s when beech was planted with little or no consideration of the origin/provenance of the material. Three measures resulted to counteract this 'wild' reforestation: (1) selected seed stands, (2) provenance testing, and (3) *in situ* conservation.

Use of forest reproductive material

Following OECD and EU rules, CEMAGREF has established a network of selected seed stands for most forest tree species used for reforestation. Their main purpose is wood production. For pedunculate oak, 143 stands have been selected in 10 regions of provenance and for sessile oak 132 stands in 15 regions of provenance (Table 2). They represent 3512.84 ha for pedunculate oak and 10 799 ha for sessile oak.

For beech, 183 stands have been selected and grouped in 20 regions of provenance (Fig. 1 and Table 3). They represent 10 000 ha. All the seed used for reforestation is collected there. CEMAGREF with the help of INRA has also released recommendations for the possible transfer of beech reproductive material between regions. A golden rule was stressed: when possible, give "absolute priority to the local material" (CEMAGREF 1991).

Provenance and progeny testing

Provenance tests

Oaks

A provenance experiment has been established in France which comprises four plantations. Their main characteristics and locations are given in Table 4. The tested populations come from the whole natural range of *Quercus petraea*. Sessile oak is represented by 108 populations and pedunculate oak by 17 populations (Table 5).

Beech

In 1974, when provenance testing was started in France, the aim was to identify adequate reproductive material and to determine what transfer between regions was possible without loss of adaptability, resistance, yield and quality (Table 6). Several results concerning adaptation, growth and form (morphology) have been published (Teissier du Cros 1993; Teissier du Cros *et al.* 1980; Teissier du Cros and Lepoutre 1983; Teissier du Cros and Thiébaut 1988). First recommendations, essentially based on bud bursting date and early growth, have been provided to practitioners.

Table 2. Regions of provenance and selected seed stands of oak (1 January 1997)

a. Sessile oak

Regions of provenance		Registered stands	
No.	Name	Number	Total area (ha)
01	Secteur Ligérien	9	3089.24
02	Charentes-Poitou	8	591.48
03	Picardie	3	217.19
04	Sud du Bassin Parisien	8	935.16
05	Centre Sud	7	1112.61
06	Allier	11	1072.09
07	Nord-Est gréseux	18	598.84
08	Vallée de la Saône	4	76.29
09	Est du Bassin Parisien	11	375.01
10	Morvan-Nivernais	7	477.61
11	Nord-Est Limons et argiles	29	613.11
12	Bretagne	2	38.08
13	Sud du Massif Central	5	101.69
14	Ouest du Bassin Parisien	6	1489.94
15	Gascogne	4	51.20
	Total	**132**	**10799.54**

b. Pedunculate oak

Regions of provenance		Registered stands	
No.	Name	Number	Total area (ha)
01	Bourgogne	23	1077.77
02	Plateaux du Nord-Est	19	797.88
03	Nord	3	248.92
04	Vallée du Rhin	6	84.54
05	Sud-Ouest *vallées*	35	488.96
06	Loire moyenne	8	77.40
07	Ouest	12	124.77
08	Bassin supérieur de la Saône	28	572.90
09	Sud-Ouest hors *vallée*	2	15.76
10	Ouest Massif Central	7	23.94
	Total	**143**	**3512.84**

Table 3. Regions of provenance and selected seed stands of beech

	Regions of provenance	Registered stands	
No.	Name	Number	Total area (ha)
01	Perche	4	348
02	Bordure Manche	11	2192
03	Picardie	4	1134
04	Nord-Est (limestone)	41	3042
05	Nord-Est (acid)	8	206
06	Nord-Est Massif Central	2	197
07	Sud Massif Central	18	354
08	Bretagne	2	87
09	Bassin Supérieur de la Saône	22	890
10	Charentes-Poitou	2	147
11	Plateaux du Jura	17	375
12	Auvergne	12	227
13	Pyrénées Centrales	13	512
14	Argonne	4	63
15	Ouest Massif Central	2	15
16	Préalpes	2	19
17	Est Massif Central	2	5
18	Alsace-Sudgau	8	201
19	Pyrénées Orientales	2	77
20	Pyrénées Occidentales	7	161

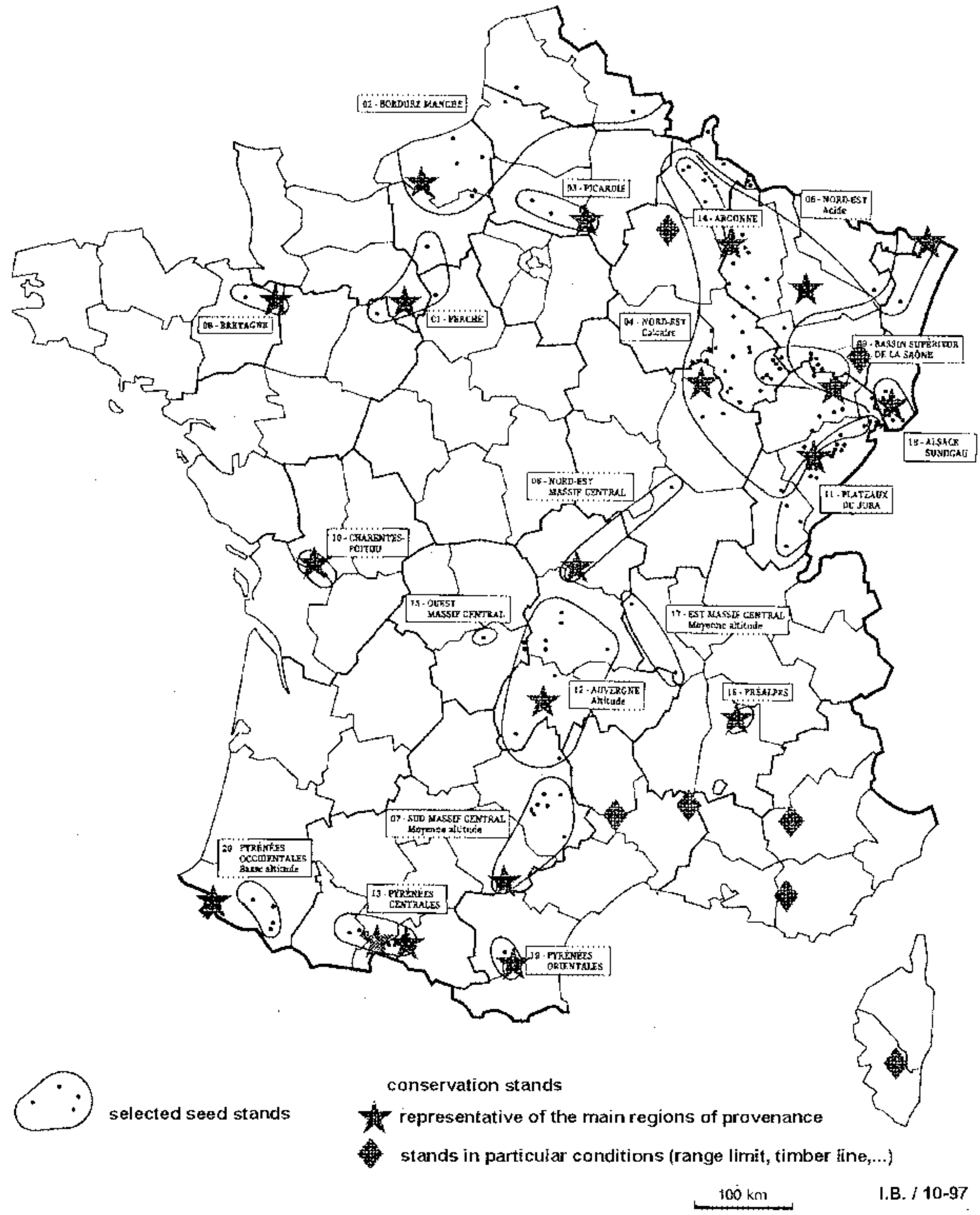

Fig. 1. Regions of provenance, selected seed stands of beech and the *in situ* conservation network.

Table 4. Location and main characteristics of the provenance test

Site	Location, region	Soil: Type	Soil: Texture	Climate
Petite Charnie	Pays de Loire, West	brown forest soil	sand and silt or silt and clay	Atlantic
Vierzon	Centre, Centre	podzol	sand	dry Atlantic
Vincence	Bourgogne, Centre	brown forest soil	silt or silt and clay	cold Atlantic
Sillegny	Lorraine, North-East	brown forest soil	silt or silt and clay	continental

Table 5. Origins of the populations tested in the provenance experiment

Country	Species	Number of populations
France	*Quercus petraea*	66
	Quercus robur	4
Great Britain	*Quercus petraea*	3
	Quercus robur	3
Germany	*Quercus petraea*	17
	Quercus robur	2
Austria	*Quercus petraea*	2
Denmark	*Quercus petraea*	3
Poland	*Quercus petraea*	6
	Quercus robur	4
Slovakia	*Quercus petraea*	1
	Quercus robur	3
Hungary	*Quercus petraea*	1
	Quercus robur	1
Romania	*Quercus petraea*	2
Russia	*Quercus petraea*	1
Turkey	*Quercus petraea*	1
Total	*Quercus petraea*	**108**
	Quercus robur	**17**
	All species	**125**

Table 6. French provenance and progeny testing network for beech

Series	Location	Planting year	Planting density (trees/ha)	Number of entries F = French, E = "Exotic"
1976	Ecouves (W France)	1979	5 000	14 provenances F
	Chaud (Centre)	1979	5 000	21 provenances F
	Sommedieue (NE)	1979	5 000	11 provenances F
	Montagne Noire (S)	1978	5 000	12 provenances F
1977	Ligny en Barrois (NE)	1980	5 000	6 provenances F
1979	Ligny en Barrois (NE)	1984	4 000	30 provenances FE
	Plachet (NE)	1982	5 000	22 provenances FE
	Ormancey (NE)	1982	5 000	38 provenances FE
	Retz (N)	1983	5 000	49 provenances FE
	Lyons (NW)	1983	5 000	40 provenances FE
	Guimont (Centre)	1982	5 000	26 provenances FE
International	Lyons (NW)	1986	10 000	24 provenances FE
	Lyons (NW)	1988	10 000	61 provenances FE
	Lyons (NW)	1995	5 000	50 provenances FE
Progeny tests	Eawy (NW)	1997	3 900	51 open-pollinated progenies
	Haye (NE)	1997	2 600	48 open-pollinated progenies

Progeny tests

A plantation programme was started this year. The project concerns two experimental tests (N.F. La Petite Charnie and N.F. Russy). The experimental design for the test at La Petite Charnie involves two species (*Q. petraea* and *Q. robur*), 30 progenies per species, 30 individuals per progeny and each individual is propagated 12 times. For the second test, the experimental design is more conventional: 30 progenies of *Q. petraea*, 120 individuals per progeny.

Progeny testing aims at estimating the level of genetic control of traits used when selecting 'seed trees' for natural regeneration. A sound use of this knowledge should result in a 'mild', long-term genetic improvement of naturally regenerated stands. For beech, two open-pollinated progeny tests, including copies of the mother trees, were established in 1997 (Table 6). They allow the estimation of several genetic parameters such as broad and narrow sense heritability, genetic correlation between traits and juvenile × mature correlation.

Conservation of genetic resources

Beech

Current situation

In France, beech is not endangered as such. But the integrity of certain stands has probably been disturbed by 'wild' planting of reproductive material either of unknown origin or from other parts of the range. The long-term effect of such a practice which has now fortunately been stopped is (1) lack of adaptation (for instance to local climatic extremes) and (2) genetic pollution of local sources. Beech is the first broadleaved species in France for which an *in situ* conservation network has been established. The underlying principles at the time of creation of this network were based on pragmatism: conservation stands were to be representative of a majority of usual beech ecological conditions but some of them were also to originate from marginal sites. Furthermore, since *in situ* conservation of forest genetic resources is a long-term process, public forests should be involved as much as possible. The current conservation network includes 27 stands (Fig. 1). Twenty of them have been chosen in the main regions of provenance representing the majority of beech ecotypes. Seven represent rare conditions or phenotypes such as: protection stands near upper tree line, Mediterranean conditions or the population with curly branching phenotype. Each element of this network is composed of a central core covering at least 5 ha (an effective genetic population size of at least 300 trees) and a minimum 50-m-wide buffer to protect the core from allogenic pollen. Of course consistent administrative sources should be given to certify that the core and the buffer were of local origin (Teissier du Cros and Bilger 1995).

To convert the pragmatism initially used to establish this network into a scientifically based sampling, complementary studies were done by B. Comps, University of Bordeaux-Talence. Each element (stand) of the conservation network has been characterized by isoenzyme markers and compared with neighbouring stands. Results were compiled with those of other scientists working in other parts of the range. French beech populations could be divided into four main groups: (1) northern half of France, (2) centre: Massif Central mountains, (3) Alps, (4) Pyrénées mountains. The curly branching population cannot be distinguished from other populations in the vicinity (northern half of France). One southern population is genetically similar to the northern population. Two important additions will be made in the near future to the current network. Both the Alpine and the Pyrenean parts of the range appear under-represented (Teissier du Cros 1997):

- the former because the French Alps are a melting pot of two colonizing currents after the last glaciations: the northern current originating from the Balkans, the southern one from south Italy
- the latter because the Pyrénées mountains include a much greater diversity than originally expected.

Management of the conservation network

In France, because the beech conservation network was the first to be established, beech is used as a pilot species for the management of *in situ* conservation units. But the management recommendations given to foresters in charge have sometimes seemed inadequate for local site conditions or stand evolution. For instance, natural regeneration is sometimes scanty because seed trees are too old, declining or too dense, and therefore do not produce seed. If such a lack of regeneration occurs in the core, at least two solutions should be proposed: (1) moving the core to more favourable plots of the same conservation unit, (2) collecting beechnuts in buffer plots to plant seedlings in the core. The consequence of such measures during the life cycle of the conservation units needs to be carefully analyzed.

Another important point is the compatibility of gene conservation with stand management. The current trend is to promote diversity and therefore to reduce the 'beech/total tree density' ratio, which incidentally is likely to favour stand health and natural regeneration. Conservation recommendations may have to consider this point and to become more flexible.

The different institutions involved in the conservation of beech gene resources are INRA (research and network coordination), Bordeaux University (research), Office National des Forêts in management of conservation stands (State and Community forests).

Oaks

Up to now oak genetic resources are not really endangered in France, except in some situations such as marginal populations (coastal sand dunes, peat bogs, altitude higher than 1400 m) and in the southeast of France and Corsica. Several problems can threaten these resources such as introduction of exotic genotypes, neglected practices, conversion to high forest, etc. For these reasons, the committee for the conservation of forest gene resources (Commission technique nationale) has launched a programme of gene conservation for oaks with four objectives:

1. Sampling the gene diversity: 20 populations are selected for this objective. The sampling strategy has been defined according to the results obtained with molecular and quantitative markers (Ducousso *et al.* 1995, 1996c; Petit *et al.* 1993; Zanetto *et al.* 1994; Zanetto and Kremer 1995, 1997). The list is given in Table 7.
2. Conservation of evolutionary mechanisms: white oaks have the highest observed genetic diversity; this results from evolutionary mechanisms like interspecific hybridization. Several mixed stands will be used for this network (Bacilieri *et al.* 1993, 1995, 1996; Bodénès 1996; Ducousso *et al.* 1996c).
3. Conservation of oak ecosystems: ecotypes adapted to different types of management for wood production (high forest, coppice with standards, coppice) and for acorn crops (provender for cattle). Most of these types are neglected because the foresters have undertaken a conversion to high forest. The objective will be included in the 'reference forest network' managed by the French National Forest Service (Office National des Forêts).
4. Conservation of marginal or endangered populations requires actions. The first step of this objective is to take a census, and then to define a policy for each situation.

Each reserve designated according to objectives 1, 2 and 3 is composed of a central core covering 15 ha surrounded by a buffer zone of at least 100 ha. The central core and the buffer must have a local origin. This origin is known by administrative records and by using chloroplast DNA. All the populations belong to the French provenance experiments.

Capacities for the conservation of forest gene resources

A committee for the conservation of forest gene resources (Commission Nationale de Conservation des Ressources Génétiques Forestières) was formalized in 1992. It has proposed four pilot networks involving beech and silver fir for *in situ* conservation, elm and wild cherry for *ex situ* conservation. These networks are almost all complete. The committee and the institutions involved have sponsored research to establish five other conservation networks: European white oaks, black poplar, Norway spruce, Maritime pine and *Sorbus* species. Methodological research is under way for *ex situ* static conservation (cryopreservation) and for the interaction between human activity on the one hand, including stand management, and gene resource integrity on the other. Oak populations will essentially be used to assess this interaction.

Table 7. List of the candidate populations for objective 1 (Vallance and Ducousso 1997)

National Forest	Region	Location
Bareille	Midi Pyrénées	Southwest
Bercé	Pays de Loire	West
Bommiers	Centre	Centre
Bussières	Champagne Ardennes	Parisian Basin
Compiègne	Picardie	North
Fontainebleau	Région Parisienne	Parisian basin
Grésigne	Midi Pyrénées	Southwest
Hagueneau	Alsace	Northeast
Loche	Centre	Centre
Orléans	Centre	Centre
Prémery	Bourgogne	Centre
Réno Valdieu	Normandie	Northwest
Saint Aubin du Cormier	Bretagne	West
Serqueux	Champagne Ardennes	Parisian Basin
Sturzelbronn	Lorraine	Northeast
Tronçais	Auvergne	Centre
Vachères	Provence Alpes Côtes d'Azur	Southeast
Valbonne	Provence Alpes Côtes d'Azur	Southeast
Vouillé	Poitou	Southwest
Westhoffen	Alsace	Northeast

Needs for international cooperation

In its natural range beech plays an important role in forestry. It has many of the 'advantages' which the 'Greens' wish to promote: it is autochthonous, broadleaved, rather flexible (provided the right reproductive material is chosen), it produces timber whose attractiveness for industry is increasing. For instance, it is one of the species which could replace certain tropical hardwoods for veneer and high-quality sawn timber if the former were to become scarce on the international market. It is excellent in many situations where conifer stands, extensively planted since the last world war, need to be converted into to more adapted stands devoted to the long-term sustainable production of high-value raw material for industry, amenity and soil conservation.

France has been involved since 1985 in the international diversity study on beech, which covers almost the entire range of the species. This study, sponsored by the European Union and coordinated by the Federal Forest Research Center in Germany, includes provenance testing and different types of genetic markers, either physiological or molecular. France has also cooperated with other European countries, particularly Slovakia, for the description of beech genetic diversity throughout its distribution range.

Any other proposal for international research and development is welcome for a common scientific approach on beech and oak genetic resources conservation, and for increasing the capacity of institutions requesting it.

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Oak and beech genetic resources in Luxembourg

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Occurrence and origin of oaks and beech in Luxembourg

The total forest area in Luxembourg is about 90 000 ha which represents 33% of the total land area. The country is divided into four main geological and climatic regions:

- Oesling (hills, 300-500 m , acid slate soils (Devon))
- Gutland (plains on heavy clay soils (200 m) and sandy hills (300 m))
- Moselle (shell-limestone valley)
- Minette (limestone hills, 300 m).

Oak (Quercus robur, Quercus petraea)

Origin:

Q. robur: indigenous; and from Westdeutsches Bergland, Plateau du Nord-Est France
Q. petraea: indigenous; Rheinisches and Saarbergland, Nord-Est France, Bassin Parisien Est

Occurrence:

All over the country
13 000 ha coppice mainly in the northern region Oesling
12 000 ha even-aged high forest with more than 60% from 100 to 180 years old.

Beech (Fagus sylvatica)

Origin:

Indigenous; Rheinisches and Saarpfälzer Bergland, Harz, Hessen and Weser hills, Nord-Est calcaire France, Vosges du Nord, Belgium (Ardennes, Forêt de Soignes, Arlon)

Occurrence:

25 000 ha even-aged high forest with more than 70% from 100 to 140 years old, all over the country, mainly on hills (300 m) in the Gutland and Minette regions.

Current economic importance for the forestry sector

The economic importance of oak and beech stands in Luxembourg relates to three sectors: wood production, recreation and nature protection (drinking water). With an overall yearly wood production of about 300 000 m^3, oak (40 000 m^3) and beech (150 000 m^3) represent more than 60% of the total production. A major part of this production is exported for further processing.

Silvicultural approaches used

Except for the old oak coppice stands in the northern part of the country which are now being transformed into high forest stands or replanted with conifers and broadleaves, almost all oak and beech stands are even-aged high forests.

Most beech stands have a small amount of oak (less than 20%) admixed to stabilize the stands, especially on sandy hills. Natural regeneration of beech is possible, but difficult on sandy soils. After regeneration or plantation (5000 plants/ha) and cleaning, the stands are thinned regularly (5-10 years) until small-scale clear-cutting (maximum 2 ha) or progressive clear-cutting at about 140 years is done to obtain natural regeneration.

Many even-aged high forest oak stands have originated from coppice with standards, so that stem quality is often rather poor. Natural regeneration is the rule, with a mean thinning interval of 5-15 years and a mean rotation period of about 180 years.

Health state of the forest stands

Since 1986, the health state (defoliation and decoloration) of forest stands in Luxembourg has been monitored by a yearly inventory of plots within a 4×4 km grid on the basis of the European ICP forest standards. From 1986 to the present, the health state has been constantly decreasing, so that for the moment, not more than one-third of the trees can be considered as absolutely healthy. In beech, 15% of trees are without damage (class 0), 52% are slightly damaged (class 1) and 33% are damaged (classes 2, 3 and 4). In oak high forest, the respective percentages are 22, 32 and 46% and in oak coppice stands 11, 36 and 52%.

The poor health state is mainly due to a lack of rainfall for 10 years and more recently because of massive attacks by insects over the last 2 years.

Research activities and capacities related to genetic resources/diversity

The CREBS Research Unit of the Centre de Recherche Public-Centre Universitaire is involved in two research programmes on genetic resources of forest trees. The first project focuses on the conservation *ex situ* of oaks and beech as well as of Noble Hardwoods. This conservation is realized using *in vitro* techniques. Up to now *Quercus robur, Q. petraea, Fagus sylvatica, Fraxinus excelsior, Prunus avium* and *Sorbus domestica* have been initiated and are multiplied *in vitro*. Mid-term conservation will be realized and the further viability, as well as the rooting and acclimatization performance, will be tested. The second research project deals with the development of techniques leading to the characterization of the genetic diversity of broadleaves. The techniques that will be used are mainly based on molecular biology.

Relevant nature protection policies and activities

- 17 nature protection areas (1862 ha).
- Protection of 16 beech and oak stands for collecting of reproductive material (180 ha).
- Selection of areas for the network 2000 of the "Directive HABITAT" (EU).

Tree-improvement activities

Tree-improvement activities are limited to phenotypic selection during seed collecting, propagation of forest trees and silvicultural operations (cleaning, thinning, etc.).

Use of reproductive material

Information on the private forest sector is not available. The Forestry Administration has four main tree nurseries producing from 500 000 to 1 000 000 plants per year, covering approximately 50% of the plant demand of the forests managed by the Administration. The seeds are mainly imported or collected in the protected stands in Luxembourg.

Institutions involved in genetic resources activities in Luxembourg

- Administration des Eaux et Forêts (Forestry Administration), Service de l'Aménagement des bois et de l'économie forestière, BP 411, L-2014 Luxembourg.
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Genetic conservation strategy for Social Broadleaves in Belgium

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Introduction

Belgian forests cover around 600 000 ha, mainly concentrated in the southern part, Wallonia (80%). With 140 000 ha, beech and oaks are the most important broadleaves. Natural regeneration is commonly used but artificial plantations have become more and more frequent since the 1980s.

For a good comprehension of the Belgian conservation strategy, it is important to know that since 1981, the National Forest Service, followed by the Forest Research Institutes eight years later, were regionalized with the creation of a federal structure. This situation involves specific policies regarding forest management and conservation objectives followed by the Regions.

Conservation strategy in Wallonia

Present situation

Indigenous oaks (*Quercus petraea* (Matt.) Liebl. and *Quercus robur* L.) and beech (*Fagus sylvatica* L.) represent the major broadleaved species of Wallonia. Considering the regional inventory, the growing stock can be estimated at 13 and 19 million m³ respectively for beech and oaks, with 8 and 18% respectively of a total productive forest area of 473 750 ha (Table 1). Oaks and beech represent, respectively, the second and third species in importance in Wallonia after Norway spruce.

Except for High Ardenne, the oaks are potentially well adapted to Wallonia. On the other hand, the potential range for beech covers the whole region.

At the economic level, beech and oaks constitute the main part (>80%) of the annual production of hardwoods which can be estimated at about 860 000 m³ of wood.

Based on this evaluation, primary income from hardwoods could be roughly estimated at 1 million BEF.

Threats

Since the 1980s, different signs of decline in oaks and beech have appeared (Table 2). A combination of factors seems to be involved. Claes (1997) cites in particular drought, fungi and insects (mainly caterpillar). Weissen (1996), on the other hand, stresses the influence of mineral elements deficiency, like magnesium shortage.

This disquieting situation should be taken into account for the elaboration of a general conservation strategy.

Another problem is the lack of natural regeneration due to two main factors. The first is the long period between good fructification years; this observation is particularly true for oaks. The second is the very high pressure of game (red deer, roe deer and wild boar), whose numbers have increased regularly since 1985 (Table 3).

The third threat is using material of foreign origin for the artificial plantations which are not necessarily adapted to local ecological conditions. The difficulties linked to the low rate of natural regeneration increase this risk.

Genetic conservation strategy

In Wallonia, the conservation programme is integrated in the general breeding programme and has been progressively developed for some years.

The classical steps of our general forest tree breeding programme are presented below.

Table 1. Importance of oaks and beech in Wallonia

Forest management	Species	High forest (ha)[†]	Coppice with standards (ha)[†]	Coppice (ha)[†]	Total (ha)[†]
Private owners	Oaks	22 250	13 000	2 250	37 500
	Beech	10 250	750	–	11 000
Forest under public control	Oaks	27 000	17 750	1 250	46 000
	Beech	27 750	500	–	28 250
Total	Oaks	49 250	30 750	3 500	83 500
	Beech	38 000	1 250	–	39 250

[†] Surface occupied by more than 66% in sectional area by the concerned species.

Table 2. Decline of oaks and beech in Wallonia

	Percentage of defoliation		
Species	1993	1994	1995
Beech	10.8	10.7	12.2
Sessile oak	7.3	9.2	9.1
Pedunculate oak	8.7	9.1	12.7

Table 3. Numbers of big game, after hunting and before births (Anon. 1996)

Species	1975	1985	1994	1994/1975
Red deer	5 144	4 830	8 095	+57%
Roe deer	19 504	22 300	31 338	+61%
Wild boar	8 484	6 348	12 609	+49%

Conservation in situ

Seed stands

For the last 5 years, an important effort has been made to increase the number of seed stands of different hardwood species. Today, the results are sufficient for beech to meet the needs of foresters. That is not yet the case for indigenous oaks where some additional surveys and selection have to be carried out (Table 4). These selections nevertheless are not directly linked to a general conservation purpose but are mainly done to ensure good timber production potential for the future.

Individual selection

Although a small number of plus trees were selected in the 1950s, mainly to study genetic variability, this work of selection was given up later in favour of a more adequate genetic improvement programme. In fact, a clonal seed orchard with oaks and beech seems to be rather ineffective. Therefore, other components such as seed stands or seedling orchards have to be considered.

Forest reserves

Besides the general genetic improvement programme, the concept of forest reserves has been developed since 1973. Today, eight forest reserves for a total of 244 ha have been registered. They generally comprise special ecological sites including beech and oaks.

Conservation ex situ

Provenance/progeny trials

In the 1950s, different tests were established to study genetic variability in beech at different levels (individual, population, ecological type, provenance) and were analyzed by Galoux (1966) and Hubert (1988). These tests, mainly limited to Belgian populations, completed by

Table 4. Present situation of the genetic conservation of Social Broadleaves

Type of gene conservation unit	*Quercus petraea*	*Quercus robur*	*Fagus sylvatica*	Total
In situ				
Seed stands				
Number	4	6	19	29
Area (ha)	47	121	552	720
Plus trees	21	23	70	114
Ex situ				
Provenance tests				
Number	1	–	2	3
Area (ha)	3.8	–	2.5	6.3
Provenance/Progeny tests				
Number	–	2	4	6
Area (ha)	–	1.3	2.5	3.8

observations in natural forests, show an important variability between populations for different characteristics like flushing, morphology of leaves and growth.

In addition, Belgium took part in an international provenance trial in 1988 from which one site was established in Paliseul and where 74 provenances are compared.

These different trials should give us more basic information to elaborate a complete long-term conservation programme.

Prospects for further conservation and priorities

A general programme adapted to all tree species has been outlined and partly completed. The main aspects of this programme (Nanson 1993, 1995; de Cuyper and Jacques 1996) are described hereunder.

Promoting the use of highly diversified reproductive material

With the regional grants delivered for hardwoods to private and public owners and considering the problem of natural regeneration, the share of Social Broadleaves plantations has been increasing for several years.

To favour the use of diversified autochthonous seed sources, the Walloon Region has created a new seed centre. This centre has been operational since 1996 and is in charge of forest seed harvesting complying with strict genetic rules like the respect of a minimum number of trees collected in each stand.

In parallel, selection of new seed stands is pursued.

Active conservation plantations of the registered seed stands

Up to now, *ex situ* conservation was included in the general genetic improvement programme through conservation of particular origins in provenance or progeny trials.

Nowadays, through collaboration between the regional forest administration, nurseries, seed centre and research institute, it is possible to set up an integrated programme to organize conservation of the major part of our officially registered seed stands in the long term. This programme should be implemented in the near future.

Trace-keeping in forest management and data storage

In the field of forest management, general rules are applied for all the Walloon public forests. Numerous data are stored in databases that allow us to know the method of regeneration and the name of the origins used in any artificial plantation at management unit level. These data and other additional information could be stored afterwards in a specific database at the regional level.

A new database developed with Germany for Douglas Fir within an EU Research Contract (No. CT95-09091 – EUDIREC) could probably also be used for indigenous oaks and beech in the future.

More details can be found in Nanson (1993, 1995) or de Cuyper and Jacques (1996).

Improvement of knowledge about forest genetic resources

As for Noble Hardwoods, a better knowledge of the genetic structure of populations is useful to put in place an efficient genetic conservation programme.

With the potential offered by new biochemical techniques (isoenzymes, DNA markers) and the growing interest of many organizations, it seems possible to propose a comprehensive programme to explore genetic diversity in the natural range.

In this field of activity, provenance trials are a step of major importance to evaluate adaptive traits, growth and form characteristics. These tests should be promoted and carefully evaluated.

Improvement of seed conservation techniques

Acorns, and beechnuts to a certain extent, are known as seeds difficult to store for a long period. The rarity of crops (10-12 years between two good fructification years in Belgium for oaks), associated with the problem of conservation, forces nursery owners to buy seeds harvested in more favourable regions where frequent fructifications occur.

The consequences of this situation could be very detrimental to forest owners by reducing adaptability and performances of the tree species in the future.

To avoid these problems, long-term storage techniques should be developed to reduce the lack of seeds between two good crops by increasing research in this field.

Conservation strategy in Flanders

Present situation

Indigenous oaks (*Q. robur* and *Q. petraea*) and beech (*Fagus sylvatica*) are to be regarded as major broadleaved species in Flanders, as they cover 8 and 3.5% respectively of the total forest area of 150 000 ha.

The available information on the current importance of Social Broadleaves in Flanders is still incomplete (Table 5). As an example, figures concerning the occurrence of oaks and beech in the different types of forest (coppice, high forest, coppice with standards) are not yet available.

More accurate data are expected in 1998, as an overall forest inventory will be initiated by the Flemish Forest Service. This inventory is to be based on some 2500 circular sampling plots of about 10 ares each, centred at the intersections of a 2×1.5 km grid.

Threats

Forest dieback

Since 1987 an annual survey of the vitality of forests in Flanders has been carried out by the Institute for Forestry and Game Management (IFG). Health condition is assessed by estimating premature leaf loss. Trees are considered to be damaged when leaf loss exceeds 25%.

Observations reveal a fast decline of the vitality of pedunculate oak and beech, culminating in an alarming situation in 1995 when respectively 42.5 and 44.4% of the trees were to be regarded as damaged (Müller-Edzards 1997). Fortunately, during the last 2 years, the health condition of both species has seemed to stabilize and, in some cases, even to improve.

Regarding the cause of this dieback, no unequivocal explanation can yet be given. It is generally assumed that the simultaneous occurrence of stress factors (repeated years with extreme drought, insect damage) has led to a severe weakening of the trees which then become susceptible to infection by secondary parasites.

Table 5. Area (ha) of Social Broadleaves in Flanders

Forest ownership	Oaks	Beech	Total
State Forests	1529	2565	4094
Public Forests	1634	430	2064
Private Forests	9032	2026	11058
Total	**12195**	**5021**	**17216**

Inconsiderate forest management

Social Broadleaves species can be endangered by 'skimming off' natural populations by excessive felling of trees with high economic value. This genetic erosion by eliminating the best genotypes heavily burdens the quality and vitality of future stand generations.

Trace-keeping

Any genetic resource of Social Broadleaves, identified, selected or created within the scope of a breeding or conservation programme, should be recorded in a well-managed, accessible database. Permanent and frequent updating of the database are essential to prevent valuable genetic elements from passing into oblivion. In addition, lack of follow-up inevitably entails unawareness of possible critical threats (felling, game damage, pests, etc.), eventually leading to accidental loss.

Conservation strategy

Conservation of genetic resources of Social Broadleaves has mainly been a logical spin-off of breeding and selection programmes, driven by motivations with a strong economic bias. Only recently, efforts are made to conserve genetic elements (i.e. local populations) with no direct economic importance through actual protection (forest reserves).

Conservation in situ

Seed stands

Seed stands are to be defined as stands which are phenotypically superior for most forest characteristics (cf. OECD/EEC regulations). These stands are selected and included in an official Register of Basic Materials (Table 6).

Plus trees

Plus trees are selected as such on the basis of their outstanding phenotype (Table 6).

In view of a continuous extension of this collection, a scouting campaign is resumed every year, mainly based on an inquiry addressed to all local forest services.

Conservation *ex situ* of selected clones is compulsory as plus trees are not only subject to the normal exploitation term, but are, in some cases, threatened by premature felling, especially in privately owned forests. *Ex situ* conservation can be achieved by creation of seed orchards and/or clone collections (see below).

Forest reserves

The Flemish Forest Decree of 1990 provides a legal framework for designating forest reserves, aiming at a final overall surface of some 2000 ha. A major criterion for selecting forest reserves is the presence of autochthonous tree species.

Sessile and pedunculate oak and beech constitute major stand-building species in 17 of these reserves (31 in total), covering an overall surface of 677 ha, i.e. 49% of the total area yet designated.

This policy ensures the conservation of Social Broadleaves as the majority of the reserves is assigned the status of 'integral reserve', meaning that 'doing nothing' is adopted as a management option, except for averting external threats.

Conservation ex situ

Provenance trials

The principal and initial objective for setting up provenance trials is to identify provenances which, through their adaptation and performance (growth, form, pest resistance), can contribute in a significant way to forest practice in Flanders. This will finally result in the drawing up of a list of 'recommendable' provenances. In a further stage, the best individuals will be selected within the most promising provenances, thus offering the possibility of creating seedling seed orchards.

A major spin-off of these experiments is the conservation of provenances outside their range, ensuring the possibility of restoring the original populations should they be lost.

Since 1989, provenance trials of Social Broadleaves have been included in the research programme of the IFG (Table 7).

Yearly efforts are made to broaden this spectrum, either by using the offer of reliable and reputable professional nurseries, or through collaboration with other foreign research institutes (e.g. exchange of breeding material). Whenever possible, the highest level of accuracy for identifying provenances will be striven for (e.g. identification at a stand level).

Seed orchards

A clonal seed orchard for sessile oak is being created at the IFG: scions were collected from 50 selected plus trees and first graftings were carried out in 1995. Considering the largely insufficient seed crops in selected seed stands of Social Broadleaves, seed orchards might offer an answer to the high demand for autochthonous reproductive material.

Although conservation of the component clones is inherent to the existence of a seed orchard, seed production still remains the prime purpose of its establishment. Thus, whenever seed productivity should prove to be insufficient, the normal lifespan of such an orchard (50 to 100 years) could be severely shortened by either felling or mere neglect, as its further maintenance loses its economic justification.

Progeny trials

Comparative progeny trials have only been established for sessile oak, involving the half-sib offspring of each of the 50 selected plus trees. These trials were initiated in 1994 and will be repeated whenever a good seed crop occurs.

Use of reproductive material

Forest authorities strongly support the natural regeneration of, among others, oak and beech stands, in view of the resulting conservation of autochthonous populations. Hence, attempts are made, through adequate forest management, to induce natural regeneration in state and public forests. Promotion of natural regeneration in private forests is achieved by granting financial support whenever stands are successfully regenerated in a natural way (subvention policy).

However, unfavourable conditions, such as high game pressure, invasive herbaceous vegetation and compact soil, often constitute barriers for natural regeneration. In these cases, artificial regeneration becomes imperative and requires high-quality, selected planting material. The availability of breeding material from authochthonous sources (i.e. seeds) is insufficient because:

- the number of seed stands is rather limited (Table 6)
- owing to their inherent phenology, good crop years in oak and beech stands are separated by long-term intervals
- as selection and breeding efforts have been focused on broadleaves only very recently, seed orchards (*in casu* sessile oak) are still in their infancy and are far from being productive.

Table 6. Selected seed stands and plus trees of Social Broadleaves in Flanders

	Seed stands		
Species	**Number**	**Area**	**Plus trees**
Pedunculate oak	11	63.6	8
Sessile oak	1	5.0	50
Beech	1	1452.6	17
Total	**14**	**1521.2**	**75**

Table 7. Provenance trials of Social Broadleaves set up by the IFG

Species	Year	Origin	Number	Countries
Sessile oak	1989	Seed stand	19	B/F/D/DK/GB/H/N/PL/TR [*]
	1993	Provenance region	11	F/D/SLO
Beech	1996	Seed stand	32	D

[*] International provenance trial with 24 participating countries, coordinated by the Danish Forest Research Station, Lyngby, Denmark.

In this way, public as well as private nurseries are forced to appeal to foreign seed origins. As provenance trials have only been set out very recently, first results are not available yet. Therefore, adaptive the value of most of these provenances is still unknown. This entails a high risk for genetic pollution which increases the vulnerability of the forest ecosystem.

Silvicultural approach

Management of Social Broadleaves forests is 'close-to-nature'. In general it can be characterized as silviculture on an ecological basis, with attention to all components of the forest ecosystem, and pursuing stable, healthy forests with a durable economic and ecological value. Such management offers best guarantees for sustained forest use. To achieve this ecological management, a set of principles is observed:

1. Short rotations are to be omitted. On average, the rotation period in oak and beech stands is set at 150 and 200 years, respectively.
2. A complex and varied stand structure is striven for, characterized by individual or group-wise mixture of age and size classes.
3. Damage caused by forest exploitation is reduced to a strict minimum by imposing regulations concerning machinery, log dimensions, hauling roads and exploitation period.
4. As management must be based on self-regulating processes, natural regeneration is regarded as a general rule.
5. Clear-cutting is altogether prohibited as it causes a severe disturbance of the forest microclimate over a long period. Felling is to be carried out on individuals or groups.

Economic importance

The economic importance for the forestry sector of Social Broadleaves mainly evolves from their ability to produce high-quality timber, suitable for multiple purposes (furniture, veneer, construction, etc.), rather than from the timber volumes produced.

The economic importance can be assessed by using the yearly timber sales as a simple criterion: the yearly revenue from oak and beech fellings in state forests represents some 0.18 million and 0.87 million ECU respectively, representing 10.5 and 51.7% of the total income for all species. Data concerning the yearly timber sales in the remaining public and private forests are not readily accessible. Rough estimates could be made, taking into account that state-owned oak and beech forests represent 12 and 51%, respectively, of the total area of these species in Flanders.

Institutions involved in genetic resources activities

Forest Research Stations of Gembloux (FRS) and Geraardsbergen (IFG) are the two sole scientific organizations dealing regularly with forest genetic resources management in Belgium. Both are integrated in their own region (Wallonia and Flanders), in a general administration involved in the fields of the natural resources and the environment. With their seed centres, nurseries and forest areas, these two structures possess the useful tools to set up a rational and practical genetic conservation policy.

Besides this main structure, different organizations (Annex 1) are indirectly involved in this programme. They belong to universities or to other scientific research organizations. These structures possess valuable knowledge or tools to complete and improve the basic work realized by the two Forest Research Stations.

Conclusion

Beech and oaks represent the major broadleaved species in Belgium. They are not really threatened in our country but some observations seem to indicate problems of decline.

The conservation strategy mainly relies on the application of the general genetic improvement programme (provenance trials, seed stands) and on the general forestry policy (grants, scientific support) in favour of an optimal utilization of the forest reproductive material.

Further activities could be focused on:

- promoting the use of highly diversified reproductive material of good genetic quality
- effective genetic conservation methods
- better scientific knowledge on genetic diversity
- improving seed conservation techniques.

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Annex 1. Institutions involved in forest genetic conservation in Belgium.

Walloon Region	Flanders
Ministry of Walloon Region **Forest Research Station** Avenue Maréchal Juin, 23 B-5030 Gembloux Tel: +32 81 61 11 69 Fax: +32 81 61 57 27	Ministry of the Flemish Community Environment, Nature and Land Development Administration **Institute for Forestry and Game Management** Duboislaan, 14 B-1560 Hoeilaart Tel: +32 2 657 03 86 Fax: +32 2 657 96 82
Agricultural Research Center Avenue de la Faculté, 22 B-5030 Gembloux Tel: +32 81 61 19 55 Fax: +32 81 61 49 41	University of Brussels Faculty of Sciences Lab. for General Botany and Nature Management Pleinlaan, 2 B-1050 Brussels Tel: +32 2 629 34 16 Fax: +32 2 629 34 13
Catholic University of Louvain-la-Neuve Agronomic Sciences Faculty Place Croix du Sud, 2, boîte 9 B-1348 Louvain-la-Neuve Tel: +32 10 47 37 07 Fax: +32 10 47 36 97	University of Ghent Faculty of Sciences Lab. for Molecular Genetics K.L. Ledeganckstraat, 35 B-9000 Ghent Tel: +32 9 264 51 71 Fax: +32 9 264 53 49
Faculty of Agricultural Sciences Forestry Department Passage des Déportés, 2 B-5030 Gembloux Belgium Tel: +32 81 62 23 20 Fax: +32 81 62 23 01	University of Ghent Faculty of Agronomic and Applied Biological Sciences Lab. for Forestry Geraardsbergsesteenweg, 267 B-9090 Melle-Gontrode Tel: +32 9 252 21 13 Fax: +32 9 252 54 66

Activities concerning Social Broadleaves genetic resources in the Netherlands

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Introduction

The current importance of Social Broadleaves in the Netherlands is increasing rapidly these days, both within the forestry sector and in landscaping.

The species covered by the name Social Broadleaves in the Netherlands include beech (*Fagus sylvatica*) and oaks (*Quercus petraea* and *Q. robur*).

Beech and oak species are not threatened so much at the species level, since they have always been much used. However their genetic resources are threatened. Autochthonous material is scarce, often located on private estates or nature reserves and therefore less accessible, and the price of seeds and plants is high. As a result of an often negative selection it appears that the quality of trees from these rare sources does not meet the requirements in terms of forestry standards.

A start was made some years ago for a national strategy of conservation of forest genetic resources, including inventories and background research on diversity. However, Social Broadleaves are not considered as a group of species, but treated like all other species, individually.

Besides *in situ* gene conservation of ecosystems, a specific gene conservation strategy is being or will be applied to every individual species.

Within the framework of the EU, the genetic diversity of presumed autochthonous oak populations is studied with molecular techniques. A national programme provided the possibilities for research and practical application of gene conservation in *Q. petraea*.

General situation of indigenous tree species

From the total of about 80 indigenous species of trees and shrubs in the Netherlands, about 9% almost disappeared, 33% are very rare, 36% rare and only 21% more or less common, though possibly threatened locally (Maes 1993).

Juniperus communis is the only species protected by law. However, a number of regulations and incentives favouring genetic resources do exist. Following the International Union for Conservation of Nature and Natural Resources (IUCN), a Red List was constructed for the Netherlands, containing eight species of trees and shrubs.

Besides the protection of the species, it is very important to be able to protect environments and locations where they occur.

Restoration of typical forest types and reintroduction of autochthonous forest material take place at forestry level and in landscaping.

Inventories have been made since 1992, whereas seeds and plant material are collected and grown on a contract basis to serve special purposes and plantations.

A proposal for a nationwide inventory was drawn up by Maes (1993) including a certain time schedule. Parts of the inventories in this proposal have been carried out by now, while other parts will have to wait for funding (Fig. 1).

Some of the species have been introduced into clonal archives, or into seed orchards, or both. In this way rare genotypes can be combined in order to increase genetic variability.

Collecting of the material, maintenance of the clonal archives and the layout of the seed orchards has so far been carried out by the Institute for Forestry and Nature Research (IBN-DLO).

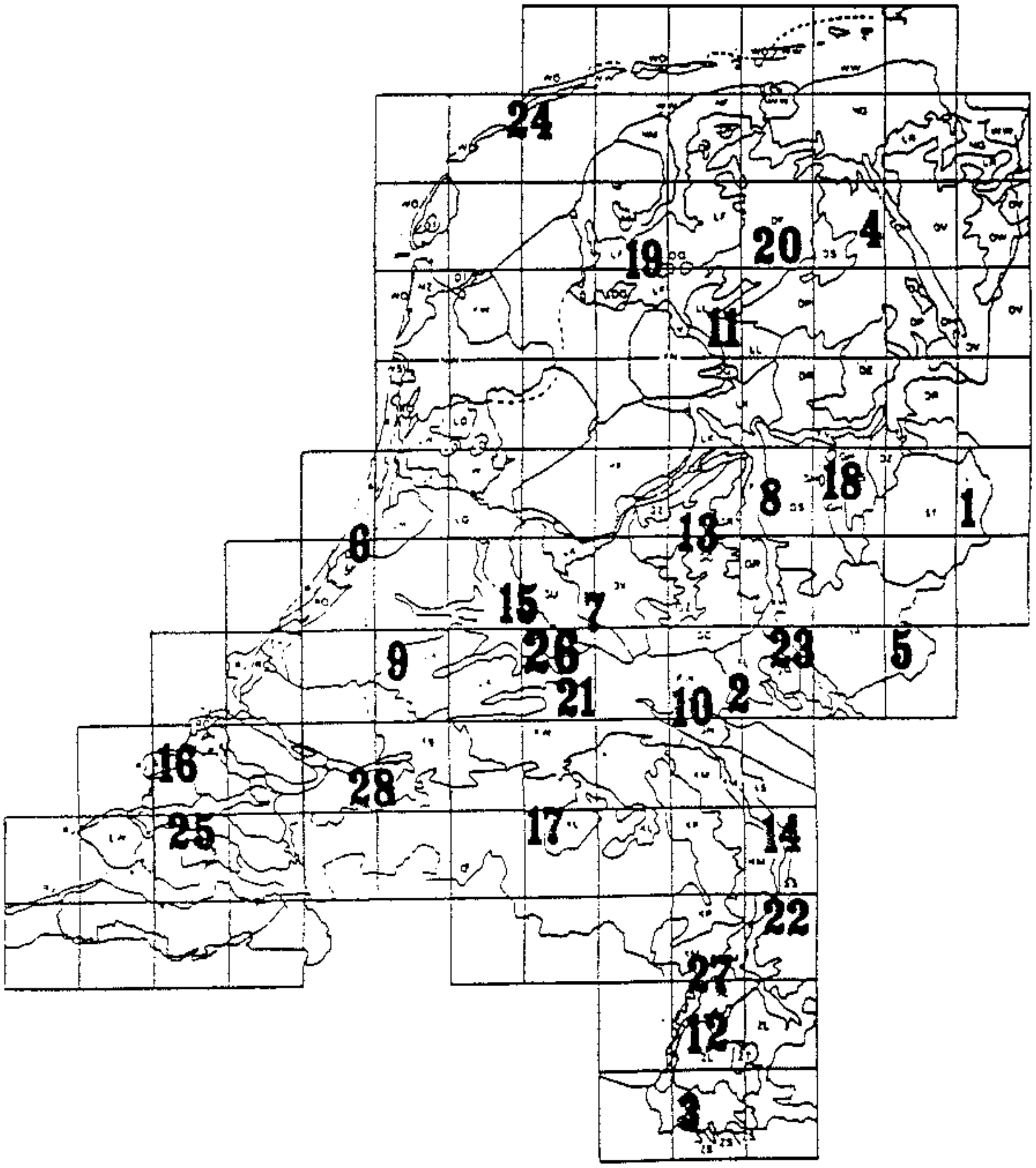

Fig. 1. Proposal for a nationwide inventory of indigenous species of trees and shrubs (Maes 1993).

Establishment and maintenance of the seed orchards has been taken care of by the State Forest Service (SBB).

Future activities in relation to genetic collections, recently initiated by the Government, also include private companies working together with SBB and IBN-DLO.

Value of Social Broadleaves

Beech is frequently planted in the Dutch forestry system. Natural regeneration is rarely used for reforestation. For this reason it is difficult to trace autochthonous material. The probability of the presence of autochthonous material concerns only cases where planting stock of local origin was used. Presumed autochthonous beech occurs only in a few places in the country and even in these cases the origin is not absolutely certain.

Quercus robur is a very important forest tree species in the Netherlands. Among generatively reproduced indigenous broadleaved species, it is the most widely spread and planted in the country. It is present in most of the natural forest ecosystems. *Quercus petraea* is of less importance than *Q. robur* in the Netherlands. Its importance is mainly based on ecological grounds rather than on wood quality criteria.

At the moment oak is the dominant tree species on 16% of the total forest area.

In addition about 25% of line and roadside plantations are established with oak. The Forest Policy Plan indicates an even higher proportion of oak in the Netherlands in the future.

Oak has been subjected to two different selection systems throughout time. In earlier days oak was a major species in the community forests. When local people needed wood they usually harvested the best material (by phenotypic criteria) and thus created a negative selection on the genetic material of oak. No positive selection was carried out in the coppice type of forest either. On the other hand, the use of oak for roadside plantations was a tradition. Seeds from these plantations were the source of new roadside plantations. The advantage of this long tradition of harvesting tree seeds in roadside plantations is the recurrent positive selection toward a certain desirable type of tree. The tree nursery selects among all its populations about 2-5% for the special purpose of establishing the next generation of roadside trees. These trees finally come to stand in a roadside plantation which after many years delivers a series of new generations in which the tree nursery again selects 2-5% to proceed with the next generation of roadside trees.

Despite this, too little emphasis has been put in the past on the use of material with high genetic quality. Seeds of good stands were very often mixed with that of poor stands for the sake of quantity only. On top of that, also in the past, a lot of seeds were imported in poor production years from unknown sources. The chance of this material being less adapted to local conditions is rather high.

Beech and oaks very often grow together in harmony in those places where they seem to have grown undisturbed for a long time. Some still existing large estates illustrate this (Maes 1993).

A major problem these days is the sudden change in water tables. In both directions, either too dry or too wet, this could mean a disaster to the ancient trees. Climate fluctuations and the need for high water supply are often the cause of these changes in the water table.

Identification of the genetic background of autochthonous oak populations

For many reasons it is considered important to learn about the genetic background of oak in the Netherlands.

During a survey of genetic resources of trees and shrubs in the Netherlands, 13 autochthonous populations of oak were identified, based on historical, taxonomic and site criteria (Maes 1993).

Within the framework of the EU project 'Synthetic maps of gene diversity and provenance performance for utilization and conservation of oak genetic resources in Europe', the genetic diversity in these presumed autochthonous oak populations is studied with molecular techniques. Laboratories and research institutes from Austria, Denmark, France, Germany, Italy, Netherlands, Spain, Switzerland and the United Kingdom are involved in this project.

Eight mixed populations of *Q. robur* and *Q. petraea* and five pure *Q. robur* populations were sampled to determine the polymorphism of the chloroplast DNA.

Three haplotypes (Petit *et al.* 1993) are dominant in the Netherlands. Two of them follow the pattern of the geographic distribution of haplotypes in Europe, one originates from the Balkans. Further studies should reveal whether this last haplotype migrated into the Netherlands during postglacial recolonization of Europe or was introduced artificially.

Combining the information gathered in Europe might allow identification of the original origin of our selected seed stands.

Beech and oak species in Germany: occurrence and gene conservation measures

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Introduction

Beech (*Fagus sylvatica* L.) and the two oak species, sessile oak (*Quercus petraea* (Matt.) Liebl.) and pedunculate oak (*Quercus robur* L.), are the most common and most economically significant broadleaved species in Germany. According to the last forest inventory of 1990 the total forest cover in Germany is 10.8 million ha with 14.0% beech forests and 8.6% oak forests (BML 1990, 1994). The two oak species are not separated in forest statistics. These three broadleaved species occur in nearly all parts of Germany with a few regional exceptions (Röhrig 1980). They grow on sites with a wide range of ecological conditions (Fig. 1).

A third oak species, the pubescent oak (*Q. pubescens* Willd.), is a submediterranean tree species native only on very warm and dry sites of southwestern Germany. The North American red oak (*Q. rubra* L.) is an important introduced and fast-growing species and was planted in large numbers in the 19th century. The Turkey oak (*Q. cerris* L.) is also grown in some regions on drier and poor sites. These last species regenerate also naturally, but will not be considered in this report.

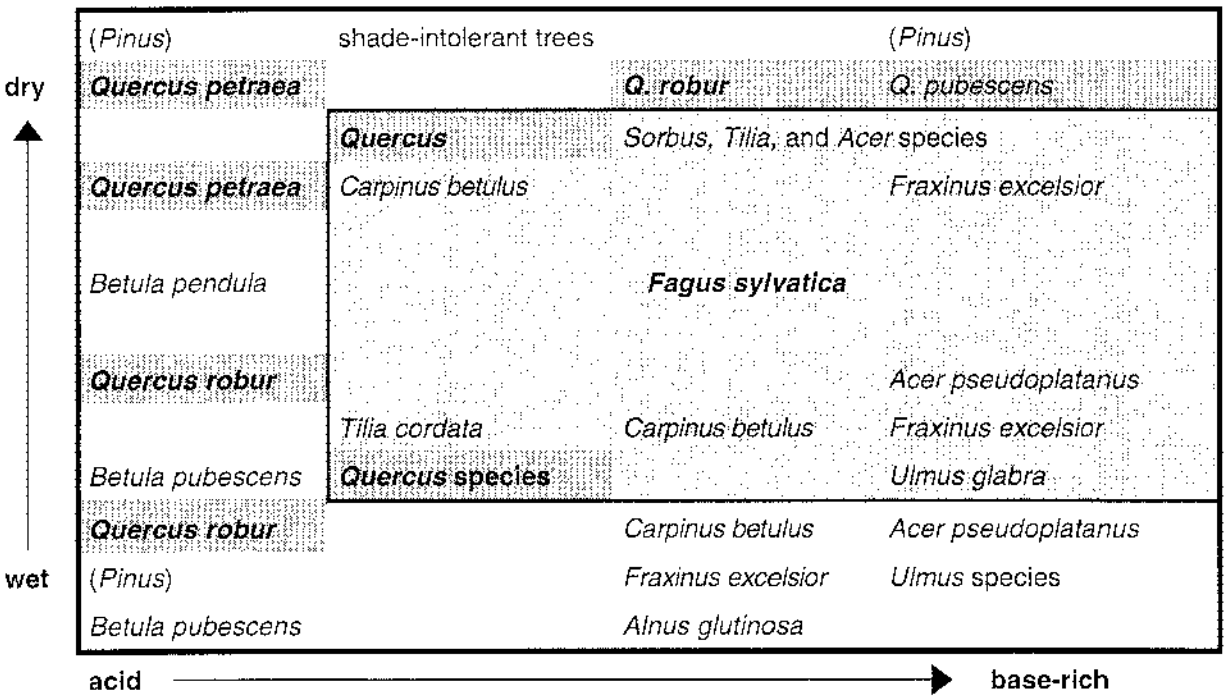

Fig. 1. Water and nutrient site requirements of main tree species in submontane regions (Ellenberg 1982, modified) [shaded = beech area; dark shaded = oak area].

The species

Beech occurs under atlantic to subatlantic climatic conditions. The species grows mainly in western and central Europe in pure and mixed stands, has a very strong competitive capacity, is shade-tolerant and very adaptive. Beech is distributed naturally from the coastal areas to an elevation of about 1500 m (1700 m) in the northern parts of the Alps. It prefers sites with a good water and nutrient supply and avoids very moist or dry and poor sites. Beech occurs typically on sites with limestone as basic rock. It can be assumed that many stands in Germany are autochthonous.

Sessile oak and **pedunculate oak** occur sympatrically in Germany from atlantic to continental climatic regions. As both oak species occur under various climatic conditions, differentiated populations have developed. The populations show a high intraspecific genetic variation and differ by phenology, growth performance, form and other traits (Kleinschmit 1993). The differences in flushing are particularly important in connection with the susceptibility to late frost (Stephan *et al.* 1995).

Mating between the two species is obviously frequent, although the proportion of tentative hybrids in natural stands is not known so far (Rushton 1993). The species concept of the two oaks is still in discussion. Sessile oak and pedunculate oak are considered taxonomically and ecologically as two separate species (e.g. Aas 1996). The distinction between sessile oak and pedunculate oak is difficult as many intermediate forms occur, and hybrids cannot be identified morphologically on an individual level. Comparing various morphological and genetic traits, Kleinschmit *et al.* (1995) did not detect any single character which had disjunctive expression. Many other studies have shown that it was in no case possible to differentiate the two species by one single trait or marker. In some cases the combination of various characters opened the possibility to distinguish between *Q. petraea* and *Q. robur*, but the genetic differentiation was very low (Müller-Starck *et al.* 1993). The combination of morphological, phenological and growth traits of the same seedling over several years also resulted in some significant correlations between traits for the differentiation between the two species (Liesebach and Stephan, unpublished). Hybridization between *Q. petraea* and *Q. robur* is possible by controlled crosses, but with different fertility rates depending on whether *Q. petraea* or *Q. robur* were taken as pollen parent (Steinhoff 1993). Some authors (Kleinschmit *et al.* 1995) concluded that sessile oak and pedunculate oak may represent different ecotypes of the same species.

The sessile oak type inhabits warmer sites and lighter soils. The species is prevalent in the warmer hilly regions of western and southwestern Germany and endures drier site conditions. Regions with famous sessile oak forests are in southwestern Germany, the Spessart and the Pfälzer Wald. In the Bavarian Alps sessile oak can be found up to an elevation of about 900 m.

The pedunculate oak type grows optimally on rich loamy soils with a good water supply and occurs mainly in the lowlands from sea level up to an elevation of 950 m in the Bavarian Alps.

Beech, sessile oak and pedunculate oak are included in the Act on Forest Seed and Planting Stock of Germany (Anonymous 1979). In the Regulations on the Regions of Provenance for Forest Reproductive Material 26 regions are defined for beech, 13 for sessile oak, and 9 for pedunculate oak, respectively (Anonymous 1994).

Current economic importance and use of reproductive material

Timber from beech and oak has a high economic importance. The amount of fellings during the past years was about 7 million m^3 wood under bark per year for beech (= 20% of the total felling), and about 1.3 million m^3 wood under bark per year for oak (= 4%) (Hein and Bitter 1997). In both groups of these two tree genera about 50% was used as stem wood and 50% as industrial wood. Prices for stem wood remained more or less stable for beech, but decreased for oak. Prices for industrial wood decreased generally in the last 10 years.

Nevertheless, high prices are paid when the timber has a good veneer quality, as the following example shows: for an oak stem with a length of 6.5 m and a mean diameter of 0.85 m, 51 765 DM were paid for the whole stem (14 500 DM/m³ solid volume).

Besides timber, seed trade of approved beech and oak stands is also of great economic significance. Seed trade is an important factor at both national and international levels. The number of approved stands and seed orchards of the EEC and OECD category 'Selected', and of the approved stands of the category 'Tested' is shown in Table 1. More than 81 000 ha approved stands – seed orchards included – are registered for beech, about 32 000 ha for sessile oak, and about 9100 ha for pedunculate oak. About 166 000 kg seeds of beech, about 400 000 kg acorns of sessile oak, and about 256 000 kg acorns of pedunculate oak were collected annually on average over the last 14 years.

Table 1. Summary list of approved basic material

Tree species	No. of stands or seed orchards	Reduced area (ha) of stands or seed orchards: Autochthonous	Non-autochthonous	Unknown	Total
Approved stands of the category 'Selected'					
European beech	14199	70434.5	691.7	9969.3	81095.5
Sessile oak	8336	26079.2	286.1	5278.1	31643.4
Pedunculate oak	2145	3858.5	535.7	4684.0	9078.2
Approved seed orchards of the category 'Selected'					
European beech	1	1.5	–	–	1.5
Sessile oak	–	–	–	–	–
Pedunculate oak	1	–	2.0	–	2.0
Approved stands of the category 'Tested'					
European beech	28	244.1	–	13.3	257.4
Sessile oak	39	202.4	5.2	2.3	209.9
Pedunculate oak	8	2.5	11.7	28.3	42.5

Silvicultural approaches

In general, beech is regenerated naturally. Oak can be sown directly or planted using wild saplings from the forest or nursery-grown seedlings. If the species are regenerated artificially, the use of local and well-adapted provenances is recommended. The aim of any silvicultural and forest management activity is to guarantee the sustainable use of the resources, the maintenance of forests as the basis for the multiple forest functions, such as production of wood as renewable raw material, regulation of watershed, various social functions, and last but not least sustainable conservation of biodiversity. Beech and oak forest communities in particular are rich forest ecosystems, given their various combinations with other species (Fig. 1).

Health state of the forest stands and threats to their genetic diversity

Although forest decline has been observed for a long time, the situation developed dramatically in the early 1980s, when heavy and increasing damage occurred in silver fir (*Abies alba* Miller), followed by severe damage in Norway spruce (*Picea abies* (L.) Karst.). For the last 10 years, broadleaved trees, including beech and oak, also have shown increasing and heavy disease symptoms. Forest decline was registered officially in 1984 and the monitoring results published in annual reports, the latest in 1997 (BML 1997).

Damage is recorded on a five-step scale with increasing grades from 0 to 4. The proportion of damaged forest trees of all ages was 20% (grades 2 to 4) in 1997. Beech was damaged at about 29%, oak at 46%. The annual proportion of damaged beech and oak trees from 1984 to 1997 is shown in Figures 2 and 3. Older stands in particular show a high percentage of damaged trees. For trees more than 60 years old, the situation was serious in 1997: 38% of beech trees and 55% of oaks showed remarkable damage (grades 2 to 4).

During recent years a Europe-wide decline of oaks was recorded, dramatic in some regions. A complex of several biotic and abiotic factors seems to be responsible for the symptoms (Wulf and Kehr 1996).

Forest decline is mainly caused by anthropogenic environmental loads (emissions) and has obviously strong effects on the genetic diversity of certain tree populations (compare, for example, Müller-Starck 1993).

Besides damage by emissions, beech and oak are sensitive to late frost in spring, beech also to drought. During recent years several epidemics by insects (e.g. *Agrilus* sp., *Lymantria dispar*, *Tortrix viridana* and others) attacked in particular the oak species in various parts of Germany (Wulf and Kehr 1996). Excessively increased populations of game can also be a burden for young forest stands.

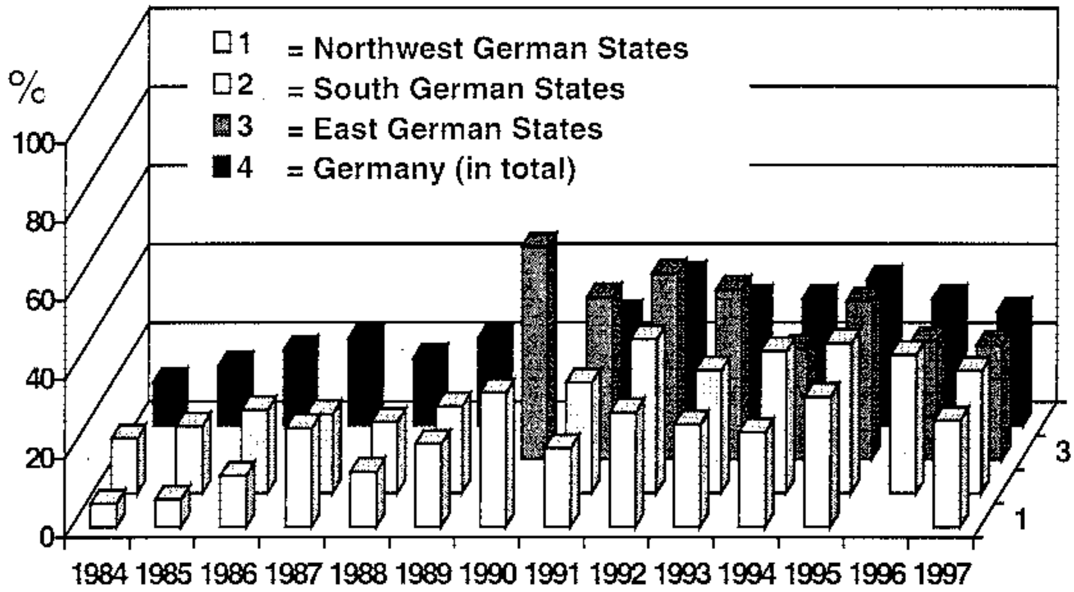

Fig. 2. Development of forest decline in beech in Germany from 1984 to 1997. The summary of damage classes 2 to 4 in % is shown for all age classes (source: BML 1997).

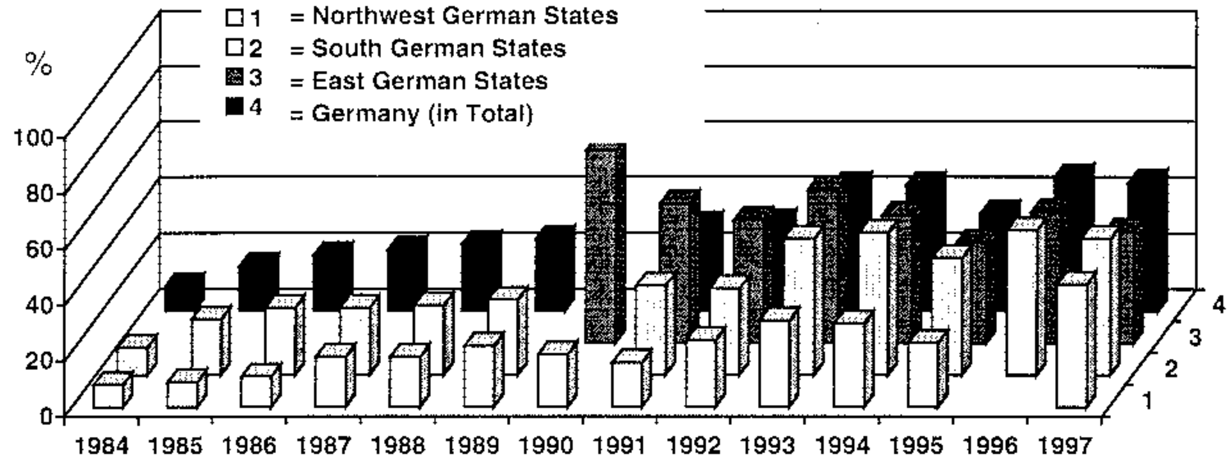

Fig. 3. Development of forest decline in oak in Germany from 1984 to 1997. The summary of damage classes 2 to 4 in % is shown for all age classes (source: BML 1997).

Current genetic conservation activities

After the establishment of the Federal and State Working Group 'Conservation of Forest Genetic Resources in the Federal Republic of Germany' in 1984, a concept was developed for conservation measures and research. Among many other tree and shrub species, the conservation activities also include beech and the two main oak species (BLAG 1989, 1997). Existing measures for direct and indirect gene conservation are carried out by federal and state institutions (*Länder*) of Germany. There is little private activity in this respect. Special legal regulations concerning the conservation of forest genetic resources are missing. But the following legal regulations contribute indirectly to the protection and conservation of forest genetic resources:

- forest laws of the Federal and State Governments
- legal regulations concerning forest reproductive material
- laws and regulations on nature protection.

The following *in situ* and *ex situ* conservation measures can be applied: conservation of stands by reduced management (fellings), support of natural regeneration, sowing and planting *in situ* and *ex situ*, establishment of seedling and clonal seed orchards, establishment of clone collections or clonal archives, conservation of seed, pollen, plants, parts of plants including tissue in genebanks, and conservation by macro- and microvegetative propagation. All these measures are applied in beech and oaks, often concurrently, minimizing the risk. The various measures have advantages and disadvantages (BLAG 1997).

Additional activities include conservation of material within the framework of breeding programmes, as well as the conservation of provenances, families and clones in field trials.

The material designated as 'worthy for conservation' includes, for example: approved basic material for forest reproductive material, selected or comparable populations covered by the Act on Forest Seed and Planting Stock (Anonymous 1979), populations under specific ecological conditions, marginal populations and material severely endangered by current damage or by its rarity.

The state (1996) of gene conservation activities in beech, sessile oak and pedunculate oak is shown in Table 2 with respect to *in situ* and *ex situ* measures. Emphasis was laid on *in situ* conservation of stands including natural regeneration (Fig. 4). As an *ex situ* measure the establishment of seed orchards is of great significance (Fig. 5).

In connection with the above-mentioned activities research is also needed on variability, genetic structures of populations, effects of silvicultural and conservation methods on genetic diversity, and methods for long-term storage of seeds. Despite the importance of beech and oak in German forestry, there is little knowledge about the genetic structure of populations throughout their range of distribution (Müller-Starck and Ziehe 1991). There are many results of isoenzyme studies in beech. A practical guide concerning electrophoretic methods of separation and for the evaluation of zymograms is in preparation. Although regional differences can be found, it was shown that generally the variation within populations is larger than between populations. Concerning oak, DNA studies have shown very recently the existence of genetic types with differences in the chloroplast genome (chloroplast DNA), which are distributed geographically (Kremer *et al.* 1991; Petit *et al.* 1993; Dumolin-Lapègue *et al.* 1997). These results can probably be used for studies about the postglacial migration, about the delimitation of regions of provenance, about the autochthonous origin of populations, and other questions. Studies on the genetic diversity in specific amplified chloroplast regions of the two main oak species in Germany are under way (König *et al.* 1998).

Relevant nature protection policies and activities

Valuable beech and oak forest stands with a rich vegetation are often protected as nature areas. Very old and attractive single trees are also under special protection.

Very recently a plan is under discussion to establish at least two large areas with natural beech forests as national parks: Hainich (Thuringia) and Kellerwald (Hesse).

Public awareness about the importance of beech and oak is high in Germany. Since 1989, each year a tree species is elected 'Tree of the Year'. Oak was the first species elected, followed by beech in 1990. Special leaflets are prepared and articles are published in newspapers to provide the public with information on the 'Tree of the Year'.

Tree-improvement activities

Selection of single plus trees is conducted in all three tree species for the establishment of seed orchards or clonal archives (Table 2).

In comparison with the significance of beech and oak, few older provenance trials exist. A review of the international trial series with more than 300 beech provenances since 1983 was presented at this EUFORGEN meeting (von Wuehlisch *et al.*, this volume).

There are also oak provenance trials (trees about 40 years old) initiated by Krahl-Urban, which give interesting results on growth performance, stem form and flushing (Kleinschmit and Svolba 1995). More recently, an international series with more than 30 sessile oak provenances was organized by Madsen (1990) and established in various countries, including Germany. First results give information about growth, flushing, bud-setting, frost tolerance and several other traits (Stephan *et al.* 1995).

The intensive breeding work with oak concluded at the Forestry Research Station of Lower Saxony, Escherode, must also be mentioned (Steinhoff 1993; Schüte 1995). Controlled crossings between and within the two oak species have been carried out successfully. The results give an insight about the possibility and importance of hybridization between the species.

Institutions involved in genetic resources activities

The Federal Research Institute, 10 Institutes of the states (*Länder*), and Institutes of four Universities are involved in the *in situ, ex situ* activities or in research. The federal and the state institutions constitute the working group 'Conservation of Forest Genetic Resources in the Federal Republic of Germany', exchange information intensively and coordinate the activities of the member institutions by considering regional peculiarities.

Summary of country capacity and priorities

Studies on the genetic structures in beech and oak, funded by several national and international projects (EU, Deutsche Forschungsgemeinschaft – German Research Association, etc.) have a high priority. German institutions are partners or coordinators of the following national and international projects on beech and oak:

- Concerted Action: 'European Network for the Evaluation of the Genetic Resources of Beech for Appropriate Use in Sustainable Forestry Management' (AIR3-CT94-2091)
- Shared-Cost Action: 'Common Beech for Forestation and Diversification: Development of Forestation Techniques and Assessment of the Genetic Variation in Reproductive Material' (FAIR3-PL96-1464)
- Shared-Cost Action: 'Synthetic Maps of Gene Diversity and Provenance Performance for Utilization of Oak Resources in Europe' (FAIR1-CT95-0297)
- Testing the Frost Tolerance of Acorns by Differential Temperature Analysis [Prüfung der Frosthärte von Eicheln mittels Differenztemperaturanalyse] (BML 115-0762-A-3-5/363).

Still very little is known about optimal conditions for long-term storage of acorns of the recalcitrant tree species beech and oak. Projects were started recently.

The mentioned international provenance trials in beech and oak will improve our knowledge about the genetic variation of beech, sessile oak and pedunculate oak and will support gene conservation measures. Therefore, it is necessary to start or to continue international collaboration with all countries in which beech and oaks occur. A first step was made by the establishment of this EUFORGEN Network on Social Broadleaves.

Table 2. *In situ* and *ex situ* conservation measures for beech and oak in Germany (at 31.12.1995)

	In situ			*Ex situ*								
	Stands			Stands			Seed orchards				Clonal archives	
Species	No.	Area (ha)	No. single trees	No.	Area (ha)	No. single trees	No.	Area (ha)	No. of families	No. of clones	No.	No. of clones
Fagus sylvatica	255	2201	145	93	152	–	10	13	64	216	1	6
Quercus petraea	75	345	444	81	96	–	7	8	–	222	–	–
Quercus robur	217	480	246	55	77	–	11	20	–	158	–	–

	Seed storage						
	Stands/seed orchards		Single trees		Pollen storage		Tissue storage
Species	No.	Quantity (kg)	No.	Quantity (kg)	No.	Quantity (cm³)	No. of samples
Fagus sylvatica	256	1961	72	16	–	–	19
Quercus petraea	2	23	16	4	42	685	35
Quercus robur	1	< 1	–	–	35	535	51

Source: BLAG 1996.

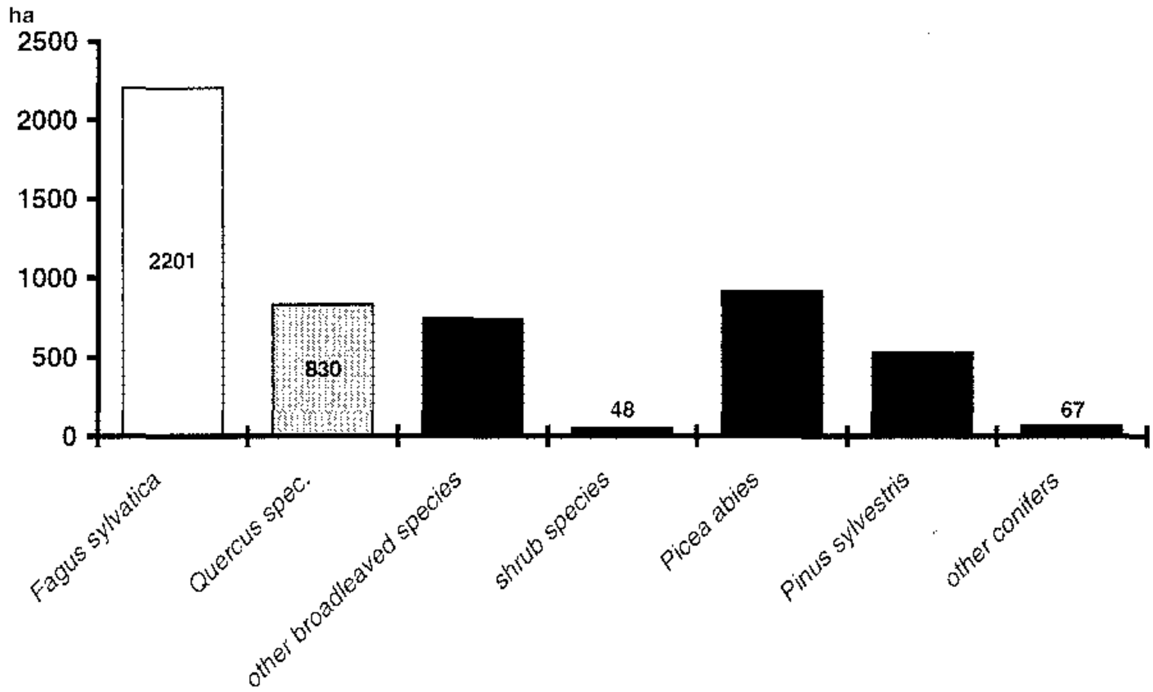

Fig. 4. Stands for *in situ* conservation (state: 1995) (sources: BLAG 1996; Tabel 1997).

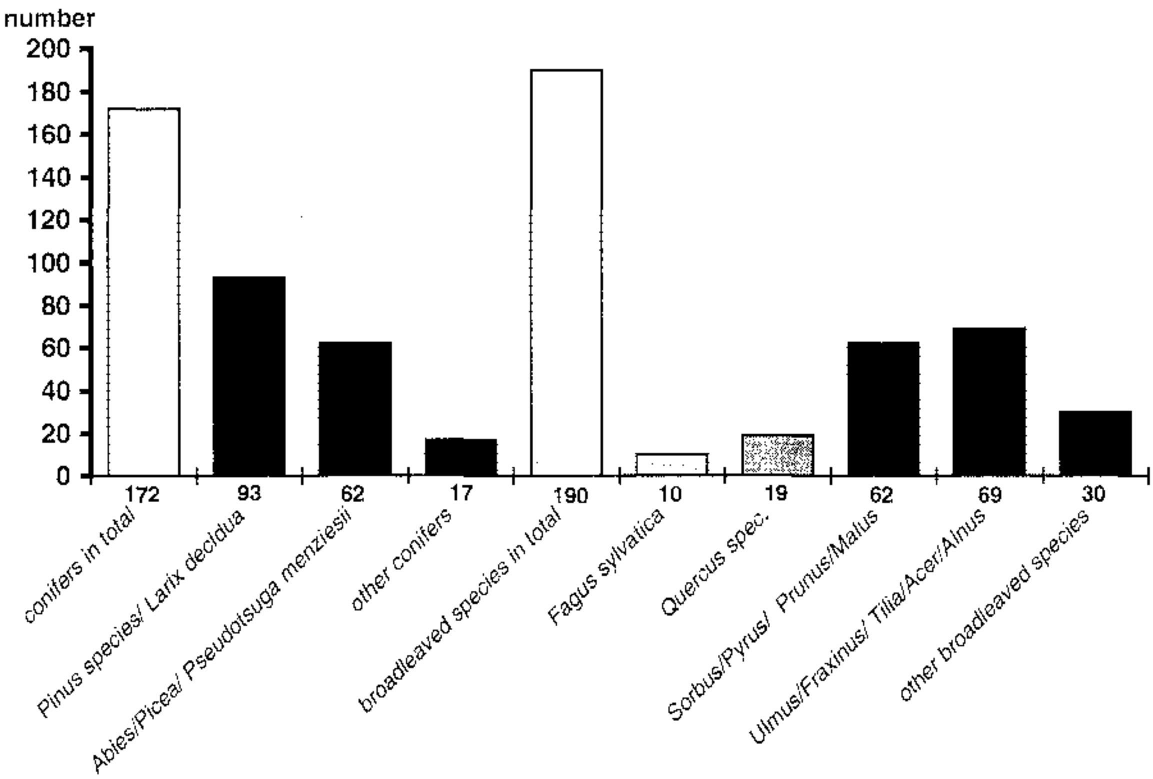

Fig. 5. Seed orchards for *ex situ* gene conservation (state: 1995) (sources: BLAG 1996; Tabel 1997).

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Conservation strategy for beech and oaks in Denmark

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Introduction

The Strategy for the Conservation of Genetic Resources of Trees and Shrubs in Denmark was prepared by the National Forest and Nature Agency in 1991-93. The general principles and approaches to genetic conservation of forest trees in Denmark are discussed in detail by Graudal *et al.* (1995).

The objective is to secure the ability of the species to adapt to environmental changes, and to maintain the basis for future tree-improvement work. For both beech (*Fagus sylvatica*) and oaks (*Quercus robur* and *Quercus petraea*) this strategy was initiated in 1992. Several *ex situ* areas have been established, but many areas for *in situ* conservation have not been designated yet.

Occurrence and origin of beech and oaks

Denmark has mainly been formed by the last Glacial (Weichselian), and the development of the forest has taken place during the last 10 000 years.

Oaks have been present since 7000 BC. Pedunculate oak (*Quercus robur*) is distributed all over the country, found on a large variety of ecological conditions. Sessile oak (*Q. petraea*) grows mainly in the central parts of Jutland, on sandy hilly locations. Sessile oak is found sympatric to pedunculate oak.

After invading Denmark in 1000 BC, beech reached its maximum distribution only 1000 years ago, replacing lime as the dominating forest species. Approximately 5000 years ago, substantial human impact on the landscape began, due to agriculture and grazing, and the forest reached a minimum of 3% of the total land area toward the end of the 18th century. Since then the forest area has increased to 12%, mainly through the establishment of coniferous plantations. Beech is dominant on better soils and is very competitive with both sessile and pedunculate oaks.

Beech occupies 72 000 ha and is slowly increasing in area after a long period of decrease. The area covered by oaks has increased from 13 000 ha in 1907 to 30 000 ha in 1996. Oaks and beech cover about 25% of the forest area.

Forest management

The expansion of beech since the Glacial is a result of both anthropogenic and natural processes. The reduction in forest area until 1800 resulted in serious fragmentation of beech and oak forests.

Human impact has influenced qualitative properties of forest trees, especially beech and oaks. Substantial genetic variation in tree form can be shown for oaks.

Slash-and-burn management reduced forest area, and instead created heathland and brushwoods in western Denmark. Large amounts of wood were used for fuel. Evidently large-dimension timber has been removed for construction purposes; straight trees have been selected primarily. Heavy grazing by domestic animals also had an effect on the forest stands. Acorns were used for fodder in historical times.

Large numbers of pigs roaming around in the forest probably favoured beech regeneration as compared with other species. All these processes have probably been acting in a complex way at different rates and strengths at various locations in the country.

Since 1800 most of the forests including coppice, shelterwoods and brushwoods has been converted into high forests, favouring straight and fast-growing trees. Management of single species has been preferred and mixed forests have almost disappeared. Beech has been planted widely in areas where it was absent before.

In contrast to other species, the Danish beech forests still retain their genetic continuity as most are regenerated naturally.

Several oak stands in Jutland were converted from coppice forest into high forest. Several methods of coppice management may have been practised in the past; this may influence genetic structure in different ways.

Both oaks and beech are important species for forestry. On better soil types, their mean economic production can reach 500-1000 DM per year based on the 130-year rotation period. The timber is used for veneer and board production. Both species possess high recreational value and historical and cultural importance.

Silvicultural approaches

Most areas with beech and oaks are owned by the public, but a number of large estates includes large stands with beech and oaks. Danish forestry is dominated by management of small compartments between 2 and 6 ha. Oaks and beech are mainly found in pure stands and along with drainage of wet biotopes, the genetic structures may be affected. Coppice forestry is seldom practised nowadays, only by a very few small private forest owners.

Beech

For the last 200 years, beech management has mainly been high forest with a rotation age 110-140 years. Intensive thinning has been practised. On a few occasions, 100-150 years ago, large compartments of 10-30 ha beech stands were established.

Oaks

Oak forests on better location have been managed as high forest with strong thinning and short rotation – 130 years. On poor sites, moderate thinning is often practised and rotation period may be up to 150-160 years.

Health state

The health state of beech varies from year to year, depending on climate, flowering, etc. Beech is considered to have endangered genetic resources owing to fragmentation or heavy imports of forest reproductive material.

The health state of oak also varies. Moderate oak dieback appeared from 1989 to 1994, but now it has almost stopped. Two extreme years with bad flushing occurred (in 1993-94) in several locations.

Research activities

Isoenzyme studies have been carried out for both oaks and beech. The highly outcrossing species show low variation between population and moderate to high variation within populations (Larsen 1996; Siegismund and Jensen, pers. comm.). The results are comparable to international studies. They do not indicate genetic erosion, which could be expected following fragmentation. However, what is mostly needed is a more intensive assessment of variation, mainly of beech.

Studies of provenance variation were initiated a hundred years ago, and were recently reported (Jensen 1993). We found high variation between populations and some clinal differences between Danish and foreign provenances. Within the Danish provenances, there seems to be a clinal pattern in flushing, as western provenances are flushing later than eastern provenances. This indicates the presence of different ecological zones in Denmark.

In 1989-90 a large international collection of sessile oak provenances was initiated by the Forest and Landscape Research Institute. For the time being, a study of Scandinavian pedunculate oak is under way including studies on adaptive traits (frost and drought stress) and genetic markers.

The Forest and Landscape Research Institute and the Agricultural University are involved in common EU projects on beech and oaks along with several partners from the EU countries. This includes management of a common database for oak provenance trials, a synthetic map of chloroplast DNA variation, and mapping of within-population variation with microsatellite DNA markers.

Relevant nature protection policies and activities

Two different strategies have been adopted concerning gene conservation of trees and shrubs in Denmark:

'A Strategy for the Conservation of Genetic Resources of Trees and Shrubs in Denmark' by the National Forest and Nature Agency was prepared in 1991-93. The strategy provides an overview of gene conservation needs and required gene conservation measures, and a plan of implementation for gene conservation in Denmark. The strategy is closely linked to the tree improvement and seed procurement programmes in Denmark.

'The Strategy for Natural Forest and Other Forest Types of High Conservation Value in Denmark', adopted in 1992. The strategy focuses on ecosystem conservation, and does not address the conservation of forest genetic resources.

Both strategies can be considered as national responses to recent international agreements concerning the conservation and sustainable use of biological diversity (Agenda 21, Helsinki and Strasbourg Resolutions).

The Danish Forestry Act protects separately oak brushwoods and coppice forest. In 1987, 314 ha of oak brushwoods were protected.

Current genetic conservation activities

Ex situ

Activities have been initiated for oaks and beech. Some of the seed sources are regarded as very valuable, especially first and second generation stands. Even if landraces have not evidently developed, these seed sources should be conserved for future use. On a few locations, a limited number of combined seed production and conservation stands have been or will be established. Several stands of beech covering 40-50 ha will be established.

Further *ex situ* tasks for oaks are also carried out through the tree improvement programme and the provenance trials.

In situ

Until recently only a limited number of forests have been protected formally. A number of virgin stands have been described, covering a total of 217 ha. Nature protection areas include forest of autochthonous origin. A number of private and public stands have been protected administratively. In 1992, The Danish Strategy for Natural Forest was adopted (see above). The Strategy should secure quantitative and qualitative distribution of nature protection areas for beech and oaks. The principle of natural forest is mainly based on a definition of genetic origin. As beech can be easily regenerated, this will give no problems. Oaks may be more difficult to assess. In total the Strategy concerns about 35 000 ha, most of it beech.

Within the strategy for forest genetic resources, the *in situ* stands of beech will be selected within the natural forest areas. A number of 5-7 isolated stands of beech covering the geographic range will be identified. Each stand comprises at least 500 individuals.

For pedunculate oak, a number of 8-10 stands will be designated, and for sessile oak 5-6 stands. Sessile oak occurs naturally in 4-7 ecogeographic zones, in two of these zones only on one site each. The conservation status of many of the sessile oak brushwoods, so-called 'purs' is good, but *in situ* conservation should mainly protect one or more of these areas against pollination from external sources.

Tree improvement activities

A tree improvement programme for oaks was initiated in 1993 by the Arboretum. As natural regeneration is not practised, there is a large demand for acorns. The breeding programme should enhance the production of valuable seeds, and for oaks of Danish origin, stem quality should be improved.

About 180 plus trees of eastern Danish origin were selected and acorns collected in 1995. Two seedling seed orchards will be established in 1998-99 (about 10 ha). This programme will also include clonal seed orchards.

Another two seedling seed orchards of oak based on plus trees of Dutch origin will be established in 1998-99 (about 8 ha).

For sessile oak used in harsh locations in western Jutland, 126 plus trees have been selected. From these trees, two clonal seed orchards are planned to be established.

A breeding programme for beech has not been considered.

Use of reproductive material

Beech is mainly regenerated naturally. For planting, a substantial amount of seed material was imported from abroad during the last 200 years. Between 1880 and 1935, the major imports were from the Carpathians, the Netherlands, Belgium, Sweden and Germany. Today reproductive material comes from approved selected stands (36 in 1997) or foreign imports. From 1960 to 1980, 86% of the total beech seeds used were imported (Larsen 1983). In recent years, the amount of seed from Danish stands has increased. From 1990 to 1995 Danish nurseries received 18 tonnes of beech seeds per year (Madsen and Søgaard 1996). Seed-processing has improved significantly and an increased number of approved stands has been selected.

Large amounts of acorns have been imported for plantations of oaks since 1780. Especially Germany and the Netherlands, but also Norway, Sweden and France have contributed with acorns. Stem form and growth have been better in the imported material; provenances from the Netherlands have shown significantly better stem straightness than Danish provenances (Jensen 1993). Furthermore, imported seed material is relatively cheaper than Danish. Within the period 1960-90 only 27% of acorns for forestry and landscape use were harvested in Danish stands (Madsen 1991). Most of the acorns were imported from approved Dutch stands, mostly comprising roadside trees. From 1990 to 1995, 39 t of sessile oak acorns and 97 t of pedunculate oak acorns were used annually in Danish nurseries. Eighty-three stands have been approved for seed production (1996). Only a few of these are presumably of Danish origin.

Summary of country capacities and priorities

In Denmark, beech is considered a well-protected species. In spite of high forest degradation (fragmentation), low interpopulation diversity and high outcrossing have been revealed. Existing genetic resources are given high priority and are well protected. Active gene conservation efforts and tree improvement are not immediately needed.

Both pedunculate oak and sessile oak are high-priority species. Generally, oak resources are considered threatened. This is due to massive import of foreign seed sources and no tradition of natural regeneration. An active programme involving tree improvement and gene conservation has been initiated.

Needs for international collaboration

International collaboration in the fields of tree breeding and gene conservation is valuable for further research and management of genetic resources.

Development of descriptive methods (morphology, phenology and biochemical markers) and more provenance experiments are necessary in general. A more precise description of seed sources, especially commercial, is also needed.

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Genetic resources and conservation of *Quercus robur* L. in Lithuania

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Introduction

Lithuania covers 65 300 km^2. The landscape is basically flat with minor hills. Sod podzolic soils are prevalent. The average altitude is 99 m. The climate is transitional between maritime and continental. The average annual temperature is +6°C and the average annual precipitation is 650 mm. The vegetation period lasts for 175 days. The southern part of Lithuania belongs to the temperate vegetation zone, the northern part to the Hemiboreal zone. Forest area represents 30.1% (1 860 300 ha).

Occurrence and origin of oaks and beech

In Lithuania deciduous hardwoods cover 4.7% of the total forest area, and pedunculate oak (*Quercus robur* L.) 1.7%. It forms mixed stands, often together with Norway spruce and softwood deciduous trees, and is only exceptionally found in pure stands. Oak forests are mostly concentrated on fertile sites of the coastal lowlands and in the central part of the country.

Lithuania is crossed by the northern boundary of the distribution area of *Carpinus betulus* L. Behind this, *Quercus petraea* grows on an area of 70 ha in the Trako forest in the southeastern part of the country. This natural stand is almost 100 years old and 90% of the oaks growing there are *Q. petraea* (Tuminauskas 1957).

Beech stands are presumably not native and grow in a small part of southwestern Lithuania near the Baltic Sea.

The optimum climate for pedunculate oak and the maximum broadleaved forests cover reached was in 4000-5000 BP (Kabailiene 1990). Climatic changes alone were not sufficient to account for the decrease of broadleaved forests. It is likely that human activity further reduced their distribution. Biological and ecological features of *Q. robur* suggest that, even in the period of maximum distribution of the species, the share of oak forests was less than 30% of total forest area. According to Lukinas (1967), in the 16th century Lithuania had 15-20% of oak stands, while in 1895 only 2-3% remained. Therefore, for economic reasons and biological characteristics it is not necessary to extend the area of pedunculate oak in Lithuanian forests above 5-7% (Karazija 1997).

Current economic importance in the forestry sector

Forests are one of the most valuable natural resources in Lithuania. Mature pedunculate oak stands produce on average 246 m^3/ha of timber. Some stands have a very high productivity: the Juravos oak stand, 660 m^3/ha at the age of 110 years; the 80-year-old Dusnioniu oak stand in Alytus, 343 m^3/ha; the 120-year-old Kulupenu oak stand in Kretinga, 354 m^3/ha, etc.

The rotation period for oak ranges from 120 to 140 years. The average age of oak stands is 80 years although the greatest part of the area is constituted of middle-aged stands (about 58%). In 49% of the stands in which pedunculate oak occurs, it represents less than 5% of the species present in the stand; not more than 5% stands have more than 50% oak trees. Stands with oak admixture cover about 15% of the forest area. Every year about 15 000 m^3 (or about 1.1% of the total amount of timber harvested) of mature and overmature deciduous hardwoods, mainly pedunculate oak and European ash, are logged. Felling of oak stands is increasing and will rise to 0.7% of the total growing stock in 1998. The needs of the national market in oak wood products are not fulfilled completely. Some oak stands are still owned by private owners (one-sixth) and the process of privatization is not finished yet.

Silvicultural approaches used

The regeneration of oak stands is prescribed in the Reforestation Regulations approved by the Ministry of Agriculture and Forestry. The planting of other species in the areas of oak felling is prohibited as well as clear-cutting. For these reasons acorns have to be collected in the seed reserves. Seed transfer is controlled by the responsible state institutions.

Health state of the forest stands and threats to genetic diversity

Defoliation of oak stands affects 24% of the trees, though the investigations on oak wood rings made at the Lithuanian Forest Research Institute did not reveal any significant increment changes. Greater defoliation is observed in older stands and it represents about 17% of the total area occupied by pedunculate oak stands. Young stands (about 16% of total) are to a large extent damaged by deer. Wood rot fungi (*Phelinus robustus* and *Laetiporus sulphureus*) heavily infect older trees on a large scale. In some cases very old trees have survived. One of the oldest pedunculate oaks in Europe (approximately 3500 years old) grows in the eastern part of Lithuania. Over 100 *Q. robur* trees are included in the list of nature conservation units. In spite of the small percentage of pedunculate oak stands in Lithuania, it is the 'national tree' and is mentioned very often in the national folklore.

Research activities and capacities related to genetic resources/diversity

Research on pedunculate oak stands in Lithuania was mostly related to typology and ecology studies (Lukinas 1956). For conservation of genetic diversity and tree breeding purposes an open-pollinated progeny test (>100 families from 10 populations) was established in 1996. The network of pedunculate oak experimental plantations will be established in 1999.

Protected stands represent 1.7% of the total pedunculate oak area (Table 1, Fig. 1). It is the highest proportion of all forest tree species.

Scientific research on pedunculate oak genetic resources is funded directly by the State and by forest enterprises through the Department of Forestry of the Ministry of Agriculture and Forestry. Forest enterprises realize the need for implementing the results of research in the forestry practice. A State programme for oak restoration in Lithuania is in preparation at the Forest Research Institute. Part of this programme deals with gene conservation. The programme plans to increase the area of oak stands by almost three times, up to 90 000 ha, by using reproductive material from the best selected stands and bred material.

In 1993-95 the Lithuanian Forest Research Institute carried out a complex study on the state of oak stands. The monograph on regeneration and conservation of oak stands in Lithuania is in press. The long-term research project on conservation of plant genetic resources will be initiated next year. This project will include genetic studies of oak and development of a programme for dynamic gene conservation in accordance with the MPBS (multiple population breeding system) concept.

Table 1. Breeding and conservation units of *Quercus robur* L. in Lithuania

Forest ecoclimatic region	No. of plus trees	Gene reserves		Seed reserves		Seed orchards		Total oak stand
		No.	ha	No.	ha	No.	ha	Area (ha)
I	3	1	54.6	1	8.6	–	–	5239.6
IIA	20	13	203.6	2	11.2	–	–	5429.9
IIB	–	3	17.7	3	17.5	–	–	2942.7
III	7	9	43.2	3	3.6	–	–	6485.8
IVA	35	6	93.4	2	20.7	1	1.2	10617.2
IVB	–	–	–	–	–	–	–	1057.8
Total	65	32	412.5	11	61.6	1	1.2	31773.0

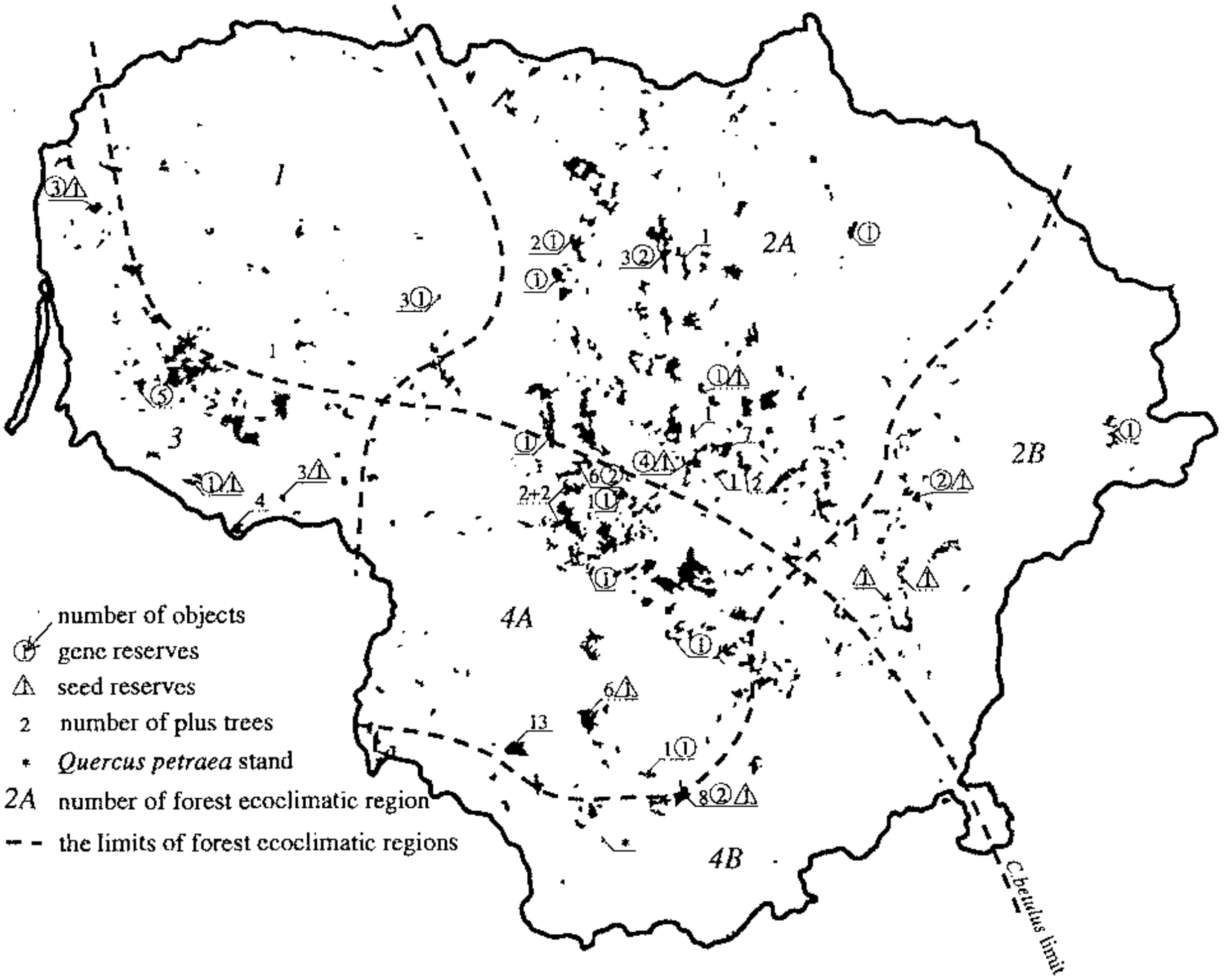

Fig. 1. Stands of *Quercus robur* and mixed stands with more than 10% proportion of *Q. robur* in stand composition in Lithuania.

Relevant nature protection policies and activities

The Forest Research Institute is involved in the joint project 'Resources of Domesticated Plants' which includes research on forest genetic resources and has been carried out since 1994. The 'Lithuanian Open State Science and Study Fund' supports this programme related to the utilization of forest genetic resources. Neither national nor international oak genetic resources committee has been established. The Department of Forestry of the Ministry of Agriculture and Forestry has appointed a coordinator for international relations in the area of forest genetic resources. There are no specialized laws for the conservation of forest genetic resources; however, they are protected at Ministry level. The Law on Protected Territories, the Forest Law, the Law on Wild Plants still do not recognize the importance of gene diversity and conservation. The catalogue of Lithuanian forest genetic resources is prepared at the Lithuanian Forest Institute. These are registered in the National Register of Forest Genetic Resources at the Lithuanian Forest Tree Breeding and Seed Management Center. All data are compiled and continuously updated in databases. A genebank was recently established at the Agricultural Institute in Dotnuva.

The state programme 'Lithuanian Forestry and Timber Industry Development' was approved in 1996 for the period until 2003. The 'Conception and Programme for Protection of Biodiversity in the Forests' is under preparation by the Lithuanian Forest Research Institute. The 'Conceptional Program for Forest Regeneration', approved in 1994, will last until 2010. It includes the perspective development of a basis for genetic diversity conservation.

The Convention of Biologcal Diversity from Rio de Janeiro was ratified in 1995.

Forest gene conservation units are partly covered by the following categories in the Forest Law: strict reserves, reserves, protected landscape units. The definition of reserves includes location for botanical reserves in which forest resources are also mentioned. However, in general, these types of reserves are aimed at conserving the plants or mushrooms and their biotopes, but not the genetic diversity. The State has exclusive property rights on the selected genetic resources.

The Forest Research Institute approves the gene reserves and the Ministry of Agriculture and Forestry funds the work undertaken for the selection of genetically valuable units.

Institutions involved in genetic resources activities in Lithuania

Three institutions collaborate closely in national forest genetic resources activities:

- The **Department of Forest Genetics and Reforestation** of the Lithuanian Forest Research Institute carries out genetic studies, develops programmes and recommendations for selection, conservation and utilization of the forest genetic resources, forest tree breeding, creates PC databases on forest genetic resources. The department carries out the selection and designation of gene conservation units, updates and maintains the databases.
- The **Lithuanian Forest Tree Breeding and Seed Management Center** is responsible for the Lithuanian forest genetic resources. The Center carries out the inventory and designation of *in situ* genetic resources, provides periodic inventory of the gene conservation units, controls their utilization, manages the documentation, compiles the data in databases. The Center also carries out forest tree breeding, guides the establishment of second-stage seed orchards, grows seedlings and graftings for seed orchards, supplies the forest enterprises with improved seed and planting material, and is responsible for the trade of seeds inside and outside Lithuania.
- The **Forest Seed Control Station** controls the utilization of forest genetic resources, the origin of seed and planting material, seed transfer, seed collecting, processing and storage, seed quality and trade. The system for the documentation of forest reproductive material is based on OECD standards.

International collaboration

The Lithuanian Oak Society was established in 1992 in collaboration with Swedish colleagues. The agreement on oak diversity conservation signed by the Polish Forest Research Institute and the Lithuanian Forest Research Institute in 1996 will help in the exchange of material and information, and also deals with pedunculate oak genetic conservation. The most common needs are:

- collaboration in joint research projects with technical support or assistance from other countries
- exchange of information with relevant institutions of European countries and international organizations
- development of appropriate policy related to forest genetic resources and use of effective models for its implementation.

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Oak and beech resources in Latvia

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Occurrence and origin of oak and beech in Latvia

The share of boreal coniferous species (Scots pine and Norway spruce) in Latvia is 60.5% of the total forest area. The remaining 39.5% is covered by broadleaved forests.

Native silver birch, downy birch, common alder, grey alder, aspen, rowan, willow species and bird cherry are typical boreal species and are situated in the optimum of their natural distribution range.

Other indigenous broadleaved species – pedunculate oak, ash, small-leaved lime, Norway maple, wych elm, European white elm, European hornbeam and white poplar – are or could be referred to as temperate forest species. Latvia is at the northern limit of the species' natural range; therefore the occurrence of these species is scattered and fragmented.

Pedunculate oak (Quercus robur *L.*)

Forests with oak as the dominant species cover about 10 000 ha or 0.35% of Latvia's 2.882 million ha forest area. According to inventory data, the area of forest stands with oak as admixed species is about 157 700 ha or 5% of the total forest area. The growing stock of oak is estimated at 7.36 million m^3 (1.5% of the total 500 million m^3 growing stock).

In spite of its insignificant share in the country's economy, oak in Latvia is regarded as a national symbol. For this reason, single trees are maintained as landscape elements and left untouched in clear-cutting areas.

Historically, oak was much more widely distributed over the Baltic region. The main decline of oak forests was related to the development of agriculture, when the most fertile forest areas were felled, and with the shipbuilding in the Russian Empire at the beginning of the 18th century.

Over the past 50 years forestry in Latvia was mainly oriented toward native coniferous species. Broadleaves (including oak) were neglected. As a result the proportion of young oak stands is less than 5% (Fig. 1).

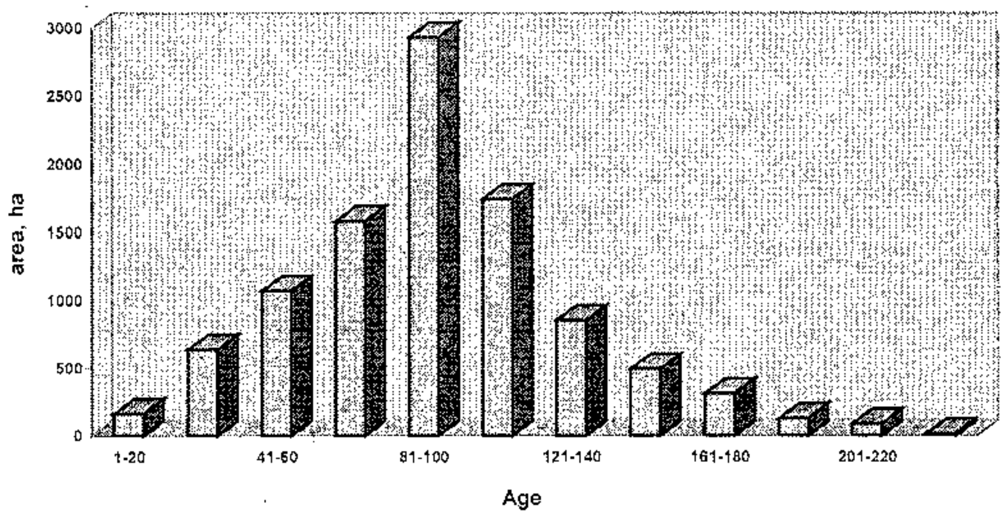

Fig. 1. Age structure of oak forests in Latvia.

The uneven distribution of oak forests does not seem to be linked with definite climatic conditions or agroclimatic zones (see Fig. 2). Few forest districts where oak stands are more than 1% can be found.

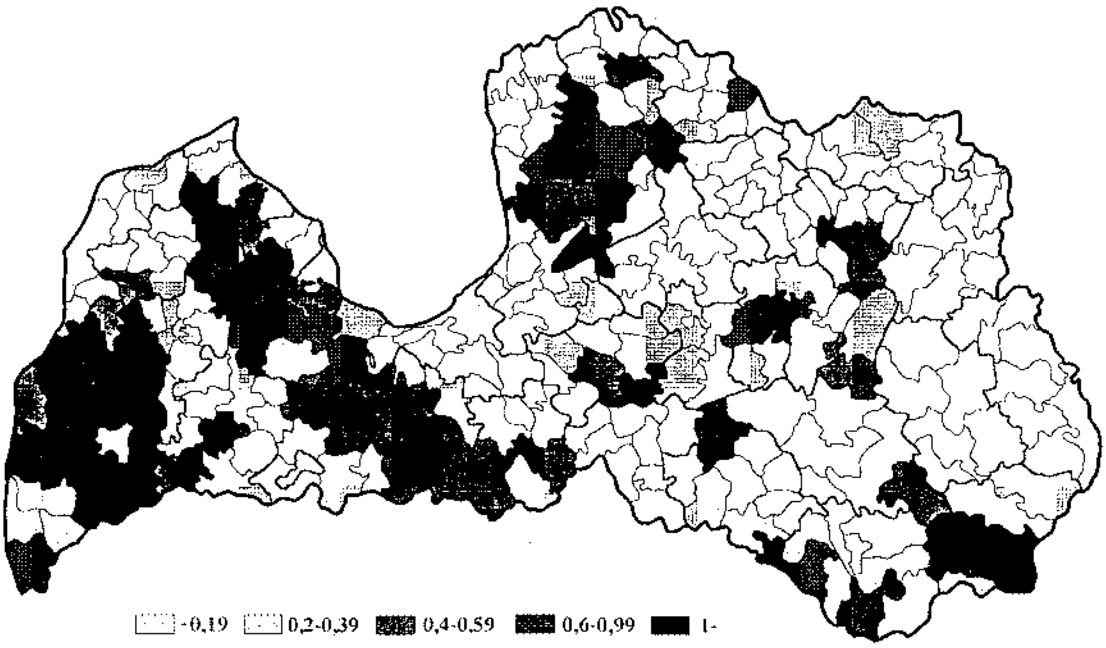

Fig. 2. Distribution of oak forests in Latvia (percentage of total oak area).

Sessile oak **(Quercus petraea *(Matt.) Liebl.*)**

Quercus petraea is an exotic species introduced from unknown origins, represented in separate forest parks mostly in the western part of Latvia. The latest introductions, in the past 15 years (Arboretum of the Forest Research Station 'Kalsnava'), originate from Lithuania, Kaliningrad Oblast (Russian Federation) and the Ukraine.

Beech **(Fagus sylvatica *L.*)**

Introduction of *Fagus sylvatica* started in the middle of the 19th century, from unknown origin(s). The first beech stands were established in 1885 in western Latvia. A quite severe climate and temperature extremes (down to –45°C) prevented beech introduction in eastern Latvia. At present beech plantations are located only in the west.

The total area covered by pure or mixed beech stands is 210 ha (the age distribution is presented in Fig. 3). Recent studies showed that cultivation of beech was successful. It is possible to obtain high-quality timber. The following example can be mentioned: within one small stand at the age of 101 years, the average tree height was 36 m, DBH 36 cm, stem volume 1.63 m^3 and the mean growing stock 867 m^3/ha.

The older stands produce quite viable seed (24-81%) in different seed years. It seems that young stands mostly appear from natural regeneration around the older ones.

Besides beech plantations in the forest, single trees were planted in parks, represented by different ornamental forms. The most common are *Fagus sylvatica* 'Pendula', 'Laciniata', 'Purpurea' and 'Tricolor'.

According to the data of the National Botanical Garden, separate beech trees and their ornamental forms are registered in more than 100 parks.

Other species include *Fagus orientalis* L. (a few trees in the National Botanical Garden) and *F. grandifolia* (represented in Latvia only by one tree in the Skriveri Arboretum).

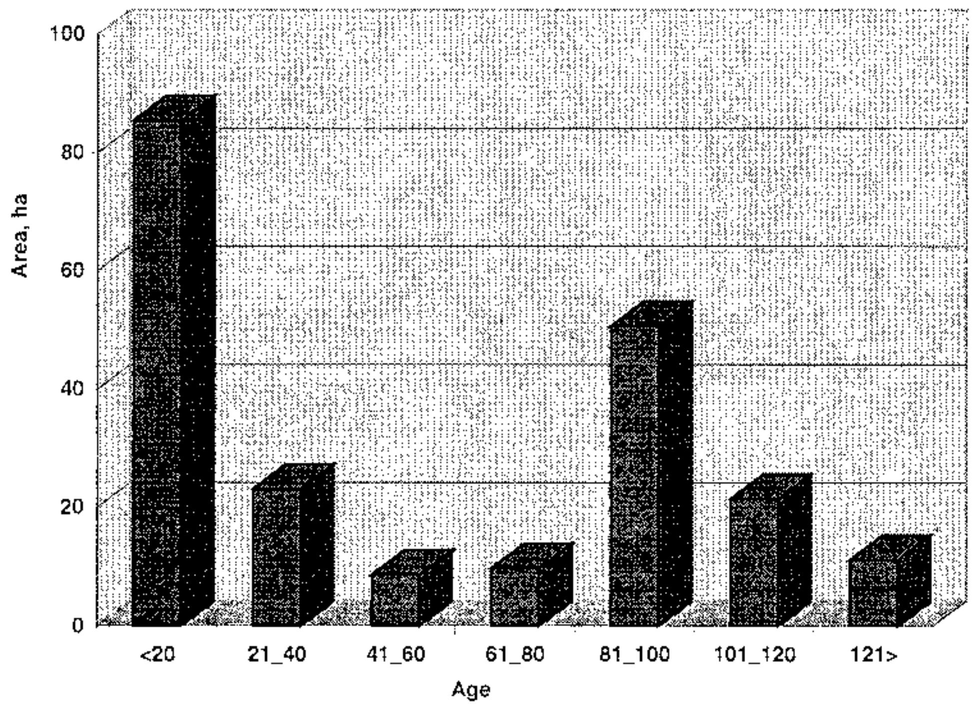

Fig. 3. Age structure of beech forests in Latvia.

Current economic importance

Oak

As already mentioned, the current economic role of oak is insignificant because of its scarce distribution and national traditions to maintain single trees after felling.

At the same time it should be mentioned that the importance of oak could significantly increase in the private forestry sector and be used for forthcoming afforestations. Therefore it was expected that the share of oak stands in the future would increase up to 200 000-250 000 ha (i.e. 7-9% of the total forest area)

Beech

Beech would be successfully used as a commercial species in the western part of Latvia by using the locally adapted seed material, after obtaining knowledge about the genetic structure of first beech introductions, and studying the possibilities of new introductions.

Silvicultural approaches

Oak

According to the latest observations, the old stands (120-250 years) are mainly regenerated naturally. Starting from the end of the 19th century artificial plantations were established, frequently with reproductive material of unknown origin. At present we can find very few successful plantations with good productivity at the age of 100 years and more.

Normally oak on fertile soil forms mixed stands with aspen, Norway spruce, ash, lime tree, grey and common alders and maple, on less fertile soil with birch and Scots pine.

Over the past 50 years forestry in Latvia was mainly oriented toward native coniferous species. Broadleaves (including oak) were neglected. The area of annual oak reforestation is shown in Figure 4. The survival rate in these reforested areas is about 10-15%.

As a result today we have little knowledge about appropriate oak regeneration, afforestation and silvicultural methods.

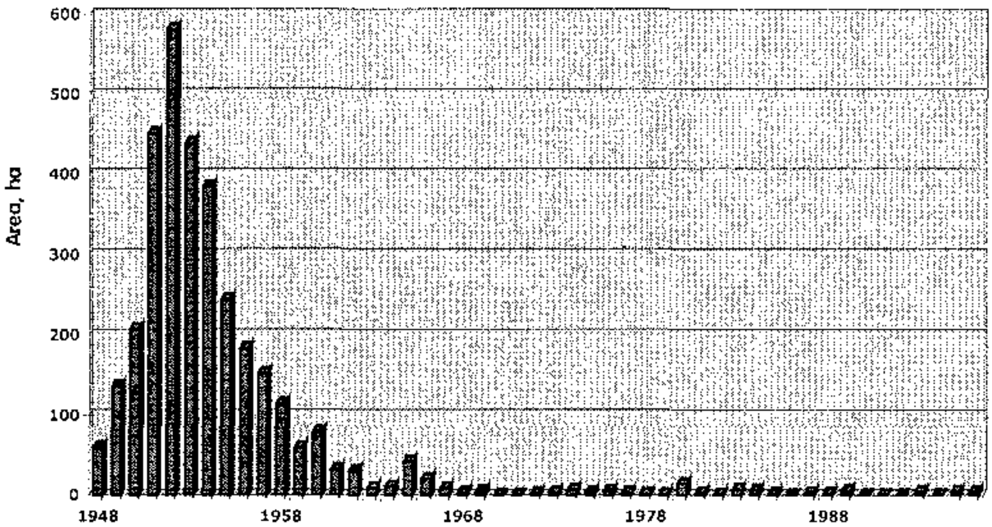

Fig. 4. Area of oak regeneration, 1948-88.

Beech

No appropriate programme has been developed yet. It was suggested that after the provenance trials (including the relevant provenances from Europe) have been evaluated, it would be reasonable to include beech in common silvicultural practice, mainly in the western part of Latvia.

Health state of the oak stands and threats to their genetic diversity

The mentioned diseases do not cause significant threats to genetic diversity of oak forests in Latvia. Decline of pedunculate oak stands has become a serious problem since the early 1980s. The typical symptoms are as follows: yellowing of leaves, thinning of crown, dying of branches, numerous water sprouts, necrotic patches in bark and phloem, discolouration of sapwood, loosening of bark, root deformation, dying of the thin roots. The frequency of these symptoms and fungi present in the necrotic tissues has not been investigated in Latvia. Investigations on oak decline in Europe have led to the hypothesis that a combination of unfavourable weather conditions (drought, very wet spring and dry summer, low temperature affecting overground parts of trees), unfavourable soil conditions (especially too much or too little water) and repeated defoliation by insects has weakened oaks to such a degree that they can easily be invaded by fungi. It may be supposed that the fungi are not the primary cause of the symptoms of oak decline. *Microsphaera alphitoides* Griff et Maubl. (powdery mildew), *Armillaria* spp. (root pathogen) and fungi of the genus *Ceratocystis* are most frequently reported in connection with oak decline, although no causal relationship has yet been established between the presence of *Ceratocystis* spp. or *Ophiostoma* spp. and the intensity of decline.

Wild game cause damage in young oak plantations or naturally regenerated stands.

The different degree of frost damage in oak stands could be related to origin. At the same time it should be mentioned that up to now we have no information about the possible sources of introduced oak, nor on the degree of pollution of the local genepool with allochthonous origins.

Research activities

Three research projects on broadleaves were started in recent years. Their main objectives are:

- Inventory of all Latvian forests (including oak) with the aim to:
  - select seed stands
  - establish gene reserve forests
  - study the genetic structure of species.
- Collection of seed material from selected stands.
- Growing of planting material for provenance (population) trials and progeny tests.

A first provenance trial was established in 1996, where eight local oak stands are represented at two locations.

Further provenance trials will be established in spring 1998 at three locations with 18 local stands represented.

The genetic structure should be studied with molecular markers to determine the effective size of *in situ* conservation stands, genetic reserves and *ex situ* collections.

Current oak genetic conservation activities

In situ *conservation*

- Since 1986:
  Cesvaine district forest – 60.3 ha
  Gauja National Park – 65 ha
- Newly approved (1997):
  Aizpute district forest (Apriki) – 322 ha
- Combined with tree improvement programmes:
  Seed stands – 15 stands, 72 ha

Ex situ *conservation*

- Seed orchards: 1 ha (1972)
- Clonal archive of Apriki genetic reserve.

Relevant nature conservation activities

In addition to genetic conservation and according to traditions since 1924, about 800 old 'noble oaks' with DBH>1.3 m were registered and maintained throughout the country. The age of these trees is about 300-1500 years. This activity, performed by the National Botanical Garden, is to be continued.

Genetic conservation is provided by protected forests:

- in nature reserves,
- in specially protected forest compartments,
- in 600 protected old parks or forest parks (oaks were mainly introduced in these locations) – total area about 2200 ha.

Tree-improvement activities

Oak

Tree-improvement activities are aimed at:

- the establishment of seed sources/seed orchards for each agroclimatic region
- ensuring improved stem quality and adaptability to changing environment
- the elaboration of appropriate afforestation and silvicultural methods.

For these reasons,

- a seed orchard was established in eastern Latvia (area = 1 ha)
- progeny tests are to be established in spring 1998 (36 open-pollinated families)
- 50 clones were grafted for a new seed orchard in western Latvia
- a new plant growing technology was developed (containers), allowing the accelerated establishment of trials
- selected seed stands include 15 stands, 72 ha.

Beech

A first trial was established in 1997 using 15 local seed sources (both forest stands and old parks).

Use of reproductive material

The use of broadleaves is expected to increase in the future for:

- afforestation needs (according to information from different sources, there are at present in Latvia about 300 000-500 000 ha of abandoned agricultural land)
- increasing the species diversity in the commercial forests.

The technology for container plants was developed during the past 2 years. Container plants will be used for the trials mentioned above.

Institutions involved in genetic resources activities

- Forest Research Institute 'Silava', in close collaboration with:
  - Forest Research Station 'Kalsnava'
  - East Tree breeding and seed procurement centre (within 'Kalsnava')
  - West Tree breeding and seed procurement centre in Kuldiga
  - the National Botanical Garden.

Needs for international collaboration

- European oak provenance trials
- Joint genetic studies of oak and beech
- Technical guidelines for *in situ* and *ex situ* conservation of Social Broadleaves
- Integrated Social Broadleaves databases (genetic resources)
- Improved silvicultural methods (exchange of literature and experience).

Genetic resources of oaks and their conservation in Finland

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Occurrence and origin of oaks in Finland

Forests cover two-thirds, or over 200 000 km^2, of the total area of Finland. There are over 20 indigenous tree species growing in Finland, but only Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and silver birch (*Betula pendula*) are commercially important at the national level. These three species contribute to 96% of the total growing stock of 1886.6 million m^3. In addition a few species, downy birch (*B. pubescens*), Carelian curly birch (*B. pendula* var. *carelica*), Siberian larch (*Larix sibrica*) and aspen (*Populus tremula, P. tremula* × *P. tremuloides*), have some commercial significance in forestry. The most abundant broadleaved tree species (*B. pendula, B. pubescens, P. tremula* and *Alnus* spp.) dominate 8.2% of the forest area, and only 0.1% is dominated by other broadleaved trees. Pedunculate oak (*Quercus robur*) is the main deciduous hardwood species of interest to forestry in Finland. It is also the only native oak.

The natural range of pedunculate oak is narrow and restricted to the southwest corner of the country, but in favourable environments it can successfully grow at least 100 km northward. The present oak populations mainly occur as small patches rather than as large and continuous stands. Beech (*Fagus sylvatica*) does not occur naturally in Finland, and the cultivation attempts have not been successful in the mainland, but it might be grown on the island of Ahvenanmaa.

With the exception of a few arctic plants, species have migrated to Finland during the 10 000 years after the latest glaciation. Hardwoods such as oak migrated about 9000 years ago mainly from the east, but also across the Gulf of Finland, and later on from the west. During the warm and humid Atlantic period 7500-4500 years ago their distribution was largest and extended about 400 km further north. The following slow cooling of the climate favoured Norway spruce, which spread vigorously from the east, whereas hardwoods withdrew to the south. More recently the demand for agricultural land has resulted in the fragmentation of these previously continuous forests. Oak was also used extensively for shipbuilding, and in the 18-19th centuries oak trees had a special status, belonging to the Crown. This resulted in the destruction of oak in certain areas as Finnish landowners drowned their oak logs in the sea rather than hand them over to the Crown. During the last few decades forest management practices were unfavourable to oak as well, as many suitable sites were turned into pure spruce plantations.

Importance for the forestry sector

Broadleaves in general are of minor importance for forestry in Finland. Statistics are available for birch, occasionally also for aspen and alder, whereas all other broadleaves are grouped together. In 1994 the share of broadleaved trees other than birch in the growing stock was 3.1%. Broadleaves are annually planted on about 500 ha while the yearly regeneration areas amount to 180 000 ha. Annually 150-180 million seedlings are delivered from about 30 central nurseries (88%) and 70 smaller family-owned nurseries (12%). The quality of nursery seedlings in Finland is supervised by the Ministry of Agriculture and Forestry in accordance with the Forest Reproductive Material Act of 1979 and the related Decision of 1992 (No. 1533/92).

Recent changes in Finnish forestry policies have increased the interest for growing hardwoods; especially alder (*Alnus glutinosa*) and pedunculate oak have been suggested as alternatives to conifers and birch in afforestations. The interest arises rather from the will to protect the cultural landscape than from forestry. These species have for centuries been an essential part of the landscape in southwestern Finland, but in some cases all afforestation plans have caused local conflicts: open fields are considered at least as important for the maintenance of the cultural landscape.

Valkonen *et al.* (1995) made an inventory of cultivated stands in Finland. The present natural and artificial oak stands are largely of too inferior quality to be of interest for the industry, e.g. owing to stem defects. Moreover, the present resources without protection mesures correspond to only a few year's use. The higher costs (e.g. growing tubes and/or fencing to protect from vole, hare and moose) and labour-intensive management required for producing high-quality timber makes the profitability of oak growing difficult to predict.

The wood of oak and beech is valued in traditional carpentry, and oak is also used for several special purposes. Louna and Valkonen (1995) made an inventory of the role of Finnish raw material in the industrial use of broadleaves. The value of the import of Noble Hardwoods[1] timber in 1993 was 150 million FIM, of which the value of oak and beech import were 56 and 51 million FIM, respectively. Oak is mainly imported from other European countries (*Q. robur, Q. petraea*), Canada, the USA (*Q. alba, Q. rubra*) and China (*Q. mongolica*). There are no commercial beech plantations in Finland, and all beech wood is imported. The Finnish resources of oak wood are of very limited local importance: less than 100 m^3 of Finnish oak wood is yearly on the market, whereas in 1993 the total oak wood use was 26 400 m^3.

Oak, ash and maple have a well-established, rather stable market share in traditional carpentry, and beech is largely used as an alternative for oak. In 1993, 11.7% of all parquets were made of oak, covering 75% of the total oak wood consumption. Beech was used for 9.4% of all parquet production. Oak is also used for several small-scale purposes, e.g. for constructing boats and parts of musical instruments.

Selected seed sources

Three oak seed collection stands have been selected, and the total number of seed collection trees is about 250. New selection is under way as additional natural or artificial stands with good quality for seed sources are needed. So far the only oak seed orchard was established by the Forest and Park Service in 1978 with 279 grafts from 24 clones. In 1995 the first seed crop was collected, but the material was not used for forest regeneration because of the low number of flowering clones.

Conservation

The important role of Noble Hardwoods including oak and beech for the conservation of biodiversity in general has been widely acknowledged in Finland, and various programmes emphasize the importance of diversity at the genetic level. Pedunculate oak is not threatened as a species in Finland, but the populations are susceptible to increasing fragmentation by road construction and enlargements of settlements. Most of the natural oak stands are protected. Genetic conservation, however, may have special needs that are not met by strict habitat conservation. Many oak stands would benefit from light management to promote natural regeneration. On the other hand, many of the stands are fairly small and isolated, and thus inbreeding and genetic erosion may play a role in them. Conservation practices should take into account the underlying genetic constitution of the stands and more knowledge, especially on the structure of small and isolated populations, is needed. Results of the population genetic research suggest that the differentiation among populations at neutral markers is more pronounced in oak than in the more common tree species (Mattila *et al.* 1994; Mattila and Vakkari 1996).

The general *in situ* gene reserve forest programme was started in 1992, and four Noble Hardwoods stands are included in the total of 33 stands (by the Finnish Forest Research Institute (FFRI), see Rusanen 1996). So far there are no gene reserve forests for pedunculate oak. For the main tree species the minimum area of a gene reserve forest is 100 ha, and silvicultural measures such as thinning and harvesting are allowed. However, for the conservation of Noble Hardwoods the gene reserve forest system is only seldom applicable. Most of the valuable stands are included in various forest protection programmes, which

[1] Noble Hardwoods as defined in Finnish forestry include oak and beech (see Rusanen 1996).

prevents the active measures used in gene reserve forests and required for gene conservation (such as collecting of seeds). Also the minimum target area of the main tree species can seldom, if ever, be met in Noble Hardwoods stands. There is only one large oak stand in Finland (Ruissalo, Turku), where oak dominates on 90 ha, of which 50 ha is pure oak; all other oak stands are significantly smaller.

The main approach to the conservation of the genetic resources of oak, and other Noble Hardwoods, will be in *ex situ* collections. The operational *ex situ* plan for oak (by FFRI) has been developed. The first seed collections were made in 1995, land areas have been chosen and their preparation is in progress. In the future these collections may also serve in the production of forest reproductive material.

Breeding and research

There is no intensive breeding programme for pedunculate oak in Finland. Three progeny tests were established in 1985-93 (in total 4150 individuals, by FFRI), and in 1995 a joint research project on oak cultivation practices (by S. Valkonen, FFRI: sowing/planting, individually/in groups, growing tubes/no tubes) and on the distribution of quantitative and adaptive genetic variation in Finnish oak stands was started. Five progeny trials will be established in 1998 by the Foundation for Forest Tree Breeding (FFTB).

A common research project on the genetic structures of Noble Hardwoods was started in 1994 by the FFTB and the FFRI. The results will give some insight into the genetic processes in fragmented populations, and thus help to make operative plans for genetic conservation, but they will also be helpful in giving recommendations for the selection of seed sources for forest regeneration. Estimates of the level and distribution of neutral genetic variation are assessed by isoenzymes in pedunculate oak, Norway maple (*Acer platanoides*) and European white elm (*Ulmus laevis*). The first results support the hypothesis that the population structure of rare species with a scattered distribution is different from that of the main tree species (Mattila *et al.* 1994; Mattila and Vakkari 1996). A new joint project, financed by the Academy of Finland and based on the isoenzyme work, was started in 1997 to acquire knowledge on the genetic processes (family structures, pollen migration, etc.) in oak and maple populations by microsatellite markers.

To elucidate the colonization history of oak in Finland R. Väinölä (Univ. of Helsinki) used chloroplast DNA (cpDNA) markers (in collaboration with C. Ferris *et al.*, Leicester Univ., UK).

The rate and potential for pollen migration between oak stands was evaluated in 1995 by direct measurements on the concentration of airborne oak pollen within and outside the largest oak stand in Finland. There was a significant decrease in the concentration of oak pollen in the air at a short distance from the pollen source (Lahtinen *et al.* 1996).

Differences between species in the onset of the hardening process and in maximum frost tolerance as measured by, e.g. differential thermal analysis, differential scanning calorimetry and magnetic resonance imaging, will be examined by T. Repo (Univ. of Joensuu). The project started in 1997; the species involved are pedunculate oak, Norway maple, wych elm (*Ulmus glabra*) and birch.

Public awareness

Forests are an important element in the daily life of virtually every Finn. In Finland one-third of the forests is owned by the state, less than 10% by companies and about 55% by private persons. The number of private forest holdings is 439 000, with an average size of 28 ha of forest land. Forests are open for everybody's unrestricted recreation use based on public rights.

The predicted climate change has also increased the interest in Noble Hardwoods (including oak and beech) as the warming of the climate might make their cultivation north of their present natural distribution possible. The forests are also subject of public debate, with topics ranging from conservation to economic aspects of forests and timber production.

As nature conservation has become popular and acceptable within the last decade, it has inevitably resulted in changes within the forestry sector. In the 1990s, forestry has increasingly emphasized the importance of forest ecology and the promotion of multiple use of forests, and both nature conservation and forest legislation have been revised (Nature Conservation Act 1096/96, Forestry Act 1093/96).

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Social Broadleaves in Sweden

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None of the Social Broadleaves occurring in Sweden (*Quercus robur*, *Quercus petraea* and *Fagus sylvatica*) reaches the boreal zone, approximately delimited by latitude 60°N. These species altogether make up less than 2% of the growing stock of forests in Sweden, predominantly composed of Scots pine and Norway spruce.

The regeneration methods used are planting in the case of oak and natural regeneration for beech. The planting stock for oak is to a large extent imported because relatively small quantities are required by users. Plantations of oak have to be protected from browsing by wild game. The health status of these species is considered good despite some indications of recent decline due to air pollution and climatic factors. These are currently under study.

Organizations involved in research and gene conservation activities on Social Broadleaves are the Swedish University of Agricultural Sciences (SLU), the Forestry Research Institute and the National Board of Forestry. Research activities on silviculture take place at SLU's southern research locality of Alnarp. Genetics is studied at SLU in Uppsala. The Swedish Forestry Research Institute (SkogForsk) maintains provenance trials for beech and breeding activities.

The Swedish Forest Gene Conservation Programme conducted by the National Board of Forestry comprises conservation activities for oak. Six gene conservation archives were established in 1995 (Fig. 1). They consist of a total of 20 000 seedlings from 513 families of autochthonous origin. It would be desirable to perform cpDNA (chloroplast DNA) analyses on this material.

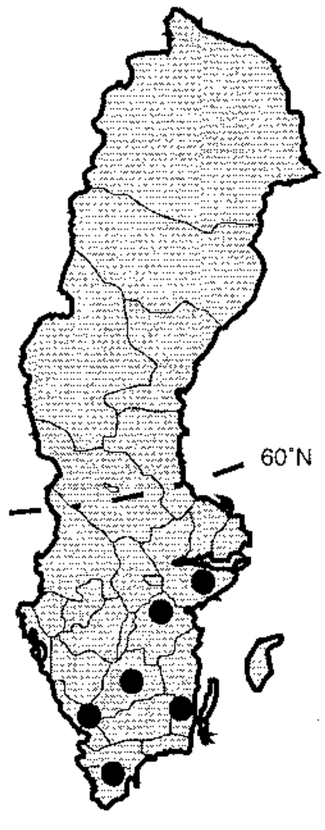

Fig. 1. Six gene conservation archives.

The genetic resources used for forest regeneration represent 115 selected seed stands of *Quercus robur* and 17 selected seed stands of *Quercus petraea*. Two seed orchards of oak are being tested. Nature protection activities concentrate on 5500 ha of hardwood forest (mainly oak and beech) in the three southern provinces of Sweden.

Sweden is very interested in the international collaboration concerning genetic resources of Social Broadleaves. As it is on the northern fringe of the species' distribution areas, the country can contribute to comprehensive studies and conservation efforts extending over the entire geographic range.

Overview Presentations

Structure of gene diversity, geneflow and gene conservation in *Quercus petraea*

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Abstract
A review of the genetic diversity of *Quercus petraea* (sessile oak) for gene markers and adaptive traits is presented. Remarkable range-wide trends of variation exist in sessile oak for all traits investigated and for the corresponding measures of diversity. We illustrate these trends for isoenzyme and quantitative trait data (bud burst and height growth assessed in a provenance test). A comparison with cpDNA (chloroplast DNA) information, which had been shown to closely reflect postglacial recolonization routes, allows testing to determine whether these general genetic trends were established during or after recolonization, or more recently, as a consequence of isolation-by-distance or adaptation to local environments. Results obtained so far indicate that contrasting trends can be observed. For example within-population diversity for bud burst follows a longitudinal pattern of variation, whereas population differences for the same trait follow a latitudinal pattern of variation. The situation is even more complex when different traits are compared. A general conclusion is that, although the geographic structure of diversity is quite strong, there is no constant trend across traits that would allow sampling of specific populations for *in situ* conservation. The review extends to investigations on inter- and intraspecific geneflow in *Q. petraea*. It is shown that *Q. petraea* is almost exclusively an outbreeding species, hybridizing in natural populations with *Q. robur*, and most likely hybridizing with other related species. Furthermore experimental results obtained with paternity analysis suggest pollen flow at rather long distances. As a result geneflow through pollen is considered a major mechanism for conserving diversity. Because of the contradictory conclusions that may be drawn depending on the traits considered, the geographic structure of diversity or differentiation would not be recommended as relevant criteria for *in situ* conservation decisions. Rather, methods conserving mechanisms contributing to the maintenance or increase of diversity as inter- and intraspecific geneflow are considered of primary importance for *in situ* conservation decisions.

Introduction

Gene conservation decisions rely on scientific and socioeconomic criteria. For the scientific community, the challenge is to provide policy-makers with relevant information on the potential of a species to adjust to future predictable or unpredictable ecological conditions. This task requires an inventory of the existing genetic diversity and insights in its future dynamics. In the case of *Quercus petraea* (sessile oak), a major component of European forests, our aim in this contribution is to update the current knowledge of the distribution and organization of genetic diversity at different spatial scales, but also to pinpoint the mechanisms that generate or reduce diversity. In the case of oaks, not only intraspecific geneflow but also interspecific geneflow should be considered as a prevalent force for shaping diversity.

During the past 10 years extensive literature was published on the distribution of genetic diversity in the sessile oak. A common characteristic of these studies was their large sampling of populations covering most of the natural range. Results from studies conducted at range-wide scale clearly indicated clinal trends of variation. Zanetto and Kremer (1995) showed that most of the allozymes exhibited longitudinal patterns of variation. Similarly Dumolin-Lapègue *et al.* (1997) confirmed earlier observations of Petit *et al.* (1993) that cpDNA polymorphism was strongly differentiated among populations along an east-west gradient. Finally, results from provenance tests showed that bud burst was most likely to follow a latitudinal trend of variation (Ducousso *et al.* 1996). As data on genetic diversity increased, interests in the Quaternary history of oaks was raised as well. Compilations of fossil deposits on a European scale in the form of isopollen maps drawn at different time slices (Huntley and Birks 1983) had revealed that deciduous oaks recolonized Europe from three separate refugia and had occupied most of the extant range about 7000 years ago. The recolonization routes have further been reconstructed with the help of cpDNA polymorphism (Dumolin-Lapègue *et al.* 1997). As a result, today's oak stands may still be considered as 'young' on an evolutionary time scale. This raises the question of whether the origin of the populations, in terms of the glacial refugium they are stemming from, still has an impact on today's distribution of diversity. The alternative hypothesis is that genetic differences between the colonizing populations were erased by extensive pollen flow favoured by the continuous distribution of the sessile oak in Europe. Finally historical impacts and ongoing geneflow may have been rapidly counterbalanced by local selection pressures, especially for phenotypic traits.

In this contribution we attempt to re-analyze some of the data previously published with the aim to depict major trends of variation for different criteria relevant to the structure of genetic diversity: the level of within-population diversity and the differentiation among populations. We will particularly compare results of genetic markers, assumed to be neutral, with those of phenotypic traits assumed to be adaptive, by computing parameters making comparisons possible. Because oaks are species for which the recent Quaternary history is now well understood, we will address the issue of the potential historical impacts on the structure of diversity. Finally inter- and intraspecific geneflow will receive particular attention as key mechanisms for future evolution of gene diversity.

Geographic structure of within-population diversity

The data set for the geographic structure of diversity and variability

One hundred populations sampled throughout the natural range of the species were collected. Harvests were made as bulk collection on a surface varying between 10 and 20 ha (Zanetto and Kremer 1995; Le Corre *et al.* 1998a). The seeds were then distributed for different analyses:

- Assessment of allozyme diversity on 13 isoenzyme loci (Zanetto and Kremer 1995), with a sample size of 120 seeds per population.
- Installation of a provenance test comprising a subset of 69 provenances among the 100 collected. The provenance test is located in the Northwest of France (Petite Charnie forest) according to a complete block design comprising 10 repetitions with a plot size of 24 trees (Ducousso *et al.* 1996). Total height was measured at age 7 (4 years after plantation) and bud burst was assessed at age 6 according to a grading system varying from 0 (dormant bud) to 5 (elongating flush).
- Assessment of cpDNA diversity on the basis of 5 sampled trees per provenance. Protocols for the cpDNA survey are given in Dumolin-Lapègue *et al.* (1997).

Geographic trends of within-population diversity

For allozymes, within-population diversity was estimated by calculating the mean number of alleles per locus (*A*) and Nei's mean gene diversity (*H*) (Nei 1987), which is equivalent to the expected heterozygosity per population. For phenotypic traits, levels of within-population genetic variability were estimated by computing the coefficient variation of additive genetic values (CV_A, Kremer 1981; Houle 1989). The CV_A values were obtained by assuming that heritability (h^2) was of similar magnitude in all populations:

$$CV_A = \frac{\sqrt{h^2 V_{Ph}}}{X}$$

where CV_A, V_{Ph} and X are the coefficients of genetic variation, the phenotypic variance and the mean value of the phenotypic character in a given population, respectively.

Heritability values of the two phenotypic traits were considered to be 0.10 for height growth and 0.30 for bud burst. These values were chosen from the review on heritability values in forest trees (Cornelius 1994). Because actual values may be different for the two characters than those chosen here, levels of CV_A will not be compared among the two characters, but only between populations for a given trait.

Sessile oak is extremely diverse and variable at a within-population level, as illustrated by several inventories conducted with either gene markers or phenotypic traits. For isoenzymes in this data set, the mean number of alleles per locus averages 2.73, and expected heterozygosities 0.245, which makes *Q. petraea* among the most variable tree species. Additive coefficient of variation amounted to 0.39 (for constant heritabilities of 0.30) and to 0.11 (for constant heritabilities of 0.10). However, in the same time, *Q. petraea* also exhibits an important inbreeding depression (Kleinschmit and Kleinschmit 1996); part of the diversity may therefore be due to the genetic load that exists in oaks. Experimental evidence of genetic load is suggested by segregation distortion that occurs quite often in control crosses of oaks (Müller-Starck *et al.* 1996; Zanetto *et al.* 1996).

To depict the geographic distribution of diversity, correlations between the within-population levels of diversity for phenotypic traits and isoenzymes and three geographical variables (latitude, longitude and altitude) were calculated (Table 1). Six of the 12 correlations are significant, and each of the four measures of diversity is correlated with either latitude or longitude, demonstrating that diversity is always spatially organized in the sessile oak at the studied scale. The following associations are significant:

- bud burst is more variable within population in the western part of the range and at high elevations
- height growth is more variable within population in the south
- the number of alleles per population increases toward the east (Zanetto and Kremer 1995)
- the expected heterozygosity increases toward the west and decreases with altitude (Zanetto and Kremer 1995).

Flowering and fruiting are known to be extremely variable across stands or years. Climatic constraints increase in the eastern part of Europe, where late frosts occur more often and impede regular flowering. One would therefore expect that geneflow among populations might be higher in western than in eastern populations. As a consequence, within-population diversity or variation is likely to be maintained at higher levels in the west than in the east. This could explain why bud burst, for example, exhibits higher CV_A values. Furthermore bud burst is also highly differentiated among populations (see Table 3).

Table 1. Correlation between four genetic diversity measures and geographic data

	CV_A bud burst	CV_A height	Number of alleles	Expected heterozygosity
N	64	65	100	100
Latitude	0.16^{NS}	-0.33^{**}	0.18^{NS}	0.12^{NS}
Longitude	-0.35^{**}	-0.21^{NS}	0.43^{**}	-0.53^{**}
Altitude	0.38^{**}	0.00^{NS}	0.06^{NS}	-0.31^{**}

* = Significant at P=0.05; ** = significant at P=0.01; NS = nonsignificant at P=0.05.
N = number of populations.

Geneflow between highly differentiated populations contributes to maintaining high levels of within-population variation. However geneflow should increase diversity for all traits, including isoenzymes. Our results indicate that allozyme diversity is higher in the east. We would advocate the higher diversity existing in the eastern refugia to interpret the contrasting conclusions between the geneflow hypothesis and the observed data. Another possibility is that the highest within-population diversity of bud burst in the west may be related to a less predictable climate in the spring in this part of the range, and especially the occurrence of late spring frosts that can damage growth of early flushing phenotypes (Ducousso *et al.* 1996). On the contrary, in the east, springs are usually shorter, and diversifying selection may not be so high. The significant relationship of bud burst variability and altitude still need to be explained. Defoliating insects may somehow play a role but this remains to be investigated.

That height growth is more variable in the south may be related with the fact that selection for this trait is relaxed there: this would be the case if not all small individuals were eliminated there. Scattered cases of hybridization with the short-sized pubescent oak (*Quercus pubescens*), which can be found in sympatry with sessile oak in the south, could also account for this pattern.

The causes for the strong longitudinal pattern of measures of diversity based on isoenzymes data have been discussed by Zanetto and Kremer (1995). The opposite trend for the two diversity measures (allelic richness and heterozygosity) is remarkable. Given the rare occurrence of sessile oak in the Iberian peninsula, it is possible that this species was absent or rare there during the last ice age, hence the lower allelic richness in the west. Furthermore, there are many closely related species or subspecies of the sessile oak in the Balkans, but not in western Europe, which may also have contributed to the higher allelic richness in the east. For heterozygosity estimates, it seems difficult to stick to neutral explanations for the trend observed. Interestingly, it appears that the regions displaying the highest heterozygosity correspond to the best growing areas for sessile oak in Europe. It is possible that rare alleles are counterselected in the climacic range of the sessile oak, which is centred to the west of Europe, which would account for the difference of allelic richness but not of heterozygosity. Finally, it should be recalled that for cpDNA, more haplotypes had been detected in the southern part of the range: only a subset of these maternal variants have indeed migrated up to the northern part of the range of the species (Dumolin-Lapègue *et al.* 1997).

Geographic structure of population differentiation

Levels of population differentiation

New methodological tools are now available to compare the subdivision of genetic diversity for molecular markers and quantitative traits. For allozymes, population differentiation was calculated as G_{st} (Nei 1987). It has been shown that when the number of populations is high, then G_{st} becomes very close to Weir and Cockerham's (1984) θ (Chakraborty and Leimar

1987). Population differentiation for phenotypic traits was derived from ANOVA following the method described in Kremer *et al.* (1997) as

$$F_{st} = \frac{V_p}{V_p + 2h^2\overline{V}_{Ph}}$$

where V_p and $\overline{V}_{Ph}$ are the between-population variance and the mean within-population phenotypic variance respectively, assuming that the heritability value was the same for the different populations.

Recent studies (reviewed in Kremer *et al.* 1997; Latta and Mitton 1997) emphasize the considerably higher values of differentiation among population for quantitative traits compared with single locus isoenzyme or DNA markers. In the case of sessile oak, the pattern is similar, with a very low differentiation for isoenzymes (3%) and a much higher differentiation for height and especially bud burst (at least 36%), indicating that selective effects acting on these traits are very high.

Table 2. Comparison of measures of differentiation ($\theta \approx G_{st}$) for isoenzyme and quantitative traits. Measures of differentiation for quantitative traits depend on their heritabilities, which are not available in sessile oak. Several likely values were therefore used.

Trait	Heritability	$\theta = G_{st}$
Isoenzymes (13 loci)	1	0.03
Height	0.05	0.22
	0.10	0.12
	0.15	0.08
	0.20	0.06
Bud burst	0.10	0.69
	0.20	0.53
	0.30	0.43
	0.40	0.36

Geographic trends of variation of population differentiation

The geographic variation of the traits themselves, and not of the related measures of diversities, will now be described, namely the allele frequencies of isoenzyme loci, and the mean of the two studied quantitative traits. The correlation between the mean intra-population values of the two quantitative traits, allele frequencies and three geographical parameters is given in Table 3.

Table 3. Correlation coefficients between population mean values and their geographic data

	Bud burst	Height growth	Frequency of allele 7 Locus *AAP*	Frequency of allele 1 Locus *ACP*
N	64	65	81	81
Latitude	−0.58 **	+0.23 NS	+0.28*	+0.13NS
Longitude	+0.17 NS	−0.35**	+0.32**	−0.29**
Altitude	+0.43**	−0.26*	−0.12NS	−0.34*

* = significant at P=0.05; ** = significant at P=0.01; NS = nonsignificant at P=0.05.
N = number of populations.

The following associations are significant:

- provenances from southern populations flush earlier (Ducousso *et al.* 1996; Deans and Harvey 1996; Stephan *et al.* 1996)
- provenances from higher altitudes flush earlier (Deans and Harvey 1996; Ducousso *et al.* 1996)
- western provenances grow more than eastern populations
- there is a clear east-west trend of variation for allozyme frequencies (Zanetto and Kremer 1995).

For illustration purposes, the maps of the mean score for bud burst, the mean height growth, and the allelic frequencies of allele 7 at the isoenzyme locus *Aap* are provided in Figures 1, 2 and 3.

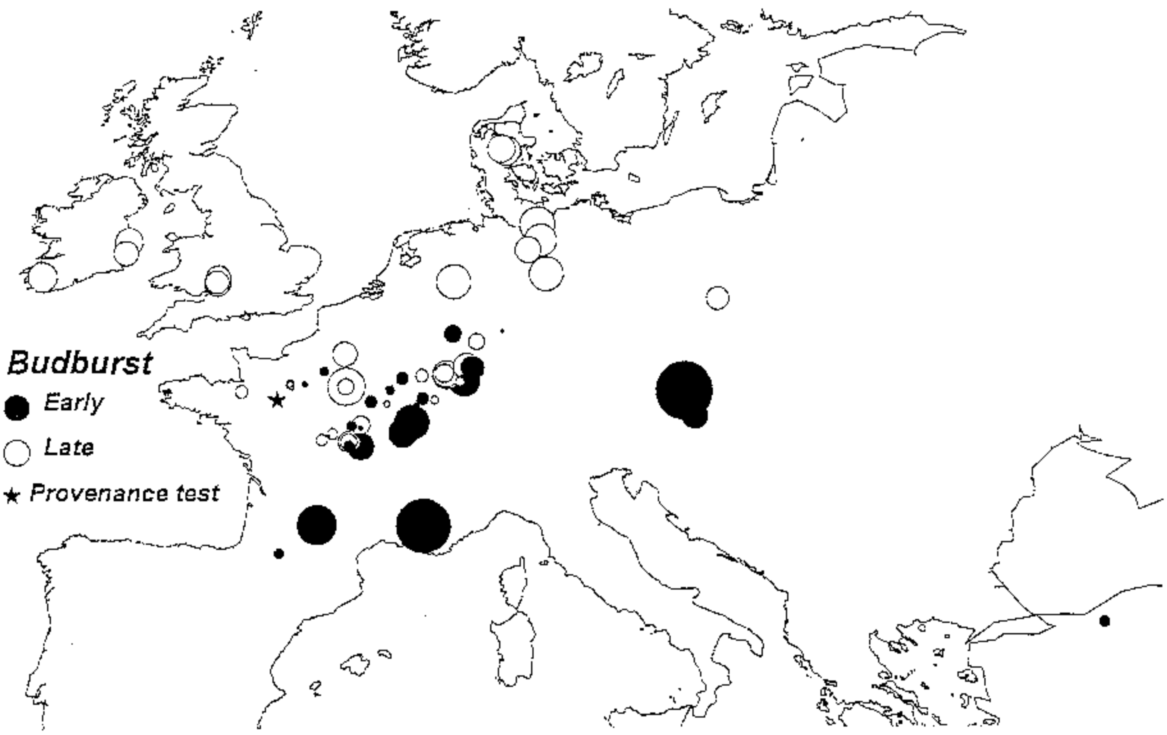

Fig. 1. Mean bud burst score. Values above the overall mean (early flushing individuals) are in black, values below the mean (late-flushing) in white. The larger the circle, the more different is the value from the mean.

A discussion concerning the origin of this trend may be found in Ducousso *et al.* (1996). They likely reflect adaptation to cold and warm conditions and to predators. Southern provenances are flushing earlier than northern as found in three separate studies (Deans and Harvey 1996; Ducousso *et al.* 1996; Stephan *et al.* 1996). However, it is remarkable that this extremely clear-cut latitudinal trend is the opposite to that documented for northern red oak and for most tree species, including conifers, where late-flushing individuals are typically found in the south.

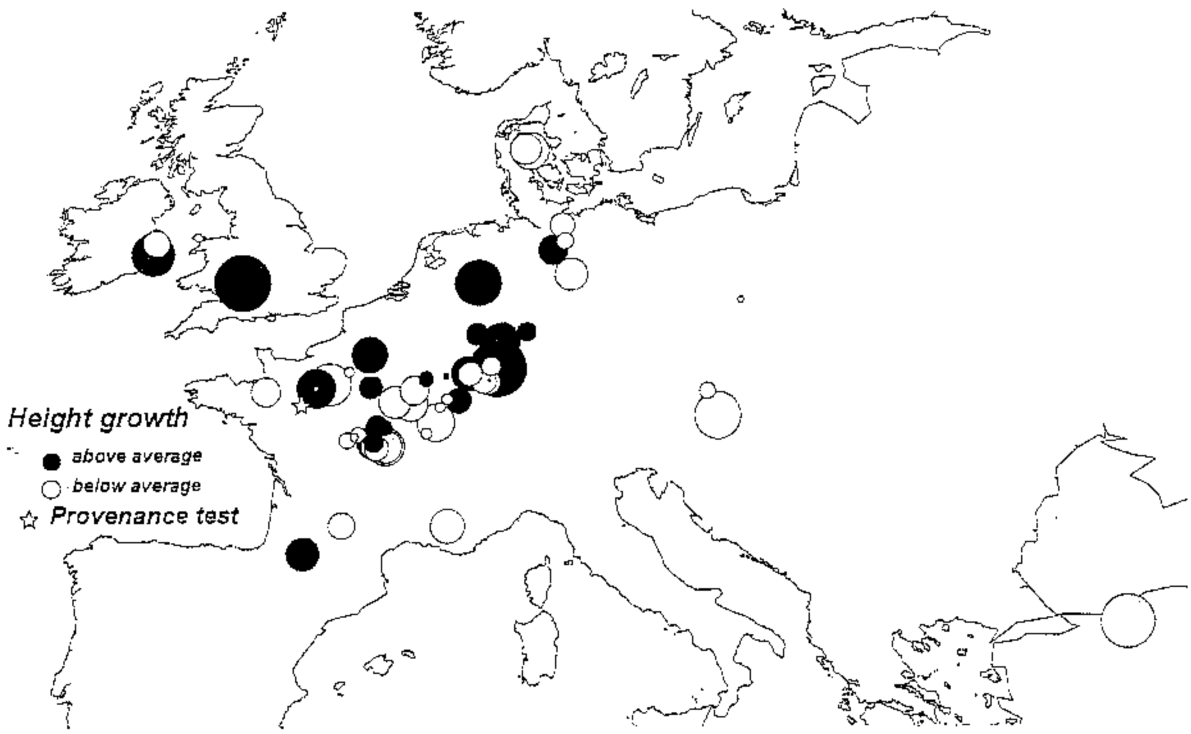

Fig. 2. Mean height growth. Values above the overall mean are in black, values below the mean in white. The larger the circle, the more different is the value from the mean.

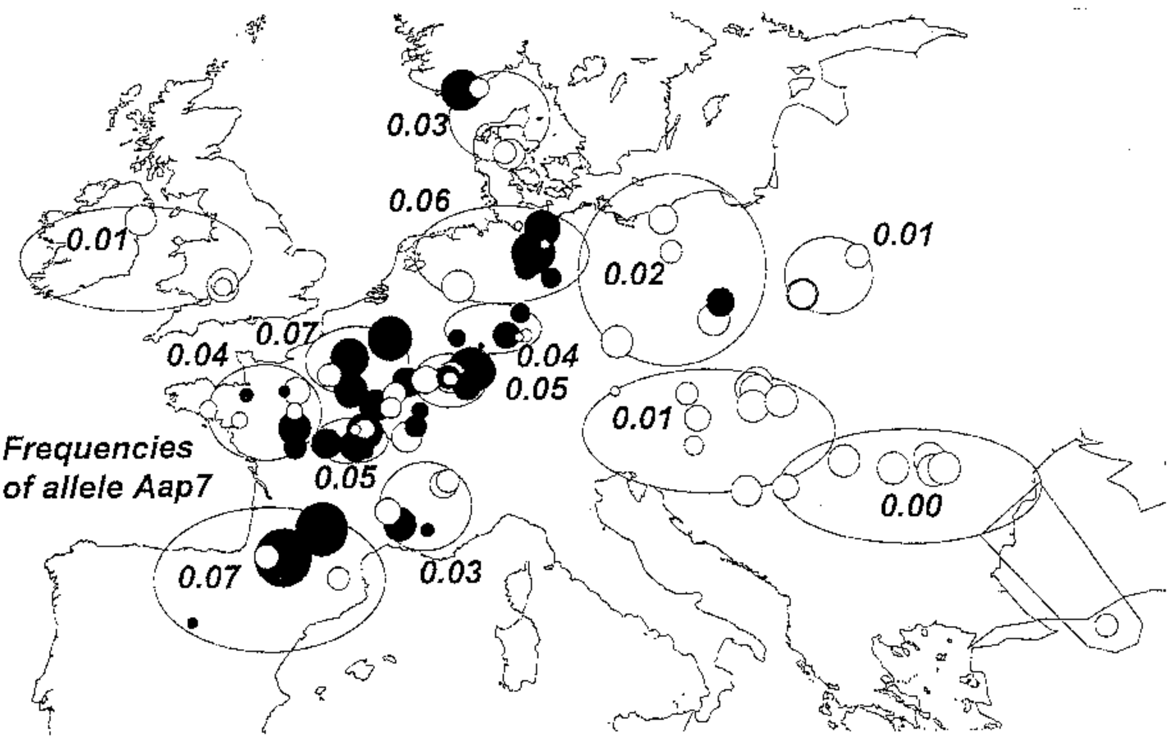

Fig. 3. Allelic frequencies of allele 7 of locus *Aap*. Values above the mean allele frequency are in black, values below the mean in white. The larger the circle, the more different is the value from the mean. Mean regional frequencies are provided for arbitrary regions corresponding to the circled areas.

The highest growth rates are found at intermediate to high latitudes and seem to correspond to the areas with the highest heterozygosity. A detailed analysis is needed to understand this pattern, as it may be highly dependent on the location of the plantation site, contrary to the previous character (bud burst), which is much more stable. However, it is possible that the more pronounced height growth for the populations from the central part of the distribution range results from the combined effect of competition and silviculture. Under optimal conditions for growth, competition for light and mineral resources between trees is enhanced. Competition would in turn promote selection for higher growth potential. This trend may be reinforced by the long history of silviculture in the central part of the natural range. Silvicultural treatments of even-aged oak stands favour thinning practices that eliminate poorly growing trees. Natural selection and human intervention may have acted together to increase growth in these central populations.

A longitudinal differentiation is apparent for allele 7 of locus *Aap*, present in higher frequencies in the west than in the east. This appears to be the general tendency for most studied alleles of all isoenzyme loci, as detailed in Zanetto and Kremer (1995). Le Corre *et al.* (1998a) by using geostatistical methods confirmed the preferential direction from southeast to northwest along which allele frequencies varied continuously. This pattern most likely reflects the genetic divergence among populations in different glacial refugia scattered from east to west, and the subsequent postglacial migration routes. The remaining oak forests were probably differentiated genetically between the glacial refugia since they were separated for more than 80 000 years.

Causes of population differentiation

Two hypotheses concerning the possible origin of the present distribution of nuclear diversity are tested: are geographic trends of variations footprints of the origin of populations (**historical hypothesis**), or are they the result of geneflow among established populations, leading to isolation-by-distance (**geographical hypothesis**) (Le Corre *et al.* 1998b). The two hypotheses are tested by comparing a set of pairwise distances between populations. Because cpDNA is only transmitted by seed (Dumolin *et al.* 1995) the spatial distribution of cpDNA polymorphisms indicates the past colonization routes. Therefore if the first hypothesis is favoured, a significant correlation is expected between nuclear genetic distances and cpDNA distances. Conversely if the isolation-by-distance hypothesis holds, the nuclear genetic distances should be correlated with the geographic distance among populations.

Pairwise genetic differences for traits controlled by nuclear genes (isoenzymes and phenotypic traits) were compared with differences in respect of their origin (glacial refugia) or their present geographic location. Comparisons were made using a stepwise procedure. First three different distance matrices between populations were constructed. The first one (GD) corresponds to the genetic differences among populations (Nei's (1987) genetic distance for isoenzymes, or absolute difference between population mean values for phenotypic traits). The second distance, called the 'historical' distance (HD), is based on cpDNA information. It is calculated as the number of restriction fragment polymorphisms that distinguish two populations (Nei 1987; Le Corre *et al.* 1998b). The third distance is the geographic distance between two populations (GeoD), calculated as the Euclidean distance between the Mercator-projected coordinates. In a second step, the product moment coefficient of correlations between distances (GD and GeoD, GD and HD) was calculated between populations. And finally the correlation coefficients were compared with a Mantel test (Mantel 1967). The Mantel test consists of constructing a null hypothesis (H_0: the two distances are not correlated) through a Monte Carlo procedure. Cells of one distance matrix (for example GD) are permuted, whereas the second matrix (for example GeoD) is maintained as such. For each permutation a product moment correlation coefficient is calculated. The procedure is then repeated 1000 times, and the actual value of the correlation is compared to the distribution corresponding to the null hypothesis. Because cpDNA polymorphisms follow a strong geographic distribution (Petit *et al.* 1993), partial correlation coefficients were calculated to remove the effects due to the correlation between the two explicative variables (GeoD and HD) as suggested by Smouse *et al.* (1986).

Table 4. Mantel's tests. Second column: partial correlation between genetic distance (based on isoenzymes) and historical distance (geographical distance constant). Third column: partial correlation between genetic distance (based on isoenzymes) and geographical distance (historical distance constant)

Traits	R (GD,HD),GeoD	R (GD,GeoD),HD
Isoenzymes	+0.025^{NS}	+0.408**
Bud burst	+0.140*	+0.288**
Height growth	+0.060^{NS}	+0.088^{NS}

* = Significant at *P*=0.05; ** = significant at *P*=0.01; NS = nonsignificant at *P*=0.05.

Geographical distances between two populations are always more strongly correlated with the genetic distances, compared with historical distances, for all three traits investigated (it is highly significant for Nei's distance based on isoenzymes and for differences in bud burst scores). However, historical distances (based on the information contained in the maternal genomes of the trees) do seem to account for some of the variation in phenology, but not in isoenzymes. This is a somewhat surprising result that needs to be confirmed.

Geneflow

The data set for geneflow

Mating system and geneflow were studied in a natural stand comprising 296 adult *Q. petraea* and *Q. robur*. The study stand is a square area of 5.76 ha (240×240 m) and is part of a continuous forest called La Petite Charnie in the northwest of France, near the city of Le Mans. Trees were assigned to either *Q. petraea* or *Q. robur* according to a multivariate analysis of leaf morphological traits. Outcrossing and hybridization rates were calculated with allozyme markers with the help of a "two species mixed mating model" (Bacilieri *et al.* 1996). A second estimation of the same parameters in the same study site was made on a different pollination year by paternity analysis using microsatellites (Streiff *et al.* 1998b). Paternity analysis furthermore allowed reconstruction of all mating events in the stand, and as a result tracing of pollen dispersion.

Interspecific geneflow

As for other oaks, sessile oak is part of a complex of species exchanging genes (Kremer and Petit 1993). Interfertility between *Q. petraea* and *Q. robur* was shown by controlled hybridization experiments. Hybridization occurs also in natural populations as suggested by the extremely low species differentiation; reported interspecific G_{st} values amount to about 3% (Table 2). All alleles, including rare alleles were shared by the two species. We estimated hybridization rates in a stand where the two species were mixed, with two different markers, isoenzymes and microsatellites. As shown in Table 5, there are gene exchanges between the two species in both directions; the preferential direction of pollination from *petraea* to *robur* that was recorded in one single year of observation (Bacilieri *et al.* 1996) has yet to be confirmed in other studies. Because species differentiation is extremely low throughout the natural distribution of the two species (Bodénès *et al.* 1997), hybridization is not likely to be restricted to specific geographic areas, but should be considered as a general mechanism. Furthermore, *Q. petraea* can also fertilize *Q. pubescens* or other species from central Europe (*Q. dalechampii*, *Q. polycarpa* and *Q. virgiliana*).

Table 5. Inter- (t_b) and intra- (t_w) specific outcrossing rates and selfing (s) rates in a mixed *Q. petraea* and *Q. robur* oak stand

Molecular markers	*Q. robur* S	*Q. robur* t_w	*Q. robur* t_b	*Q. petraea* S	*Q. petraea* t_w	*Q. petraea* t_s	Reference
Isoenzymes	0.05	0.63	0.32	0	1.20	–0.20[†]	Bacilieri *et al.* 1996
Microsatellites	0.03	0.94	0.03	0.01	0.89	0.11	Streiff *et al.* 1998b

[†] Negative values of hybridization rates indicate that *Q. petraea* was most likely pollinated by extreme *Q. petraea*-like trees.

The potential of *Q. petraea* to hybridize with other species should be seen as a mechanism to maintain and enrich its own diversity and those of its related species, and as a mechanism of *Q. petraea* to colonize new sites. The importance of hybridization as an evolutionary mechanism is witnessed by the complete sharing of cytoplasmic genomes among *Q. petraea* and *Q. robur* when they cohabit in the same forest. This indicates that the two species had continuous gene exchanges, since one of them colonized that forest; and that the second species, by continuously pollinating the recipient species through backcrosses, colonized the site as well (Petit *et al.* 1997). In other words, *Q. petraea* was 'regenerated' in each forest by hybridization.

Intraspecific geneflow

Paternity analysis on the experimental study site of 5.76 ha resulted in the assignment of a male parent for only 310 acorns out of a total of 984 analyzed (Streiff *et al.* 1998a). More than 68% of the pollen that pollinated mature trees of the study stand originated from outside the stand! The construction of the pollen dispersion curve resulted in extremely flat tails, meaning that the pollen cloud is composed of pollen grains of widely spaced trees. Calculation of pollination distances in *Q. petraea* resulted in a mean value of 287 m with a standard deviation of 139 m (Streiff *et al.* 1998a). These figures should be considered as only rough estimates, since male parents from outside the stand were not identified, and pollination distances were inferred from mathematical models. However, reported studies in other oak species using the same technology also mentioned the long-distance pollen flow (Dow and Ashley 1996). Lahtinen *et al.* (1996), by monitoring pollen dispersal of *Q. robur* with traps on the edges of the natural distribution of the species, showed that pollen density was still present at 7 km from the source. Even at low rates, long-distance pollen flow is a strong homogenizing force, as shown by the extremely low population differentiation of *Q. petraea* for nuclear markers (about 3%, Table 2). *Quercus petraea* is widespread and its distribution is almost continuous except in alpine and Mediterranean regions, suggesting that genes could rapidly diffuse throughout the natural distribution.

Conclusions

Remarkable range-wide trends of variation exist in sessile oak for all traits investigated and for the corresponding measures of diversity. Actually, the trend for a trait and for its associated measure of diversity can differ, as in the case of bud burst, where the intrapopulation means vary with the latitude, whereas the corresponding coefficients of variation vary with the longitude. In the case of isoenzymes, most allele frequencies vary according to longitude, but depending on the measure of variation chosen (allelic richness or expected heterozygosity), the more variable region is either the east or the west. A striking result of this review is also the contrasting subdivision of diversity according to the traits; more than one-third of genetic diversity exists among populations for bud burst, whereas only 3% account for population differentiation for allozymes. Furthermore, depending on the goal and purpose of each investigator, at a given time, some traits may be more relevant for conservation than others. Consequently, given our results, this means that no region of the natural range should deserve more attention than others, as long as there is no serious threat for the maintenance of the species. Because of the contradictory conclusions that may be drawn depending on the traits considered, the geographic structure of diversity or differentiation would not be recommended as relevant criteria for *in situ* conservation issues.

However an alternative attitude would be to favour the maintenance of the mechanisms generating diversity, rather than the maintenance of diversity *per se*. As shown by our results, recent evolutionary factors as geneflow and diversifying selection in various areas of the natural distribution had a profound impact on today's structure of gene diversity, erasing progressively the initial structure established at the end of last glaciation. As for practical issues for *in situ* conservation, management measures conserving inter- and intraspecific geneflow among oak stands coexisting in the form of a metapopulation would be an appropriate solution. Owing to the high levels of diversity that exist in *Q. petraea* stands, and the extensive geneflow through pollen dispersal, this species has a great evolutionary potential and is probably able to react extremely rapidly to ecological changes.

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Oak decline in European forests

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The spread of oak decline, a concern in many parts of Europe

Oak forests are important for the forest economies of many European countries. Because of the importance of oak, the increasing number of cases of oak decline in many European countries is causing much concern. Results of the 1995 survey on Forest Condition in Europe showed abundant occurrence of severely damaged oak trees in Central Europe (EC-UN/ECE 1996). The most severe deteriorations were observed in Germany, the Czech Republic, Poland and the Slovak Republic. Are the oak forests going to follow the coniferous forests in suffering from air pollution or from the new vascular mycosis disease which is spreading over the European continent? Oak decline is widespread in many districts of Italy (e.g. Lazio, Marche, Toscana, Puglia, Basilicata and Calabria) and has been spreading during the last 10 years. A survey carried out in 1988 on 1000-m^2 plots showed that around 85% of *Q. cerris* trees were declining or already dead in Puglia, 76% in Lazio and 51% in Basilicata. Even more alarming were the figures for *Q. pubescens* in Puglia, where approximately 95% of trees were declining or dead (OEPP/EPPO 1990).

In the Netherlands, according to the national forest health survey which has taken place annually since 1984, the health of oaks is deteriorating. In 1988 only 21% of trees were estimated as healthy. Mortality in individual stands varied from 20 to 50% (OEPP/EPPO 1990).

In Poland in 1984-85 oak decline spread very quickly all over the country, affecting 145 000 ha (2% of the total forest area) (Oszako 1994). The progression of the disease was so swift that for example in one forest district (Krotoszyn) during the period 1982-89, foresters had to remove 30 000 m^3 of timber from the forest (40% in 1984 and 40% in 1985). The amount of salvage felling expressed in m^3 was 690 times higher in 1984 (20 194 m^3) than in 1980 (29 m^3). Such a large supply of wood interfered not only with the harvesting plan of a particular forest division but also with the local wood market.

Even in countries which do not report oak decline as a major problem, a number of types of dieback can be recognized. In one of the few studies undertaken in Great Britain, about 40% of the 60-year-old trees in an affected area of about 8 ha had died. Additionally, figures obtained during a sample survey of hedgerow oak in 1990 indicated that some 18% of oaks were suffering from dieback affecting more than 10% of the crown (OEPP/EPPO 1990).

There is a long list of descriptive names given to instances of sudden oak decline: cohort senescence, 'T' disease, bark canker, epidemic wilt, Eichensterben, new-type damage, damage of various types, oak mortality, vascular disease, spiral disease, lethal yellowing and oak wilting are the most common (Ragazzi *et al.* 1995).

Why is it important to study oak decline?

Although it can be asked "Why engage in research on oak decline while major and important tree species are endangered by general forest decline?", the following arguments support the necessity for engaging in further oak research:

- Oaks are ecologically and economically indispensable. Many forest sites on pseudogleyic soils would be easily destabilized without oaks. Oaks are essential for a wide range of forest products and are a valuable asset for forest enterprises.
- The health of oaks in Europe has steadily declined in the last decade in contrast to the recovery of other tree species (e.g. fir, spruce). Oak may be a tree of minor importance on a national scale, but on a local or provincial scale it is quite important.

- Oak and mixed oak hardwood stands improve the effect of forests on climate and hydrology in areas where the 'agricultural steppe' is dominant. Forests in these areas provide valuable habitats for many plant and animal species. A change in tree species would endanger many of them.
- With global warming the potential range of oak silviculture will be expanded. At the same time, the steadily deteriorating conditions for coniferous species make oak forests more attractive or even indispensable in some European regions.

Oak decline is not a new phenomenon in Europe but when it occurs it causes important economic perturbations. Therefore it is important to understand this decline syndrome – to predict its appearance and mitigate its effect on the forest economy.

A review of the literature on oak decline in Europe shows a chronological and geographical progression (Table 1). The first report originated more than 250 years ago and other cases have been reported regularly since the 18th century. However, in the last 15 years the incidence of oak decline has shown a dramatic increase all over Europe, and even by 1989 was reported in every European country. Such a situation has prompted many investigations in both Europe and the United States. Up to now, no single universal causal factor (abiotic or biotic) has been found which could explain the widespread abnormal death of oaks. In the beginning of the 1980s some researchers from Romania, Poland and the former Czechoslovakia, after preliminary studies, reported the fungus *Ceratocystis fagacearum* as a cause of oak disease. Actually, the symptoms were very similar to these observed in North America. We now know that this was a mistake and that this serious pathogenic fungus is not yet present in Europe. However, the possibility of its appearance is a real threat because of the steadily growing wood timber trade. For this reason quarantine regulations do not allow the importation of oak wood timber with bark or without chemical or drying treatments. As a consequence of the panic over a possible outbreak within the European oak forests of the well-known and dangerous USA vessel disease called 'oak wilting', many trees showing first decline symptoms were immediately removed from the stands. During necessary sanitary harvesting operations many live trees in the stands were injured. These wounds of plant tissues were open gates for fungi infections, mostly *Phellinus robustus*, which colonized internal parts of the trees, causing internal rot of stems. This wood is now only used for firewood. In some stands, up to 40% of trees are infected by this fungus and have lost their primary high quality value. The removal of many trees changed the light condition in the oak ecosystem. More light reached the litter level in the oak stands and enhanced weed grass development, causing quick site degradation and silvicultural problems (e.g. with regrowth of natural regeneration). Light stimulated the development of water sprouts which decreased stem wood quality. Oak decline has caused not only direct financial losses because declining trees had to be removed before their maturation or harvesting age, but also indirectly affected wood quality and growing conditions in the ecosystem. The total economic cost should also include the negative effect on the site (soil).

According to the literature, oak decline is a result of a general weakening of the trees and is manifested by a dieback of the crown. Trees either die within a few years or suffer for many years. Some of them do recover, producing resprouts along the trunk and branches. Usually, oak decline is recorded when numerous trees die or when symptoms are exhibited over quite a large area. The symptoms can vary among sites according to environmental (ecological and silvicultural) differences and the oak species affected. Symptoms common to all oak species throughout the European range are crown thinning, growth of epicormic shoots, and bleeding.

Some researchers view oak decline as a pernicious new event that will lead to the disappearance of oak forests. Others regard it as a chronic occurrence common to all plants and forest ecosystems. There are at least two hypotheses to explain the nature of this complex disease (Ragazzi *et al.* 1995):

- The first emphasizes the synergistic action of different factors which previously operated separately, and which have caused an increase in oak decline during the last decade.
- The second suggests that it is a quite new phenomenon which first appeared about 15 years ago. Earlier cases were sporadic and localized events which have no real bearing on current oak decline.

Researchers are agreed that numerous biotic and biotic causes are involved in the development of the disease. Their importance depends on varying local circumstances and their interrelations. Research carried out in many European laboratories detected many different organisms, e.g. fungi, nematodes, bacteria, MLOs and viruses:

- A high number of fungi isolated from declining oak tissues have been reported by numerous scientists. They mainly belong to the Deuteromycotina and Basidiomycotina classes, the most frequently recorded being *Armillaria* spp., *Fusicoccum quercus, Hypoxylon mediteraneum, Phomopsis quercella* and *Phytophtora cinnamoni*. Most of those species are already known to be pathogenic and to occur on declining oaks.
- Sapwood nematodes (*Bursaphelenchus* spp.) were found to be common in declining and dying oaks. A correlation was found between the quantity of nematodes and vitality (expressed by conditiometer measurements).
- Only a few bacteria have been found in Romania in association with oak decline: *Erwinia quercicola* Georges et Bad. and *Erwinia valachica* Georges et Bad. (Petrescu 1974).
- Mycoplasma Like Organisms (MLOs) have been detected on declining oaks in Romania (Ploaie *et al.* 1987).
- The only virus identified so far in declining oaks is the tobacco mosaic virus (TMV) on *Quercus robur, Q. petraea* and *Q. cerris* in Germany (Nienhaus 1975) and Hungary (Horvat *et al.* 1975).

There are two common models of oak decline accepted by most researchers: the classical chain disease model of Keller (Dominik 1971) in which sets of factors act in succession, and the spiral model developed by Manion (1981) which consists of three main groups of factors acting simultaneously in the same space and time. Initially, factors acting over the long term (e.g. climate, site conditions, air pollution, genotype) predispose trees to the inciting factors which cause direct damage to the trees (e.g. insect defoliation, frost damage, etc.). It is a combination of these factors which ultimately causes the death of the trees.

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Table 1. Causal factors involved in incidences of oak decline in some European countries

Year	Oak species	Drought	Defoliation by insects	Secondary pests	Fungi	Silviculture	Other	Author
Austria								
1982-83	–	only in some cases in 1986	–	*Scolytus intricatus*, Jassidae, Hemiptera, Cynipidae, Buprestidae	*Armillaria* spp. *Ohiostoma piceae*, *O. cf. valachicum*, *O. prolifera*, *O. cf. roboris*	–	Nematodes *Bursaphelen-chus* spp.	T. Cech, E. Donaubauer, C. Tomiczek
Slovakia								
1979	*Q. dalechampii*, *Q. polycarpa*, *Q. petraea* × *robur*, *Q. petraea*, *Q. robur*, *Q. slavonica*, *Q. virgiliana*, *Q. cerris*, *Q. pedunculifora* *Q. frainetto*, *Q. pubescens*	predisposing factor is soil moisture dropping below wilting point in summers 1976-77		*Scolytus intricatus* as a vector of fungal diseases	*O. quercus*, *O. valachicum*, *O. roboris*, *O. kubanicum*, *O. piceae*, *Diaporthe fasciculata*	summer fellings, increase of volume and size of mechanical damage and attractiveness for beetles	high temperatures, temperature increase since 1970 about 1-1.5°C, atmospheric pollution, fluorine, aluminium	R. Leontovic
Denmark								
1910	*Q. robur*, *Q. petraea*		*Operophtera brumata*, *Tortrix viridana*		*Microsphaera alphitoides*, *Armillaria mellea s.l.*, *Gloeosporium quercinum*, *Stereum rugosum*, *Nectria dittisima*, *Colpoma qercinum*, *Myxosporium lanceola*, *Pezicula cinnamomea*		damage to bark by woodpeckers	A. Yde Andersen

Year	Oak species	Drought	Defoliation by insects	Secondary pests	Fungi	Silviculture	Other	Author
France								
1921 1942 1976 1986	*Q. robur*	does not always lead to decline, limits radial growth			*Collybia fusipes, Armillaria mellea, Microsphaera alphitoides*			C. Delatour
Germany								
1989	*Q. robur*	summer 1983	Lepidoptera		*Cytospora* sp., *Pezicula cinnamomea*, *Armillaria* sp., *O. piceae, O. roboris*		reduced ground-water level, winter extreme temperature 1984/85	A. Wulf
Hungary								
1978	*Q. petraea*	last decade, soil water content below critical level in July	outbreaks of leaf-eating insects	*Scolytidae, Cerambycidae, Buprestidae, etc. Scolytus intricatus* as vector of fungi	*Armillaria melea (sensu lato), Ophiostoma* spp., *Botryosphaeria stevensii (an. Diplodia mutila), Cytospora* spp., *(C. leucosperma), Phomopsis* sp., *O. piceae, O. pilifera, O. moniliformis*	inadequate forest management practices, lack of thinning and sanitary felling, too large game population	lack of snow, shallow root system of cop-pice stands and increased depth of underground water, air pollution, acid precipitation, acidification of soil, aluminium toxicity	J. Toth, L. Vajna
Italy								
1988	*Q. cerris, Q. pubescens*	last 10 years small amount of precipitation in August			*O. coerulescens, O. piceae, Diplodia mutila, Graphium penicillodes, Hypoxylon mediterraneum, Phoma cava, Phomopsis quercina, Pyrenochaeta quercina, Acremonium* spp., *Sporotrix* spp., *Armillaria* spp.	atmospheric pollution		A. Vannini, N. Luisi

Year	Oak species	Drought	Defoliation by insects	Secondary pests	Fungi	Silviculture	Other	Author
Netherlands								
1984 1986	*Q. robur*, *Q. petraea*	1982, wet spring and dry summer 1983, most serious on wet sites with a groundwater level which fluctuates	caterpillars of *Tortrix viridana* and *Operophtera brumata* 1983		*Pezicula cinnamomea*, *Armillaria* spp., *Microsphaera alphitoides*, *Leptographium* spp., *O. piceae*, *Acremonium* sp.		Winter 1984/85 mild until late December and sudden severe frost	A. Oosterbaan
Poland								
1982 1984	*Q. robur*	1982-84	*Tortrix viridana*, *Operophtera brumata*, *O. fagata*, *Hiberia defoliaria*, *Lymantria dispar*, *L. monacha*, *Malacosoma neustria*, *Biston histortata*, *Tischeria dodonea*, *Phalera bucephala*, *Euproctis chrysorrhoea*, *Altica quercetorum*	*Saperda scalaris*, *Scolytus intricatus*, *Plagionotus arcuatus*, *Ragium mordax*, *Leiopus nebulosus*, *Agrilus sulcicollis*, *A. angustatus*, *A. biguttatus*, *Phymatodes testaceus*, *Plagionotus detritus*, *Xylotrechus antilope*, *Dryocoetes villosus*, *Xyloterus domesticus* × *saxeseni*, *A. monographus*, *Xipphydria longicollis*, *Hylecoetus dermestoides*	*Armillaria* spp., *Microsphaera alphitoides*, *Phellinus robustus*, *Colpoma quercinum*, *Coryneum umbonatum*, *Dothiorella advena*, *Cytospora intermedia*, *Ophiostoma* spp., *Ceratocystis fimbriata*, *Fusiccocum quercus*, *Pezicula cinnamomea*, *Phomopsis quercella*, *Amphiporte leiphaemia*, *Coryneum* sp.		Unsuitable soil conditions (especially too much or too little water)	T. Kowalski, K. Przybyl, T. Oszako, J. Starzyk
United Kingdom								
1989	*Q. robur*		caterpillars of *Tortrix viridana* in several consecutive years	scale insect *Kermes quercus*	*Armillaria* spp. *Sphaeropsis* spp.		Intensification of farming (hedgerow oak)	N. Gibbs
Yugoslavia								
1985 1987	*Q. pubescens*, *Q. robur*, *Q. petraea*, *Q. cerris*, *Q. rubra*	no correlation with soil moisture and state of health		*Coraebus bifasciatus*	*Armillaria* spp.		air pollution, strong winds in 1985, shallow soils, interrupted forest structure	D. Jurc

Year	Oak species	Drought	Defoliation by insects	Secondary pests	Fungi	Silviculture	Other	Author
Russia Central Part								
1941–43	*Q. robur*	dry summer and low snow winter of 1938-1939	–		*Microsphaera alphitoides*	–	Hard winter of 1939-40 and 1941-42	
1971-73	*Q. robur*	drought of 1972	–		*Microsphaera alphitoides*			
1991-94	*Q. robur*	–	Periodical defoliation by *Limantria dispar* L., *Operphthera brumata* L., etc	Secondary defoliation by *Ocneria dispar* L. and others	*Phellinus robustus*, *Polyporus sulphureus*, *Daedalea quercina*, *Armillaria* spp., *Ceratocystis* spp.	improper forest management, destruction of complex oak stand structure, pasture, damages by elk	Periodic change of wet and dry periods (climatic factor - ecological stress)	N.V. Napalkov
Middle Povolzhje region								
1941	*Q. robur*	–	–		–		Hard winter frost	
1968-69	*Q. robur*	–	–		–		Little snow and hard winter frost	
1978-79	*Q. robur*	–	–		*Microsphaera alphitoides*, *Phellinus robustus*, *Polyporus sulphureus*, *Daedalea quercina*		Hard winter frost	
1991-94	*Q. robur*	–	*Tortrix viridana*, and *crataegana*, *Operophtera brumata* and others	Secondary defoliation by *Ocneria dispar* L. and others	*Microsphaera alphitoides*, *Phellinus robustus*, *Polyporus sulphureus*, *Daedalea quercina*	inadequate forest management practices, destruction of complex forest stand structure, decreasing stand density, pasture	–	Igor A. Yakovlev

Genetic diversity of beech populations in Europe

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Introduction

European beech (*Fagus sylvatica* L.) is considered at present the most widespread economically important broadleaved tree species in Europe. The extent of beech forests (*Fagus sylvatica* and *Fagus orientalis*) in Europe and Asia Minor is estimated to be between 17 and 20 million ha (e.g. Milescu *et al.* 1967 estimate 16.8 million ha) and represents approximately 10% of European forests. The proportion of beech forests in individual regions represents frequently up to 30% of the total forest area (e.g. Croatia, Slovakia, Romania, etc.).

Natural range and systematics

Both *F. sylvatica* and *F. orientalis* belong to the forest tree species with the widest natural distribution range in the western part of Eurasia. *Fagus sylvatica* is distributed in western, central and southern Europe with individual occurrences in southern England and southern Scandinavia. *Fagus orientalis* is distributed in Asia Minor, in the Caucasus, in the Amanus mountains (Syria), and in the Elburz mountains (Iran). A contact zone between the natural ranges of both species is located in northern Greece and Bulgaria. Isolated occurrences of *F. orientalis* outside the natural range were recorded in eastern Serbia (Gliši 1973), in Macedonia (Černavski *ex* Milescu *et al.* 1967), in Banate and Moldova (Milescu *et al.* 1967), and in Dobrudja and Central Bulgaria (Czeczott 1932).

Problematic taxonomic identity of beech exists in the Crimea. Poplavskaja (1927) described beech in the Crimean peninsula as an independent species – *F. taurica*. Beech occurs in the Crimea in two altitudinally separated zones. The lower zone was more frequently described as *F. orientalis* and the upper one as *F. taurica* (Molotkov 1966; Milescu *et al.* 1967), but Wulff (1932) described it as *F. sylvatica*. It is necessary to point out that the name *F. taurica* is used in different ways. While Poplavskaja described it as the intermediate form between *F. sylvatica* and *F. orientalis*, Milescu *et al.* (1967) considered it another species with its occurrence not limited to the Crimea.

A further dubious taxonomic unit is *F. moesiaca* with the most frequent occurrence in the Balkans. Mišič (1957) considered it a separate species of Tertiary origin. It is most frequently considered a subspecies of *F. sylvatica*.

It is obvious that taxonomic status of beech in a rather large zone is unclear. The original description of *F. moesiaca* and *F. taurica* was based mainly on the morphological traits of leaves. Seldom do these presumed species occur in comparative provenance trials together with *F. sylvatica*.

The aim of recent investigations carried out in Slovakia, France and other countries was to describe both species – *F. sylvatica* and *F. orientalis* – using genetic markers, to define the zone of introgressive hybridization and the limits or the direction of geneflow between them, and to characterize the structure of diversity within the genus *Fagus* in Europe and western Asia.

Fagus sylvatica is a tree species of oceanic and suboceanic climate. Its eastern distribution limit is parallel to the limit of continentality (Stanescu 1979) and is defined by the air humidity and late frost (Pukacki 1990). Although it is resistant to fairly low temperatures, which does not exclude it from the higher altitudes, it is sensitive to late spring frost – a limiting factor at lower altitudes with a great accumulation of cold air (Becker 1981). For this reason beech does not occur in frost valleys or in the regions with a more pronounced continental climate.

Phylogeny

The oldest fossils that can be attributed to the genus *Fagus* originate from the late Mesozoicum (Milescu *et al.* 1967). The remnants of different forms of beech are much more abundant from the Tertiary. They were even found in regions where beech does not occur at present, e.g. Greenland, Iceland and Svalbard (Walter *ex* Milescu *et al.* 1967). Among the Tertiary fossils, at least four different species were described: *F. attenuata*, *F. pliocenica*, *F. sylvatica* and *F. feroniae*. Ettingshausen (*ex* Milescu *et al.* 1967) considers all these species the different forms of one collective species *F. feroniae*. The forms similar to *F. ferruginea* (*grandifolia*) were also found in Europe. From both beech species found in Europe and western Asia, *F. orientalis* is generally considered a more ancient, ancestral form, of which *F. sylvatica* has evolved.

During the Pleistocene, beech underwent several retreats within the glacial periods and expansions during the warm interglacials. Unfortunately, it is not possible to reconstruct the early history completely on the basis of fossil remnants. A more or less reliable description, based on pollen diagrams, is possible only for the last Würm/Weichsel glacial period and the recolonization of Europe in the Holocene (Huntley and Birks 1983). The refugia of beech were probably situated in central Pyrenees, southern France, Sicily, Apennines and Balkan Peninsula. The expansion started ca. 12 500 years ago. Further development of pollen values indicates that the main source of expansion was the refugium in the southern Balkans (Macedonia, western Bulgaria, southeastern Serbia). Beech from this area recolonized the whole present range, intermixing with the populations from local, smaller refugia. There seems to be one exception – beech in the Apennines and in Sicily, which preserved its continuity and was not affected by immigration from outside.

This view, although generally accepted, seems to contradict in some aspects the differentiation patterns identified utilizing isoenzyme genetic markers.

Genetic inventories

History

The application of genetic markers to investigate genetic diversity of beech populations started later than in conifers. Kim (1980) identified the first enzyme gene locus by studying zymograms of parent trees and their offspring. He used in his investigations only two loci – *Acp* and *Lap*. Paule (1992) and Hattemer *et al.* (1993) published reviews of the isoenzyme systems, their biochemical analyses and controlling gene loci which were applied in genetic inventories of beech. They have listed a total of 17 isoenzyme systems controlling 27 gene loci (Table 1).

Müller-Starck and Starke (1993), Thiébaut *et al.* (1989) and Merzeau *et al.* (1989) studied inheritance patterns of the enzyme gene loci in progenies from controlled crossings and single trees.

SDS-PAGE was applied to find species-specific differences in the seed protein content of *F. sylvatica* and *F. orientalis* populations from Bulgaria. The comparative analysis of their patterns showed a greater similarity than dissimilarity between both species (Busov 1993).

Finally, the polymorphism in the chloroplast genome has been detected by resolutive restriction site studies of PCR-amplified fragments. Eleven haplotypes, which could be phylogenetically ordered, were detected in a large survey (399 individuals in 85 populations) encompassing most of the natural range of the species (Demesure *et al.* 1996).

Institutions involved

Beech is now considered to be a tree species with the most extensive genetic inventory of the broadleaves. The first investigations used a quite small number of isoenzyme gene loci (3-6) (Comps *et al.* 1987, 1990). In later studies the number of polymorphic isoenzyme loci increased to 10–16 (Müller-Starck and Ziehe 1991; Gömöry *et al.* 1992; Hattemer *et al.* 1993; Turok 1993, 1996; Leonardi and Menozzi 1995; Tröber 1995; Larsen 1996).

Table 1. Review of the isoenzyme systems used for population genetic investigations in European beech

	Authors who used the isoenzyme systems and loci													
Locus	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
6Pgd-1	x		x	x	x	x		x		x	x	x	x	
6Pgd-2			x			x	x	x	x			x	x	
6Pgd-3			x			x	x	x	x					
Aap-1												x		
Aap-2												x		
Aco-1			x	x		x	x		x					
Aco-2			x	x		x	x		x	x				
Acp-1	x			x										
Acp-2														
Adh-1				x										x
Adh-2													x	x
Adh-3												x		
Amy-1												x		
Dia-1					x		x		x		x	x		
Fum-1												x		
Gdh-1							x		x					x
Got-1	x		x		x		x		x			x		
Got-2		x	x				x	x	x	x	x			
Idh-1	x	x	x		x	x	x	x	x	x	x			
Lap-1		x					x	x	x		x			
Lap-2														
Mdh-1		x						x					x	x
Mdh-2	x	x	x		x	x	x	x	x	x	x	x		x
Mdh-3	x	x	x		x	x	x	x	x	x	x	x		x
Mnr-1	x	x	x			x		x		x				
Ndh-1			x											
Pgi-1												x		x
Pgi-2	x	x	x	x	x		x	x	x	x	x		x	x
Pgm-1	x	x	x			x	x	x	x	x	x		x	
Px-1	x	x					x							
Px-2	x	x		x	x				x				x	
Skdh-1			x		x	x	x	x	x	x	x			x
Skdh-2														x
Sod-1	x													

1 Comps *et al.* 1991
2 Gömöry *et al.* 1998
3 Konnert 1995
4 Larsen 1995
5 Leonardi and Menozzi 1995
6 Löchelt and Franke 1995
7 Müller-Starck and Starke 1993
8 Müller-Starck 1996
9 Müller-Starck and Ziehe 1991
10 Tröber 1995
11 Turok 1996
12 Kitamura *et al.* 1992 (*F. crenata* and *F. japonica*)
13 Houston and Houston 1994 (*F. grandifolia*)
14 Premoli 1996 (*Nothofagus*)

Genetic inventories of beech populations have been carried out at several institutions in Europe. To these belong mainly the French group from Bordeaux which focused attention on the western European populations and compared them with some central European and Balkan ones (Comps and Thiébaut and other coworkers). The second group is from Zvolen, Slovakia, which focused on the eastern European populations and the transition zone of *F. sylvatica* and *F. orientalis* in the Balkans, Asia Minor and Caucasus. Numerous other groups analyzed regional sets of populations in Italy (Leonardi, Belletti, etc.), Germany – Bavaria (Konnert), Saxony (Tröber), North Rhine-Westphalia and Rhineland-Palatinate (Turok, Ziehe, etc.), Denmark (Larsen), or combined their studies with the air pollution effect (Müller-Starck in Germany, Brus in Slovenia, Vyšný *et al.* in Bohemia), silvicultural practices (Starke *et al.*). A rough estimate of the number of populations analyzed within the European genetic inventories would be around 800.

Genetic diversity

The levels of genetic diversity and multiplicity are strongly affected by the choice of marker loci. As mentioned above, the number of loci, used in different studies on beech, is quite restricted, in general not exceeding 16. Loci exhibiting at least a minor polymorphism are used. These loci, which are generally considered monomorphic, are not utilized, they are not even recorded although they appear on the gels stained (an example is the fastest migrating monomorphic zone, appearing on gels stained for malate dehydrogenase in *F. sylvatica*. It was proven that it is controlled by one locus, which is polymorphic in *F. orientalis*). Therefore, caution is necessary when comparing results from different studies. An incomplete overview of the published levels of genetic multiplicity, diversity and differentiation measures is given in Table 2.

Despite this, there are no substantial differences when comparing genetic multiplicity in different parts of the distribution range. The mean number of alleles per locus is in general about 2.5. Although there is no clear trend, it seems that mean number of alleles tends to increase in the eastern and southern regions. Low estimates for the Italian Piedmont and/or for Denmark could be influenced by a lower number of loci used (8 and 7, respectively) than in the other studies.

Among the genetic diversity measures, the values of the expected heterozygosity are frequently available. However, no geographic trends can be identified, probably because of the choice of different sets of marker loci. Expected heterozygosity values (which measure gene diversity) range between 0.2 and 0.4, effective number of alleles between 1.25 and 1.6. Contrasting estimates of diversity for Denmark (0.177, Larsen 1996) and Sweden (0.290, Comps *et al.* 1993) underline the presumed effect of the choice of loci.

Genetic differentiation

As indicated by G_{st}-values presented in Table 2, isoenzyme markers do not allow discovery of much differentiation. The major part of the genetic variation (mostly over 95% of the total variation) is observed within populations. Despite this, several studies succeeded in identifying geographic trends of single allelic frequencies, or geographic patterns of the genetic variation based on multilocus approach.

One of the first large-scale studies on beech, focusing on the Atlantic region of western Europe (Comps *et al.* 1987), proved the existence of a latitudinal trend for *Px-1/105* (peroxidase) allele (frequency decreasing toward the north). For other loci, certain trends were also observed: the frequency of the *Px-2/13*, *Got-1/105* and *Pgi-1/87* alleles is highest in the Pyrenees and decreases toward the north as well as the south. The frequency of the *Got-1/105* is significantly correlated with altitude. Similar trends were reported by Felber and Thiébaut (1984), Cuguen *et al.* (1985) and Barrière *et al.* (1985). They found the heterozygosity as well as frequencies of alleles *Px-1/105*, *Px-2/13* to be highest in extreme climatic conditions within Europe.

Table 2. Selected values of measures of the genetic multiplicity, diversity and differentiation of beech forests in Europe

Country/Region	N_a	H_e	n_e	G_{st}	Reference
Spain		0.301		0.046	Comps *et al.* 1993
France		0.306		0.040	Comps *et al.* 1993
Germany	2.3–2.9	0.188–0.229	1.32–1.44	0.045[†]	Müller-Starck and Ziehe 1991
Bavaria	2.1–2.9	0.247	1.299–1.404	0.019	Konnert 1995
North Rhine-Westphalia	2.1–2.8	0.23–0.38	1.30–1.59		Turok 1996
Baden-Württemberg	2.2–2.6	0.226–0.289			Löchelt and Franke 1995
Czecho-Slovakia	2.1–2.6	0.281–0.346			Gömöry *et al.* 1992
Italy – Piedmont	2.0–2.3	0.177–0.278		0.043	Belletti and Lanteri 1996
Italy	2.0–2.9			0.046[†]	Leonardi and Menozzi 1995
Balkans	2.4–3.2	0.230–0.260 0.228–0.282	1.295–1.346	0.014–0.040[†]	Gömöry *et al.* (1998) Hazler *et al.* 1997
Croatia	2.2–2.5	0.297–0.315		0.053	Comps *et al.* 1991
Ukraine	2.4–2.6	0.186–0.247			Vyšný *et al.* 1995
Denmark	2.0–2.4	0.164–0.187		0.006[†]	Larsen 1996
Sweden		0.290		0.039	Comps *et al.* 1993

[†] – F_{st}

N_a – mean number of alleles per locus, H_e – expected heterozygosity, n_e – effective number of alleles, G_{st} – interpopulation component of the genetic variation.

Leonardi and Menozzi (1995) found a very clear differentiation between Italian stands from the southern and northern parts of the country. They attributed these differences to the glacial and postglacial history.

In a recent study, Comps *et al.* (1998) investigated 78 populations on a west–east transect from the Alpine Chain to the Hungarian Basin. A principal component analysis of multilocus allelic frequencies allowed assignment of the populations to four groups: French Alps, Swiss Alps, Northeastern Alps (Germany, western Austria), and eastern Austria together with Hungarian Basin.

In Ukrainian Carpathians and the adjacent lowlands, Vyšný *et al.* (1995) found differences between populations from the southwestern slope, northeastern slope and the lowlands, but the grouping was not unequivocal. However, principal coordinate analysis of the genetic distance matrix proved the existence of a clear altitudinal cline.

Comps *et al.* (1991) analyzed 35 populations from Croatia. Discriminant analysis based on allelic frequencies allowed distinction of two strongly differentiated groups of populations originating from higher altitudes (mountain regions) and lowlands (maritime regions). At the same time, the populations belonging to the phytosociological association *Selerio-Fagetum* exhibited significant differences, compared with the other associations.

The populations from the transition zone between *F. sylvatica* and *F. orientalis* represent a specific problem and were subjected to several studies. Eastern beech itself seems to be much more differentiated than European beech, but there are features of allelic profiles which are common for all regions with the occurrence of *F. orientalis*: the loci *Got-2* and *Mdh-3* are almost or completely monomorphic, while in *F. sylvatica* the representation of the most frequent allele does not exceed 0.8. The opposite proportion is at *Mdh-1* and other loci where a higher degree of polymorphism is shown in the populations of *F. orientalis* (Paule *et al.*, unpublished).

Balkan beech (designated by local botanists as *Fagus moesiaca* Czeczott) differs from the typical *F. sylvatica* by morphological traits of leaves, flowers and fruits, a high sprouting capacity and a considerably higher frequency of seed years, as well as ecological requirements (Mišić 1957). Hazler *et al.* (1997) compared beech populations from the northwestern Balkans (Croatia), generally considered pure European beech, with populations from Macedonia and Bulgaria. The southeastern populations differed by the occurrence of specific rare alleles (*Mnr-1/131, Pgi-1/76, Pgi-1/113, Pgm-1/93, Pgm-1/109*) and could be clearly distinguished from the northwestern ones by means of discriminant analysis of multilocus allelic profiles.

The gap of information from the central part of the former Yugoslavia was fulfilled in the study of Gömöry *et al.* (1998), where populations from Serbia and Bosnia-Herzegovina were included. Although they found a clinal character of the overall genetic variation as expressed by multilocus genetic distances, the stands classified as *Fagus moesiaca* could be distinguished from the remaining ones. They exhibited a similarity of allelic frequencies and of the presence of rare alleles not only with the neighbouring *F. orientalis* beech populations from eastern Balkans and Asia Minor, but, strikingly, also with beech in Calabria.

Overviews of the investigations performed in different regions and covering the whole range in detail have not been published yet. Preliminary results for the eastern part of range were published by Paule *et al.* (1995) and Gömöry *et al.* (1995). The results indicate that differentiation is higher within *F. orientalis* populations than within *F. sylvatica*, although the populations of *F. orientalis* originate from a much smaller territory. The *F. sylvatica* populations originating sampled the Carpathians exhibit a rather compact group, thus having very similar genetic structures. There seem to be two links between the recent beech species. One link is represented by Crimean beech (sometimes described as *F. taurica* Popl.). There is a rather smooth transition of allelic frequencies from *F. orientalis* in the Caucasus through Crimea, Moldova to the Romanian Carpathians (Gömöry *et al.* 1998). The second link is represented by Balkan beech, as described above. Although both Balkan and Crimean beech seem to be transitional taxa, they differ clearly by their allelic structure. It is quite difficult to decide, solely on the basis of the knowledge about the allelic frequencies, which of these links (if any) represents a true phylogenetic transition from *F. orientalis* to *F. sylvatica* and which is only a product of later introgression and geneflow processes. The capacities of isoenzyme markers are rather limited and seem to be reached by the described studies. Further range-wide studies employing DNA markers, similar to that of Demesure *et al.* (1996), would therefore be very useful and could bring solutions to questions which could not be answered using other tools.

Mating system and intrapopulation spatial structure

A very detailed study of beech mating systems was performed by Merzeau (1991), the results were later summarized in Merzeau *et al.* (1992, 1994). She analyzed six populations in total with different characteristics (isolated treed, forest edge, forest massive, populations in different altitudes) and investigated also the effects of tree height and crown density on outcrossing rates. In general, she found very high outcrossing rates, approaching 1.0. Significant heterogeneity of outcrossing pollen pool frequencies was found not only among stands, but especially among individual trees within populations in five out of six analyzed stands. She concluded that although beech is a highly outcrossing species, beech populations cannot be considered panmictic. The intrapopulation spatial structure was investigated using spatial autocorrelation analysis. In most cases, the spatial distribution of genotypes was random, only in one forest she found a weak patchy structure.

In two natural beech stands from Italy, Rossi *et al.* (1996) obtained very similar results. Only in dormant seeds from one stand, the outcrossing rate was significantly lower than 1.0. As in the previous study, pollen pool allele frequencies were significantly heterogeneous among parent trees.

A wide study of the spatial structure was performed in 14 Italian beech populations (Leonardi and Menozzi 1995). They revealed a patchy structure in several populations. Although they did not use equal distance classes, they found in general a high proportion of positive autocorrelations between like genotypes and negative autocorrelations between unlike genotypes in first distance class (upper limit of 32 to 77 m), with decreasing proportions of significant values in further distance classes.

Starke (1996) estimated outcrossing rates in stands managed by different silvicultural systems. She found substantially lower outcrossing rate estimates (0.862 to 0.929). This may be due to a different estimation method, since she did not use the mixed mating model as in previous studies, but estimated outcrossing rate on the basis of xenoheterozygosity.

Selection processes

The discussion in the scientific community, of whether isoenzymes are selectively neutral or not, does not seem likely to end in the foreseeable future. However, there are several studies available which indicate the effect of selection due to different external factors on the allelic and genotypic structure of populations of forest trees, including beech.

One of the most intensively investigated factors was air pollution. Müller-Starck (1989) investigated the differences between sets of individuals apparently tolerant and sensitive to air pollution. He found substantially higher heterozygosity values in the set of tolerant trees than in the sensitive ones. The difference amounted to 25% of the actual heterozygosity and almost 10% of the conditional heterozygosity. Similarly, the genetic multiplicity as measured by the number of alleles was slightly higher in the 'tolerant' set. About 5% of alleles were found only in the sensitive trees.

In the investigations of changes of the genetic structure under complex environmental stress, Müller-Starck and Ziehe (1991) observed a reduced heterozygosity in 2-year-old seedlings, compared with the seed stage. On the other hand, the number of alleles decreased, which the authors ascribe to a reduced sample size. They also showed a directional selection at *Lap-A* locus.

Brus (1996) found significant differences in allelic frequencies at *Lap-A* and *Idh-A* in a comparison of polluted and unpolluted beech stands in Slovenia. In addition, a complex multilocus response was identified: in general, the polluted stands were considerably more differentiated and exhibited unpredictable deviations of the allelic structures.

Studies on the effects of other stress factors on the genetic structures of beech are scarce. Recently, a paper on the genetic differences in susceptibility to infestation of young beech trees to *Cryptococcus fagisuga* was published by Gora *et al.* 1995. They found significant differences of infestation rates associated with particular genotypes at *Idh-A*, *Per-B* and *Mdh-B* loci.

The effect of human activities on the genetic structures is a specific problem. Kim (1980) compared the viability selection processes in natural conditions and in the greenhouse. He found a selective advantage of homozygotes at *Lap-A* locus in the greenhouse, whereas in the forest, the heterozygotes containing the a specific allele are favoured. The changes of the genotypic structure were observed at *Acp-A* locus as well. At *Skdh-A* locus, rare genotypes decreased in frequency or even vanished in the studied seedlings after 2 years in field conditions (Hattemer *et al.* 1993).

A more profound study was published by Starke *et al.* (1996). They investigated the effects of different soil-preparation procedures on the genetic structures. Strong changes of genotype frequency distributions were observed at most loci. It was proved that the modification of environmental conditions changes selection regimes and leads to changes of genetic structures.

DNA analyses

The lack of sufficiently variable genetic markers for studying haploid tissue of broadleaved forest trees gives cause to develop a method for analyzing DNA from single pollen grains. Using the PCR technology the DNA from single pollen grains of beech (*F. sylvatica*) could be amplified. The pattern generated from a 10-base random oligonucleotide of haploid and diploid tissue was compared. The described method will offer a new approach for paternity analysis in angiosperms (Vornam 1996).

Heinze and Geburek (1995) used PCR analysis of the total DNA from leaves to find a marker linked to the locus controlling leaf colour in copper beech. Among five markers exhibiting Mendelian segregation they found one weakly linked with the purple leaf colour.

The Mendelian inheritance of RAPD and I-SSR markers has been assessed using a progeny from controlled crossings of *F. sylvatica*. Out of a total of 165 amplification products, 30 Mendelian markers with dominant mode of gene action were found. A subset of 11 markers has been used to estimate population parameters in a sample of 46 trees from a natural stand in the Northern Apennines (Italy). As expected, higher expected heterozygosity was observed than reported in the literature for allozyme studies of this species. The same subset of markers was used for assessing paternity of 81 seedlings belonging to 9 open-pollinated sibships of 9 individuals each. In spite of the low power of the analysis (only 2 unambiguous paternity assignments out of 46 potential fathers) its results seem in agreement with the lack of spatial clustering already known for the species (Troggio *et al.* 1996).

Demesure *et al.* (1996) used the polymorphisms in the chloroplast genome of *F. sylvatica*, which have been detected by resolutive restriction site studies of PCR-amplified fragments. Eleven haplotypes, which could be phylogenetically ordered, were detected in a large survey (399 individuals in 85 populations) encompassing most of the natural range of the species. The high level of genetic differentiation (G_{st} = 0.831), together with the highly structured geographic variation, contrast with the low level of nuclear genetic differentiation measured in previous studies with isoenzymes and indicate a low level of geneflow by seeds. The northernmost populations are genetically uniform, suggesting a bottleneck at the time of postglacial recolonization, a scenario which fits with palaeobotanical reconstructions. The description of the matrilineal genetic structure of this important tree species enables the detection of a clear case of introduction of an exotic population due to long-distance seed transfer.

Practical application

The investigations of the genetic diversity and differentiation of beech all over Europe have been a good basis to understand the inner structures of beech populations and the processes that maintain them. Naturally, parallel provenance experiments are the best way to answer the question of whether an intentional move of reproductive material could be recommended for the establishment of beech forest stands under conditions of the environmental stress, or on abandoned agricultural lands outside or even inside the beech natural distribution range.

The artificial regeneration will become more common for regenerating beech stands in the future. There are vast areas in Europe that were converted from mixed or broadleaved stands to coniferous monocultures. It is a common case that these stands are frequently not on the appropriate sites and their ecological stability is at risk. Mainly in the air-polluted areas the consequences are already visible. It is expected to convert these stands again into mixed or broadleaved stands with higher resistance potential.

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Table 1. Number of provenances in the Beech Trial Series established in 1986, 1987, 1988 and 1995 and the Institution in charge of the trial

Country	Person responsible	Institution	1986 Series 1	1987 Series 2	1988 Series 3	1995 Series 4
Austria	U. Schultze	Federal Forest Research Centre, Vienna				49
Belgium	D. Jacques	Station de Recherches Forestières, Gembloux			73	
Bulgaria	V. Karamfilov	Forest Committee, Sofia				49
Croatia	J. Gracan	Forest Research Institute, Jastrebarsko				51
Czech Republic	V. Hynek	Forest Research Institute, Jiloviste - Strnady				49
Denmark	S. F. Madsen	Ministry of Environment and Energy, Hørsholm	48			49
France	E. Teissier du Cros	INRA, Avignon		17	58	50
Germany BY	W. Ruetz	Centre for Tree Improvement, Teisendorf, Bavaria				57
Germany NW	M. Rogge	Forest Gene Bank, Arnsberg, Northrhine-Westfalia				116
Germany SN	H. Wolf	Saxonian State Centre for Forestry, Graupa, Saxony				104
Germany ST	F. Schuffenhauer	District Government, Dessau, Sachsen-Anhalt				49
Germany SH	H.-J. Muhs	Institute for Forest Genetics, Grosshansdorf		48	31/68[1]	147
Germany NW	H.-J. Muhs	Institute for Forest Genetics, Grosshansdorf	54	28		
Germany HE	H.-J. Muhs	Institute for Forest Genetics, Grosshansdorf	48		58	
Germany BW	H.-J. Muhs	Institute for Forest Genetics, Grosshansdorf		29	33	
Luxembourg	F. Theisen	Administration for Water and Forests, Luxembourg				49
Ireland	D. Thompson	COILLTE Research Laboratory, Newtownmountkennedy				49
Italy	R. Giannini	Faculty of Forestry, University, Florence				49
The Netherlands	S. de Vries	Institute for Forestry and Nature, Wageningen		32	70	
Poland	Z. Rzeznik	Forest Dept., Akademia Rolnicza, Poznan				71
Poland	M. Sulkowska	Forest Research Institute, Warsaw				49
Romania	V. Enescu	Academy of Agriculture and Forestry , Bucharest				27
Romania	V. Enescu	Academy of Agriculture and Forestry , Bucharest				44
Sweden	M. Werner	Forest Research Institute, Ekebo				36
Slovakia	L. Paule	University of Forestry and Wood Technology, Zvolen				100
Spain	F. Puertas Tricas	State Forest Service, Navarra				100
United Kingdom	N. Cundall	Northern Research Station, Roslin, Midlothian				53
Ukraine	I. Shvadchak	Institute of Forestry and Wood Technology, Lvov				70
		Total number of trials per series	**3**	**5**	**7**	**23**

[1] There are two parallel trials at this location.

Seed collecting and establishment of trials

It was aimed to have trials in all regions covered naturally by beech. However, owing to differing seed sets and availability because of political restrictions (e.g. former East Germany, Bosnia-Herzegovina) the number of trials and the regions represented vary considerably between the trial series. Figure 1 shows the location of the 38 field trials in 19 countries throughout the range of distribution of beech. A trial is located in most of the regions, except in Bosnia-Herzegovina/Serbia (Dinaric mountains), and Switzerland/France (western Alps/Jura) trials, which should have been included to give an even better coverage. A number of trials are near the border of the range of distribution and the trial in Ireland is outside the natural range of beech.

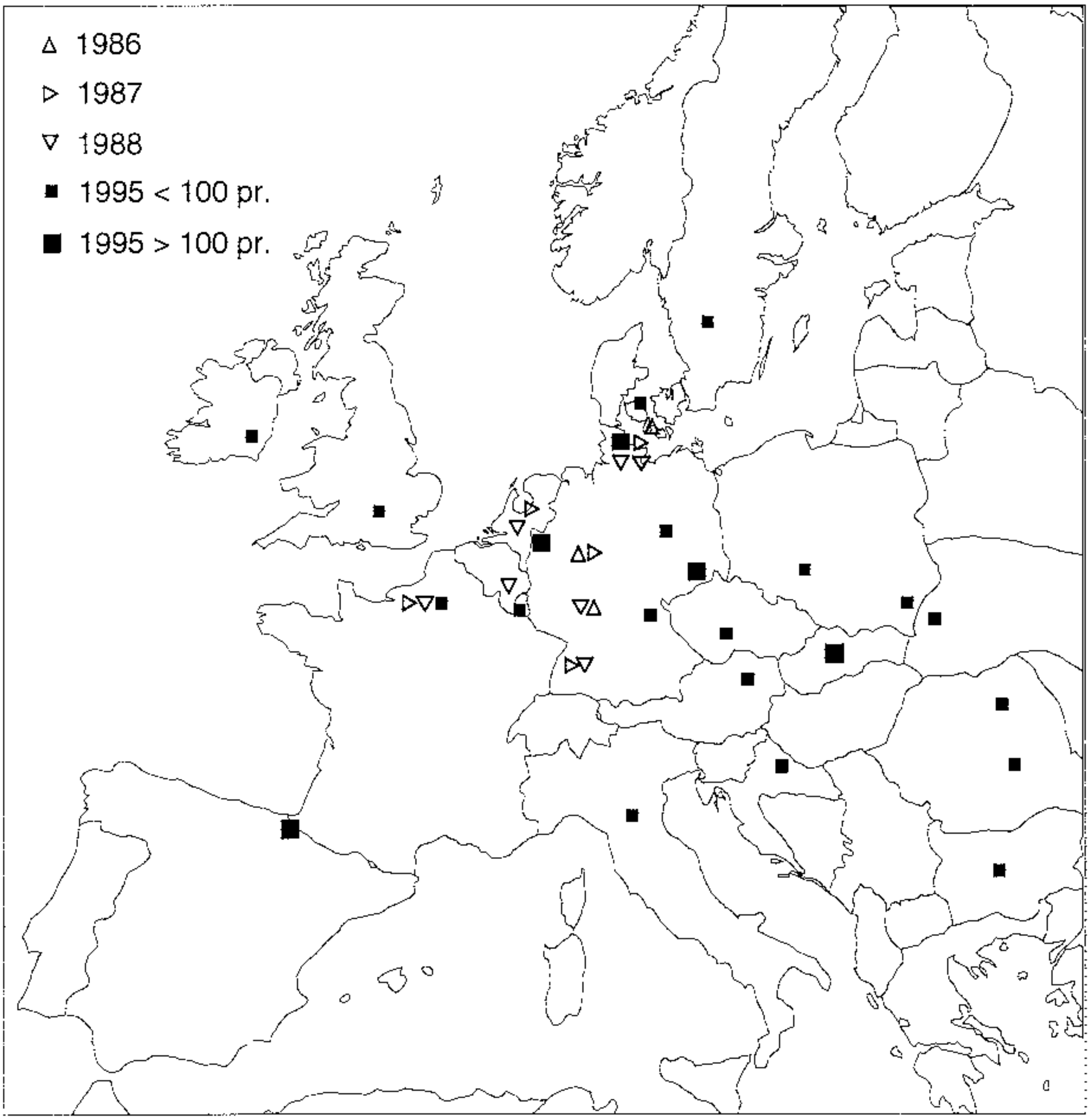

Fig. 1. Location of the trials. The 38 trials were established in 1986, 1987, 1988 and 1995 in 19 countries. The larger squares indicate trials with 100 or more provenances; the other trials contain between 17 and 73; most trials have 49 provenances.

Figure 2 shows the origins of the seed samples in the different trials. The different parts of the area of distribution of beech are sampled with different intensity. Czech Republic, Germany, Romania and Slovakia are very well represented. Bulgaria, France, Poland, Spain, Slovenia and Ukraine are quite well represented, whereas Austria, Croatia and Italy, especially southern Italy, are poorly represented. The area between Bosnia-Herzegovina, Serbia, Macedonia, Albania and Greece is not represented. This is regrettable because in this area, owing to the high variety in site conditions and the long period during which beech has been able to adapt to these sites, a large genetic variation and special ecotypes can be expected.

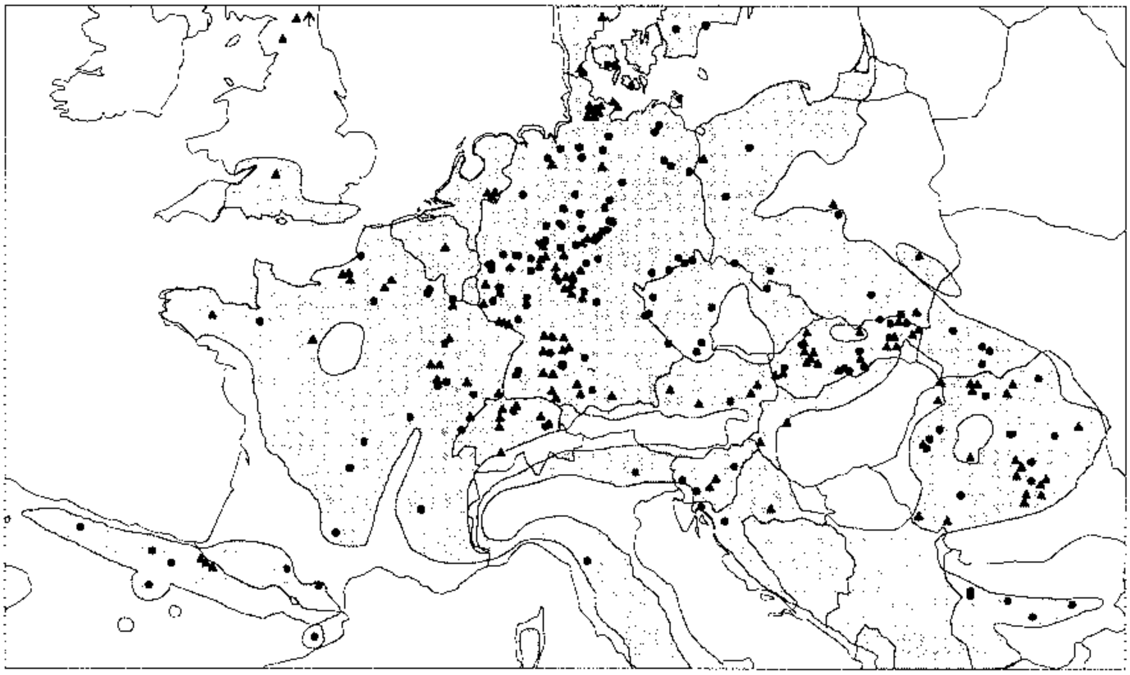

Fig. 2. Location of the 335 provenances included in the 38 trials established in 1986, 1987 and 1988 (triangles) and 1995 (dots).

Seed sample quality

The seed samples received at the Institute differed strongly in many respects: cleanliness, means and duration of transport, collecting method (by hand, by nets), commercial, state or scientific collection, pretreatments, etc. Seed quality differed accordingly. Some samples were too dry (<10% water content), others were mouldy because there was too little air exchange in the shipping bag, some seed samples showed a lot of damaged seeds. Generally, seed samples from distant places which had a longer journey were in worse condition than samples from nearby places.

Seed sample treatment

The seed samples were first cleaned and their moisture content determined. Depending on the freshness of the seeds they were left for a period of after-ripening of up to 4 weeks. The seed samples from 1990 and 1991 were stored by reducing the moisture content to about 10% and freezing at –5°C. Before seeding, the seeds were carefully remoistened to 30% water content and stratified at 3°C. When dormancy was broken, the seeds were frozen with water at –2°C until seeding. The seeds collected in 1993 were stratified to break dormancy and, as all other seed samples, frozen with water at –2°C until seeding time.

The time required to break dormancy differed strongly between the provenances. This was due to the preconditions (e.g. after-ripening) and possibly also to genetic differences. These effects could not be studied because the preconditions (harvesting, transport, treatments) were too different.

Seeding and rearing of plants

Seeding was done at the nursery of the Institute at Grosshansdorf and, because there was not enough space, also at commercial nurseries. Germination frequency and rate differed strongly between provenances. There seemed to be a relationship between the time required to break dormancy and germination: provenances which needed a long time to break dormancy seemed to have low germination frequency and were slow to germinate. Also, these provenances were prone to fungi attack in the seed bed. Shortly after germination and development of cotyledons the plantlets were struck severely by various damping-off fungi (e.g. *Phytophthora* sp.) from which they usually did not recover and dropped out quickly.

The different sensitivity of seed samples toward the fungi attack is probably not due to provenance differences. The duration of storage also had some influence, although there were seed samples collected in 1990 and 1991 which yielded a high number of plants. The sensitivity to fungi attack may also be the result of improper seed handling before storage which led to a general loss of vitality of the seeds. This can be presumed because damping-off fungi are mostly not specialized but rather occur ubiquitously. A general loss of vitality might also explain the longer periods required to break dormancy, and the slow, as well as low, total germination.

After the critical postgermination stage had passed, no further attack by fungi was observed. Following this, there was some irregular attack by *Phyllaphus fagi* L.. The plants of the 1995 series, sown in spring of 1993, were undercut during the first growing season for easier lifting and lifted in autumn of 1994 at 2 years of age. The plants of the other series were lined out after 1 year, transplanted for a further 2 years and were planted as 1+2 seedlings.

Design of the field trials

The layout of the trials is a randomized incomplete (series 1-3) or complete (series 4) block design with three replications. Planting was done in rows with a space of 2×0.5 m (series 1-3) or 2×1 m (series 4). Each plot was laid out with 100 plants (series 1-3) or 50 plants (series 4), resulting in a plot size of 10×10 m. Thus, a trial with 49 provenances occupies an area of about 1.5 ha. Plots are considered large enough to maintain the trials for 60 years. There are no bordering rows between the plots, usually only two rows were planted around the trials.

Table 1 gives the number of provenances included in each trial. In most trials there are about 49 or more provenances included, in five trials 100 or more provenances are represented. In the series planted in 1995, of the total of 147 provenances only 19 are represented in all of the trials and 36 provenances are included in more than 75% of the trials. The remainder of the provenances are represented on a differing number of field trials depending on the number of plants available. A number of joint partners added up to 24 mostly local provenances to their trial.

Traits to be recorded

The large number of trials and joint partners involved in this experiment requires precise definition of the characters to be recorded. Survival, plant height, trunk diameter (when trees have reached measurable sizes), flushing time, growth cessation, lammas shoots, stem form and any damages that might be observed will be recorded primarily. Additional traits are other form characters (branching, spiral grain, etc.) and genetic markers (isoenzymes, molecular). An important feature is that the position of the single trees measured is recorded to enable calculation of the effects of neighbouring trees as well as stand density effects and meaningful age-age correlations.

Participating institutions

Table 1 lists the persons and Institutions that have established and are maintaining one or more trials. We are very thankful for their endeavour and contribution. We are also very thankful to all those, mostly foresters, who provided the numerous seed samples for this trial. Neither without the field trials nor without the seed samples would the establishment of the trial network have been possible on a Europe-wide scale.

Database

A data bank is located at Grosshansdorf, where the geographical and site data of the provenances (stand age, soil, climate, etc.), the location data of the field trials (position, soil, climate, etc.), management of the trials, and the data collected in the field trials for the different traits will be kept centrally and made available to the joint partners. Processing will also be performed at the data bank.

Survival

Survival varied between trials, depending on the local conditions during planting and the weather in the year of establishment. Drought and strong late frosts after planting caused higher mortality in some trials (Bjelovar, Croatia; Nedlitz, Sachsen-Anhalt; Bayreuth, Bavaria). At other locations (Attendorn, Northrhine-Westfalia), extreme high soil acidity (pH 3.2-3.7), and damage by voles (Sweden) caused high mortality rates. At a polder site in the Netherlands there was high mortality due to flooding. Of the total of 38 trials, three had to be given up and two trials are strongly reduced in their usability because the survival rate is less than 50%. Thus, the remaining 34 trials are in a state to give reliable data potentially for a long period, which is important in a species with long rotation periods like beech. Differences in the survival rates between the provenances were observed. However, no general trends could be established so far.

Flushing

The times of bud burst and leaves flushing have been recorded on a number of the field trials in different years (Muhs 1985, von Wuehlisch *et al.* 1993, 1995a; Madsen 1995). These results show large differences in leaves flushing time in spring. Generally, provenances from the eastern and southeastern part of the distribution area (e.g. Slovakia, Romania, Bulgaria), as well as provenances from high elevations, require a smaller heat sum for flushing and thus flush early. Provenances from the western part of the distribution area (Spain, France, The Netherlands, Belgium, England) and from low elevations where late frosts occur, require a higher heat sum and flush late. Depending on the temperature development during spring, the time difference between the earliest and last individuals to flush in a set of provenances in a trial can be 4 to 6 weeks. Between the different years and over a number of sites, a certain stability in the ranking of flushing time was found in the provenances analyzed. More studies are necessary to also study year-to-year and site-to-site interactions in the flushing reaction of the provenances. It can be concluded that this character is adaptive and reflects the adaptation to a certain site in respect to late frost occurrence. T his makes flushing a very interesting character for the estimation of adaptation and adaptability of beech populations.

Temperature sum requirement for bud burst

In a further study on bud burst and leaf flushing the temperature sums at which flushing occurs were estimated (von Wuehlisch *et al.* 1995b). When summing up all degree-hours above 5°C from beginning of January, it was found that the investigated total of 159 provenances required an average of 9750 degree-hours for bud burst. The first tree to flush required 7600, the last one 14 750 degree-hours before bud bursting, which is about twice as much. Large differences were also found between the provenances. The first to flush required an average of 8500, the last one an average of 11 000 degree-hours. These differences underline the adaptive character of this trait. It may be assumed that when a provenance is frequently struck by late frosts because it flushes too early, it is probably also not adapted to that site in other characters.

Height growth

Plant heights have been recorded in the year after planting and in the following years at regular intervals. However, at this early stage, the height increment does not reflect the potential growth and the effect of the local environment on the genotype. The height increment reflects mainly how the plants took root and how they overcame the planting shock. Therefore it is too early, especially for the trial planted 1995, to present height data.

For the trials established in 1986, 1987 and 1988 some results have been published (von Wuehlisch *et al.* 1992, 1995c; Madsen 1995). No general trends could be established. In all regions studied, fast- as well as slow-growing provenances could be recorded. In some trials distinct differences between provenances were shown, in others not. In some trials with contrasting sites, e.g. poor, extremely acidified soil, as opposed to neutral soil, rich in nutrients, distinct genotype × environment interactions were found. However, among other trials no genotype × environment interactions could be proven. To conclude, in a species known for its compatibility and ability to change rank even above 42 years of age (Kleinschmit and Svolba 1995), the trials are still far too young to reflect the growth potential of the provenances.

Significance of the trial network for the genetic conservation of beech

Primarily, the collection of provenances and the network of trials throughout the area of beech occurrence opens the possibility of an evaluation of beech populations on a species-wide scale. This is of great value and provides the means to observe and document the growth and other adaptive or economically important traits of a set of provenances originating from most regions, on sites located in most of the regions of beech occurrence. The trial data will show how well populations have adapted to certain site-inherent environmental features, e.g. late frost occurrence, acidic or calcareous soil, etc., how non-adapted populations react to such situations, and how successfully they might cope with them. This is of great significance for formulating evaluation criteria to be able to assess the value of a given population in respect of the conservation of the genetic resources of beech.

Acknowledgements

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Programme

22 and 23 October
Arrival of participants at Bordeaux-Mérignac Airport

23 October

08h30	Departure for a visit of the molecular marker labs at INRA Forest Research Station
09h00-11h00	Visit of the molecular marker labs
11h00-12h00	Registration
12h00	Welcome aperitive with members of the 'Commission Nationale de Conservation des Ressources Génétiques Forestières'
13h00-14h30	*Lunch at INRA restaurant in Pierroton*
15h00-15h15	Welcome address (M. Arbez, INRA)
15h15-15h30	Introduction and format of the meeting (J. Turok, IPGRI)
15h30-16h15	Genetics of European oaks (A. Kremer)
16h15-16h30	*Coffee break*
16h30-17h15	Oak decline in Europe (T. Oszako)
17h15-18h00	Genetic variation of beech in Europe (L. Paule)
18h00-18h45	International provenance experiment on beech (R. Stephan)
19h00	Transfer by bus to Bordeaux city
20h00	*Dinner in Bordeaux City*

24 October

08h30-10h00	Regional working groups (country reports): session I
10h00-10h30	*Coffee break*
10h30-12h30	Regional working groups (country reports): session II
12h30-14h00	*Lunch*
14h00-16h30	Regional working groups (country reports): session III
16h30-17h00	*Coffee break*
17h00-18h45	Summary: Common needs, priorities and existing capacities on the conservation and sustainable use of genetic resources of oak and beech in Europe
19h00	Transfer by bus to Bordeaux
20h00	*Dinner in Bordeaux City*

25 October

08h30-10h00	Network session I: Coordination of ongoing activities at a European level
10h00-10h30	*Coffee break*
10h30-12h30	Network session II: Development of shared Network tasks according to the needs and capacities
12h30-13h30	*Lunch*
13h30-17h00	Excursion to local oak forests (riverside and coastal sand dunes)
17h00-18h30	Establishment of a workplan, conclusions and approval of the Report of the meeting
19h30	*Farewell dinner at restaurant Les Pavois in Arcachon Bay*

26 October
Departure of participants by shuttle bus service to the Airport

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