Noble Hardwoods Network

IPGRI

Report of the third meeting — 13-16 June 1998 — Sagadi, Estonia

J. Turok, J. Jensen, Ch. Palmberg-Lerche, M. Rusanen, K. Russell, S. de Vries *and* E. Lipman, *compilers*

EUFORGEN

European Forest Genetic Resources Programme (EUFORGEN)

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

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The International Plant Genetic Resources Institute (IPGRI) is an autonomous international scientific organization, supported by the Consultative Group on International Agricultural Research (CGIAR). IPGRI's mandate is to advance the conservation and use of genetic diversity for the well-being of present and future generations. IPGRI's headquarters is based in Rome, Italy, with offices in another 14 countries worldwide. It operates through three programmes: (1) the Plant Genetic Resources Programme, (2) the CGIAR Genetic Resources Support Programme, and (3) the International Network for the Improvement of Banana and Plantain (INIBAP). The international status of IPGRI is conferred under an Establishment Agreement which, by January 1998, had been signed and ratified by the Governments of Algeria, Australia, Belgium, Benin, Bolivia, Brazil, Burkina Faso, Cameroon, Chile, China, Congo, Costa Rica, Côte d'Ivoire, Cyprus, Czech Republic, Denmark, Ecuador, Egypt, Greece, Guinea, Hungary, India, Indonesia, Iran, Israel, Italy, Jordan, Kenya, Malaysia, Mauritania, Morocco, Pakistan, Panama, Peru, Poland, Portugal, Romania, Russia, Senegal, Slovakia, Sudan, Switzerland, Syria, Tunisia, Turkey, Uganda and Ukraine.

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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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Contents

Introduction

The third EUFORGEN Noble Hardwoods Network meeting was held at the Forestry Training Centre in Sagadi, Estonia, 13-16 June 1998. It was attended by 28 participants from 24 countries (see Participants). Network members from a further 3 countries were unable to attend. The meeting was opened H.E. Villu Reiljan, Minister of Environment of the Republic of Estonia. Prof. Gösta Eriksson, Chair of the Network, introduced the agenda of the meeting and asked for volunteers to serve as discussion leaders and rapporteurs. The importance of further joint efforts on forest genetic resources in Europe in view of the outcomes of the Third Ministerial Conference on the Protection of Forests (Lisbon, 3-5 June) was highlighted by Dr Jozef Turok, EUFORGEN Coordinator.

The first day of the meeting (see Programme) was focused on the further development of strategies and methodologies for the genetic resources of Noble Hardwoods. The European long-term gene conservation strategies, previously developed for maples (*Acer*), elms (*Ulmus*), rowan (*Sorbus*) and the wild fruit tree species, are concerned with a number of issues ranging from inventories of occurrence and abundance, genetic variation and variation patterns, breeding and reproductive systems, to regeneration, silviculture and sustainable use.[1] Further strategies on ash (*Fraxinus*), chestnut (*Castanea*) and lime trees (*Tilia*) were prepared and discussed at the meeting. The authors were commended for their documents. After incorporation of the comments and suggestions provided by the participants of the meeting, the three new Network's strategies are published in this volume. The core of any conservation strategy for Noble Hardwoods is their silvicultural management and sustainable use carried out with due attention to genetic principles. An overview paper was also presented on this topic, including a number of recommendations for the practical management. Recognizing the progress made by European countries, it was agreed that technical guidelines for the long-term gene conservation of Noble Hardwoods species be developed by the Network. They will be aimed at the forest officers in European countries. Their outline and production schedule were approved (see Workplan update).

The second day of the meeting was devoted to an excursion leading to some Noble Hardwoods stands located at the margins of the species' distribution areas in Europe. Practical gene conservation and tree breeding activities were presented by Estonian colleagues. Information on international developments in the area of forest genetic resources (FAO) and summary of the activities of the other EUFORGEN Networks was also provided and discussed.

With regard to global climate change, it is very important to ensure that genetic variation is available in tree populations to allow them to adapt to the changing environmental conditions. A discussion paper on this topic was presented on the third day of the meeting (see p. 98). An urgent need was expressed to give priority to research on mating patterns and reproductive biology of the Noble Hardwood species, as a basis for the development and implementation of the long-term strategies. The Network also discussed the information management of Noble Hardwoods genetic resources in Europe. The common descriptors, previously proposed by the Network, should be kept to the very minimum. While the development of national databases was encouraged, the issue of a common, centralized information system will need to be further discussed. In the meantime, a page has been set up on the Network's Internet site including electronic links to existing national databases as requested by the countries concerned. The Network decided to regularly update the overview of ongoing national and

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[1] The Reports of previous EUFORGEN Noble Hardwoods Network meetings and other related publications can be obtained from the EUFORGEN Coordinator, IPGRI, Via delle Sette Chiese 142, 00145 Rome, Italy. Fax +39-06-5750309; E-mail: j.turok@cgiar.org; <http://www.cgiar.org/ipgri/euforgen/networks/noble.htm>.

international research projects. The possibilities of securing additional EU funding for some of the Network activities were discussed, including shared-cost projects (EU Framework Programme V, INCO-Copernicus, etc.). Participants also expressed their wish to strengthen the links between EU-funded research projects and scientists in non-EU countries. The need to continue to raise awareness of policy-makers, foresters and the general public of the role and potential of these often overlooked species was emphasized. A first step has been taken through the recently published leaflet on Noble Hardwoods, but much still remains to be done in this area.

The meeting was concluded by adopting the workplan of tasks to be conducted by Network members as inputs in kind before the next meeting (see Workplan update). Four countries offered to host the next meeting and Gmunden, Austria was chosen as the venue. The meeting will be held 3-7 September 1999. The local organizers of the meeting were thanked for the excellent arrangements.

Workplan update

European long-term gene conservation strategies

The documents on *Fraxinus* spp. and *Castanea sativa,* which had been prepared and distributed before the meeting, were presented by the authors (A. Pliūra and J. Fernández-López and R. Alía, respectively).

The strategy on *Fraxinus* spp. was discussed. It was suggested that the document should refer to all parts of the distribution area and to the variety of situations in Europe.

The strategy document on *Castanea sativa* should also be revised. The objectives of the strategy should be stated explicitly and a part on gene conservation in general (including fruit cultivars) should be added.

J. Jensen presented a draft gene conservation strategy on *Tilia* spp. Owing to the distribution of *Tilia* and other Noble Hardwood species over large areas, the Network considered it important to exchange information with countries outside Europe. J. Turok offered to provide a link between the Network and the relevant non-European countries.

The Network asked all the authors of the strategy documents to incorporate the comments and suggestions made. The strategies on *Fraxinus* spp., *Castanea sativa* and *Tilia* spp. were adopted as joint Network outputs. It was recommended that the need for further research be emphasized in the papers.

It was noted that the strategy documents on *Alnus* spp. and *Juglans regia* (J. Gracan and R. Alía, respectively) could not be presented at this meeting. These documents will be discussed at the next Network meeting.

The European long-term gene conservation strategies should help in the conceptualization and development of national strategies. There should be close links between the two levels. However, regional strategies can never replace national strategies. National gene conservation strategies should be much more detailed than regional ones, and should be adapted to national objectives, needs and resources. Regional strategies, on the other hand, provide a common framework and will serve as a basis for developing the Technical Guidelines of the Network (see below).

Action to be taken and deadlines

All Network members will provide additional comments (including editorial suggestions) to A. Pliūra and J. Fernández-López and R. Alía **by 1 July 1998**, and to J. Jensen by 1 August 1998 (J. Jensen will send a draft document to all Network members before 1 July 1998). The three authors will submit revised documents to J. Turok **by 1 September 1998**, in order to be included in the Report of the meeting. The strategy on *Alnus* spp. (J. Gracan) and *Juglans regia* (R. Alía) will be finalized **before 1 September 1998**. J. Turok will circulate them to all Network members for comments. These two strategy documents will be discussed during the next meeting.

Technical Guidelines

Since its beginning the goal of the Network has been to produce minimum standards for gene conservation of Noble Hardwoods in the long term. Recognizing the progress made so far, it was agreed that technical recommendations for the long-term gene conservation as well as conservation and silvicultural management of Noble Hardwood species be developed. A new Network document should be produced aiming at the general forest officer or manager in charge of applied forest gene conservation. The objective is to provide generally valid guidelines which will then be "translated" according to the situation in each country.

The following outline was approved and co-authors invited to contribute:

1 Foreword
2 Introduction (G. Eriksson, J. Kleinschmit and J. Turok)
3 Evolutionary genetics and forest tree gene conservation (G. Eriksson)
4 Gene conservation of Noble Hardwoods in situations where their occurrence is widespread (M. Rusanen, A. Pliūra and J. Jensen)
5 Gene conservation of Noble Hardwoods in situations where their occurrence is rare (B. Demesure, R. Stephan and J. Kleinschmit)
6 Case study: Multipurpose Noble Hardwoods – chestnut and walnut (J. Fernández-López and R. Alía)
7 Case study: Gene conservation of elms and possibly other species that require special treatment (E. Collin)
8 Descriptors (J. Jensen)
9 Conclusions (G. Eriksson, J. Kleinschmit and J. Turok)

The document on *in situ* conservation and silvicultural management strategies of Noble Hardwoods, prepared by P. Rotach and circulated before the meeting, was acknowledged by the participants. After incorporating the comments provided, this paper will be included in the Report of the meeting. It was adopted as an output of the Network. Parts of the paper will be used in the relevant chapters of the Technical Guidelines.

Action to be taken and deadlines
G. Eriksson will lead the preparation of the draft document. The draft Technical Guidelines (except for the Conclusions) will be distributed to all Network members **2 months before the next meeting.**

Table 1 ("Noble Hardwood species considered important for gene conservation in European countries"–Page 5 in the Report of the second Network meeting) will be updated. It was agreed to simplify the format of the Table. J. Turok will remind the Network members to revise the Table in their countries **by 1 July 1998**, providing information in the new, agreed-upon format (see Overview, p. 7). Each Network member will reply **before 1 August 1998.**

P. Rotach will send the revised paper on *in situ* conservation and silvicultural management to J. Turok **by 1 September 1998.**

Progress made in the national gene conservation strategies on Noble Hardwoods

Progress made in each country since the last meeting was presented during the meeting. Although heterogeneous, the presentations gave an overview of current work and offered references to further information. Introductory reports were presented by countries attending for the first time: Bulgaria, Estonia and the United Kingdom. These new reports are published in full in this Report of the meeting. The need for publishing progress reports was discussed. It was agreed that the progress reports will not be included in the Report of the meeting but will be available on request and on the internet.

Action to be taken and deadlines
A synthesis of the progress made will be prepared by J. Turok and included in the Report of the meeting. All Network members will send him brief, written progress reports **by 1 August 1998** to be used in the synthesis. The reports should be no longer than one page, will be sent electronically and should cover the following points: main current threats, research activities, applied gene conservation activities, public awareness and references. It was

agreed that these reports will be compiled in a standard format, that one copy will be sent to each Network member and that the compilation will also be included on the Network's internet site (by J. Turok, **by 15 September 1998**).

Inventories and documentation on Noble Hardwoods genetic resources

Descriptors: The Network acknowledged the list of descriptors developed previously by J. Jensen and published in the Report of the second meeting. These descriptors provide the minimum required information standards of the Noble Hardwoods Network.

Databases: The main objective of the Network in this regard is to share information on genetic resources and gene conservation of Noble Hardwoods. B. Demesure presented a concept note on the development of databases at national level which aims at providing assistance in building up these databases. It is essential to encourage the establishment of national databases wherever they do not yet exist. E. Collin was suggested to act as the focal person of the Network for databases. Consideration will be given to establishing decentralized or centralized databases by the Network in the future.

Several countries mentioned that their databases on genetic resources at a national level include Noble Hardwood species, but these are often not itemized separately. They are usually referred to as a group of "broadleaves". The Network, therefore, recommended that inventories of Noble Hardwoods be given priority in each country.

R. Stephan presented a report on the basic requirements for inventories of Noble Hardwood genetic resources and mentioned an example of the databases used in Germany.

Overview information on the Global Forest Resources Assessment of FAO was provided by C. Palmberg-Lerche.

Action to be taken and deadlines

J. Turok will set up a link page on the Network's internet site and will include the electronic version of the common list of descriptors. Network members from countries wishing to have an electronic link to the respective national database from that internet site will provide details to J. Turok (including names and addresses of the persons directly responsible) **by 1 September 1998**.

B. Demesure and R. Stephan will complete their contributions and submit them to J. Turok for the Report of the meeting (**by 1 September 1998**).

Research

Following the presentation of G. Eriksson on Genetic Resources of Noble Hardwoods in view of the global changes of the environment, the participants recommended that priority in research be given to studies on mating patterns in Noble Hardwood species. This issue is very important for the further development and implementation of the European long-term gene conservation strategies.

E. Collin presented the current activities within the EU/GEN RES 78 project on elms, J. Fernández-López described the work of COST Chestnut Working Group on Genetics and Breeding, B. Demesure mentioned the new multi-species project FAIR-CYTOFOR. A. Alexandrov described a collaborative project on broadleaved species in southeastern Europe.

The Network encouraged and will technically support the efforts of COST Chestnut WG in establishing combined provenance/progeny trials.

The participants expressed their wish to strengthen the links between EU-funded research projects and scientists in non-EU countries.

Action to be taken and deadlines

G. Eriksson invited the Network members concerned to attend an *ad hoc* meeting (**in October 1998**) in Uppsala in order to formulate a shared cost project proposal (mating patterns of Noble Hardwoods) that would be submitted for funding to the EU Framework V programme. The call is expected in January 1999. It was proposed to include an item on research needs on the agenda of the forthcoming meetings. This would allow for participants to express interest.

The Network decided to regularly update the overview of ongoing research projects, national and international. A. Prokazin will be asked to circulate an update. All Network members will send him any new information **by 1 September 1998.**

J. Turok will summarize and provide to Network members information about the possibilities for developing various international collaborative projects (e.g. INCO, Copernicus of the EU) **by 1 October 1998.**

Literature reviews

The completed bibliography on *Ulmus* spp. (E. Collin) was published in the Report of the second meeting and on the internet. The compilers responsible for the other species requested all countries to send references or notify them about the non-availability of such references. It was suggested that the bibliographies included on the internet should be available in a searchable database format. The compilers (see below) will send a reminder to all Network members.

Compiler	Species
B. Demesure	*Prunus avium, Sorbus* spp.
V. Buriánek	*Carpinus betulus, Fraxinus excelsior, Malus sylvestris, Pyrus pyraster*
F. Ducci	*Alnus cordata, Acer lobelii, Betula pendula, Pyrus amygdaliformis*
S. de Vries	*Acer platanoides, A. pseudoplatanus, A. campestre, Tilia cordata, T. platyphyllos, Alnus glutinosa*
R. Alía	*Castanea sativa, Juglans regia, Fraxinus angustifolia*

Action to be taken and deadlines

The complete remaining species bibliographies will be sent by the compilers to J. Turok **by 1 October 1998.** They will be made available on the internet **before the end of the year**. Hard copies will be available on request from J. Turok.

Other tasks of the Network

It was noted that a joint letter clarifying the position of the Network on the movement of forest reproductive material of Noble Hardwoods had been distributed (S. de Vries with J. Turok) and that a public awareness leaflet on Noble Hardwoods had been produced (text by F. Müller). The Network members were encouraged to distribute, in consultation with National Coordinators, the Network publications to all those concerned or interested in their respective countries.

Next Network meeting

Offers were received from Austria, France, Italy and Sweden. It was decided to organize the next Network meeting **in Gmunden, Austria, 3-7 September 1999.**

Overview: Noble Hardwood species considered important for gene conservation in European countries

Species	AUT	BEL	BGR	HRV	CZE	DNK	EST	FIN	FRA	GBR	DEU	HUN	ITA
Alnus cordata									×				×
Alnus glutinosa	×	×		×	×	×			×	×	×		
Acer campestre	×					×	×			×	×		
Acer lobelii													×
Acer platanoides	×		×	×	×	×	×	×			×		×
Acer pseudoplatanus	×	×	×	×	×	×			×		×		×
Betula pendula					×		×	×		×	×		×
Carpinus betulus	×					×				×	×		
Castanea sativa			×	×					×	×	×		×
Fraxinus angustifolia	×		×	×	×				×				×
Fraxinus excelsior	×	×	×	×	×	×	×	×	×	×	×		×
Juglans regia	×		×	×					×	×	×	×	×
Malus sylvestris	×	×			×	×			×	×	×	×	
Prunus avium	×	×	×	×	×	×			×	×	×	×	×
Pyrus amygdaliformis													
Pyrus pyraster	×				×	×			×		×	×	
Sorbus aria	×				×	×				×	×		×
Sorbus aucuparia	×				×	×			×	×	×	×	×
Sorbus domestica	×				×				×	×	×		×
Sorbus torminalis	×				×	×			×	×	×		×
Tilia cordata	×	×	×	×	×	×	×	×	×	×	×		×
Tilia platyphyllos	×	×	×	×	×	×				×	×		
Ulmus canescens													
Ulmus glabra	×	×	×	×	×	×	×	×	×	×	×	×	×
Ulmus laevis	×	×	×	×	×	×	×	×	×		×	×	×
Ulmus minor	×	×	×	×	×				×		×	×	
Ulmus procera										×			

Species	LVA	LTU	MLT	NLD	POL	PRT	ROM	RUS	SVK	ESP	SWE	CHE	UKR
Alnus cordata													
Alnus glutinosa	×	×		×		×	×		×	×			×
Acer campestre				×	×	×	×	×		×			
Acer lobelii													
Acer platanoides	×	×				×	×	×	×	×		×	×
Acer pseudoplatanus				×		×	×	×	×	×		×	×
Betula pendula	×	×						×		×			×
Carpinus betulus	×	×		×							×		×
Castanea sativa						×	×	×		×		×	×
Fraxinus angustifolia			×			×	×		×				×
Fraxinus excelsior	×	×		×	×	×	×	×	×	×	×	×	×
Juglans regia						×	×	×		×		×	
Malus sylvestris	×	×		×		×	×		×			×	×
Prunus avium	×	×		×		×	×		×	×		×	×
Pyrus amygdaliformis			×										
Pyrus pyraster	×	×		×		×			×			×	
Sorbus aria					×	×	×		×				
Sorbus aucuparia	×	×		×		×	×		×				×
Sorbus domestica	×					×	×		×			×	
Sorbus torminalis					×	×	×		×			×	×
Tilia cordata	×	×		×		×	×	×	×		×	×	×
Tilia platyphyllos	×			×	×		×		×			×	
Ulmus canescens			×										
Ulmus glabra	×	×		×	×		×	×	×	×	×	×	×
Ulmus laevis	×	×		×	×		×	×	×		×	×	×
Ulmus minor		×		×	×	×	×		×	×	×	×	
Ulmus procera						×	×						

AUT=Austria, BEL=Belgium; BGR=Bulgaria; HRV=Croatia; CZE=Czech Republic; DNK=Denmark; EST=Estonia; FIN=Finland; FRA=France; GBR=United Kingdom; DEU=Germany; HUN=Hungary; ITA=Italy; LVA=Latvia; LTU=Lithuania; MLT=Malta; NLD=Netherlands; POL=Poland; PRT=Portugal; ROM=Romania; RUS=Russia; SVK=Slovaka; ESP=Spain; SWE=Sweden; CHE=Switzerland; UKR=Ukraine.

European long-term gene conservation strategies

Ash (*Fraxinus* spp.)

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Introduction

In Europe, four *Fraxinus* species grow naturally, the common ash (*Fraxinus excelsior* L.) and narrow-leaved ash (*Fraxinus angustifolia* Vahl.) being the most important commercially. Common ash is the most important forestry species in many European countries. This species is intensively used for the production of timber of high value. Therefore, interest in silviculture, breeding and gene conservation activities of common ash in many countries has risen recently. However, so far only a few European countries have developed gene conservation programmes or strategies for *Fraxinus*.

Most conventional concepts of conservation of biodiversity as a whole, and genetic diversity in particular, build on a misconception that maximum fitness has already been obtained in nature. Consequently, the present genetic constitution is identified as the prime objective of conservation. This results in a static character of conservation activities where no active silvicultural measures are taken. Eriksson *et al.* (1993) strongly emphasized that the present-day genetic structure is transient. It should, therefore, not be regarded as the objective of gene conservation but as the starting point. The conventional programmes for conservation of forest genetic resources are not able to cope with extensive human expansion into forest lands, rapid global and local environmental changes which are caused by human activity, and with stochastic perturbations in the natural ecosystems that are heavily altered by humans. The limitations put on management in strictly protected areas or gene conservation populations are not able to compensate for the negative impacts of these environmental changes and increased magnitudes of the stochastic perturbations. An active, targeted management is the only way to counteract these impacts and enhance the diversity and adaptedness of forest tree species.

The understanding that to cope with present and future pressure on forests a sound forest tree gene conservation should be based on an evolutionary approach and be dynamic is increasing (Namkoong 1984a, 1984b; Hattemer and Gregorius 1990; Eriksson *et al.* 1993; Finkeldey and Hattemer 1993; Hattemer 1995; Koski *et al.* 1997; Pliūra 1997; Pliūra and Eriksson 1997). The evolutionary approach means that the prime objective of gene conservation is not just to conserve existing genetic variation but also to create good conditions for increasing adaptation and future evolution of the species. Therefore, gene conservation must be dynamic and based on evolutionary genetics. Defining a long-term gene conservation strategy and subsequently developing programmes on gene conservation requires knowledge on the natural range of species, pattern of distribution, population structure, ratio of within- and among-population variation, role and stage in the ecosystem, pollen and seed disseminators (vectors), particular biological features, present status and tendencies of forestry and silviculture, current and future demands for all kinds of forest utilities and changes of climate and environment.

Current status of *Fraxinus* species and some particular features

The common ash is the largest forest tree in the genus *Fraxinus*, typical of European fertile, multispecies, broadleaved and mixed deciduous forests. The natural range of the common ash covers nearly all Europe with the exclusion of the most northern and most southern parts, from the shores of the Atlantic in the west to the Volga river in the east (Fig. 1). The most northern limit of its natural range is in Norway at about 64° lat. N. The southern margin reaches the latitude of 37°N in Iran. In the mountains, common ash reaches its maximum elevation in the Pyrénées at 1750-1800 m asl, in the Swiss Alps at 1630 m asl (Hegi 1927). It can be found at much higher elevations in Asia, up to 2200 m asl in Iran (Browicz 1990). The natural range of taxonomically more complicated narrow-leaved ash is shifted more to the south; it covers the Mediterranean region and is spread in northern Africa and in West and Central Asia.

The centre of natural occurrence of common ash in most of Europe is mainly in floodplain forests. However common ash also grows along the water runs even in higher vegetation zones. In southern Europe especially, the natural occurrence of common ash is shifted to the higher elevations. Besides floodplain wet soil sites, the common ash represents a typical species of slopes and ravines, growing there in mixture with some other characteristic species like maple, lime and elm. In such conditions ash can grow from the oak altitudinal vegetation zone to the beech-spruce zone of submountain and mountain regions, sometimes even at top areas, mainly on basal soils. Owing to difference in sites occupied and stand types, some publications refer to the existence of different ecotypes of common ash – the floodplains ecotype, the hillside ecotype growing along smaller water runs in higher forest zones up to beech-spruce stand class, the scree ecotype growing on slopes, and limestone ecotypes. However, the existence of ecotypes has not been proven in experimental field tests and therefore postulated soil races or ecotypes should be considered as being phenotypic (Weiser 1995).

On the European scale, neither the common ash nor the narrow-leaved ash are endangered as forest tree species. However, the natural range and areas of ash forests have decreased constantly during the last 4000 years. Many common ash forests have been destroyed by humans in the areas currently occupied by agricultural lands. Many of the present populations of ash occupy the scattered refuge areas that were less suitable for agriculture. Taking all these circumstances into account, most countries consider *Fraxinus* to be threatened at the population level. Only recently (during the last 3-4 decades) silviculture has promoted common ash (supporting natural regeneration, planting, favouring during thinning, etc.), considering its high economic value. For this reason, common ash has increased in proportion in the younger forest stands in many countries.

A combination of two types of pollen and seed dispersal in the species (anemochory and zoochory) provides the powerful mechanism for successful natural regeneration that can be observed in many stands or temporarily unforested habitats. The common ash exhibits properties that are intermediate between typical pioneer tree species and a permanent forest component. The diversity of behaviours depending upon ecological conditions, which expresses itself in the effective use of many ways of achieving reproduction successfully, is the most important feature of the biology of *Fraxinus* species (Falinski and Pawlaczyk 1995). Its reproduction strategy could be based on either vegetative or generative regeneration, or on a combination of both. Abundant young generations of ash occurring under the canopy grow very slowly but small trees preserve the capacity to survive for a long time. They can regain normal growth rhythm after thinning or clear-cutting of the stand (Lust 1972). In spite of the high regeneration potential of the species, the reproduction of some valuable autochthonous populations is not ensured.

It is recognized (Lande 1988) that future conservation plans should be based on both knowledge of the species demography and population genetics in assessing the requirements for species survival. One of the most important steps in defining the conservation strategy is to identify factors threatening that species. The factors leading to extinction can be subdivided into two categories: systematic pressures and stochastic perturbations (Shaffer 1981). The systematic pressures lead to the deterministic extinction (Gilpin and Soulé 1985).

Fig. 1. Natural range of *Fraxinus excelsior* L. distribution in Europe.

Among systematic pressures that have already threatened, continue to or will threaten *Fraxinus* gene resources in the future, the following should be considered: deforestation and loss of habitats due to glaciation and human activity; natural climatic changes; climatic changes due to global warming; different effects of air pollution; long-term pressure on forests for all types of human utility production; improper forest management practice; competition by other species; damage by game; uncontrolled transfer of reproduction material for artificial regeneration. Gene conservation activities should be designed to compensate for all these systematic pressures threatening the species. All these threats can be considered as having stochasticity aspects too. Shaffer (1981) distinguished four types of stochastic perturbations (variation, fluctuation) that contribute to population extinction: demographic stochasticity, genetic stochasticity, environment stochasticity, and catastrophes. All these perturbations can be considered to affect the populations of *Fraxinus*. Therefore our task is very demanding – to compensate or overcome both systematic and stochastic pressures.

Genetic knowledge

The knowledge on the genetic structure of *Fraxinus* is still insufficient since there has been little research on the population genetics of *Fraxinus*. Nevertheless, the differences among provenances have been clearly identified in phenotypes and have been repeatedly proven in progeny tests and in practical forestry (Nikolaeva and Vorob'eva 1978; Smintina 1993; Giertych 1995a, 1995b; Kleinschmit *et al.* 1996). The similar geographical pattern variation of different traits was found in studies on American species of ash (Clausen *et al.* 1981; Clausen 1984; Raymond and Lindgren 1990; Roberds *et al.* 1990; Schuler 1994). Population structure and ratio of within- and among-population variation are influenced by the pattern of the species distribution, its role and stage in the forest ecosystem, pollen and seed vectors, particular biological features, etc. The present scattered distribution and specific ecological requirements indicate that the populations of *Fraxinus* are probably more differentiated than those of wind-pollinated species with continuous distribution. Results from half-sib progeny trials have shown the existence of significant within-population variation as well. In most experiments a variation between single tree progenies between families within provenances was as high as variation between provenances.

Gene conservation objectives

A sound gene conservation strategy should be based on sound objectives. The prime objective of gene conservation is to ensure a continuous survival and adaptability of the species over an unlimited number of generations in a continuously changing environment through evolution. Gene conservation should be based on methods that are able to cope with all types of systematic pressures and stochastic perturbations. One of the general prerequisites for successful evolution is that the gene resource population be regenerated. Thus, active measures should be foreseen where there are difficulties in maintaining the designated gene resource population over generations.

In a long-term perspective there will, with high probability, be an increased pressure to raise the production of timber. The increased demand in the future (FAO 1994) raises the importance of tree breeding. Gene conservation ought to be carried out jointly with tree breeding in order to save costs. Such combined breeding/gene conservation also has to be dynamic in order to cope with the uncertain future.

Gene conservation approach

In order for gene conservation to be successful, attention needs to be given to the links and interdependencies of conservation at the ecosystem, species and interspecific levels. Conservation of genetic diversity is one of the three key issues in sustainable conservation of biodiversity. To be successful, the conservation of biodiversity should be built on gene conservation as its elementary component. Therefore, gene conservation should be considered as an integral part of nature conservation and be integrated into nature conservation programmes.

To reach the main objective of gene conservation, it is necessary to promote the maintenance of a broad genetic variation and to create good conditions for the fast adaptation of species. To be able to compensate for the negative impact of environment changes and increased magnitudes of stochastic perturbations, gene conservation should be dynamic and based on an evolutionary approach with continuously increasing adaptability by means of targeted management.

Conservation of genetic diversity in forest ecosystems can be achieved through a diversity of approaches combining strictly protected areas with forest intensively managed for the production of timber or other utilities (Kemp 1992; Ouedraogo 1997; Palmberg-Lerche 1997). Two different strategies of gene conservation can be used: a) specific active gene conservation measures, and b) sustainable forest management and nature conservation. They should be complementary to each other. If specific conservation programmes are only successful in designated gene conservation areas in the future, there may be only "an oasis of flourishing genetic diversity in the desert of vast landscape". The ideal situation would be to integrate silviculture in the commercial forest stands similar to the areas of dynamic gene conservation. Therefore, the main elements of the strategy that is designated for gene conservation in targeted areas should also be strongly recommended for common commercial forestry. Gene conservation activities have to be integrated into management plans. The strategy for promotion and gene conservation of Noble Hardwoods by sustainable forest management (silviculture) is presented in the paper of Rotach (see p. 39). We scrutinize the strategy for specific active gene conservation measures in designated gene conservation areas.

Genetic variation is a function of allele frequencies and allelic effects. The species carries a low number of common alleles at intermediate frequencies and a very large number of low-frequency alleles resulting from mutations (Fig. 2). Two variables could be distinguished to describe the distribution of alleles: first, alleles can be divided into those which are common (>0.05) and those which are rare; second, the alleles can be divided as to whether they are widespread over populations or localized to a few populations (Adams 1981; Yang and Yeh 1992). That classification results in four types of alleles: common widespread, common localized, rare widespread, and rare localized. The main contributors to existing genotypic variation are the 'common' alleles. These alleles are of main interest for the diversity of reproductive material. Additive variance is a prerequisite for progress by natural or artificial selection. However, genes at low frequencies (<0.01) as well as genes at high frequencies (>0.99) do not contribute much to the additive variance. Therefore, neither natural selection nor breeders will be able to raise low-frequency genes. Less common alleles contribute to potential variation (Danell 1993a). Therefore, rarer alleles should be conserved for long-term tree breeding and evolutionary needs (Fig. 2). At present there is a general consideration that gene conservation should aim at conserving alleles of frequencies above 0.01 (=1% of alleles).

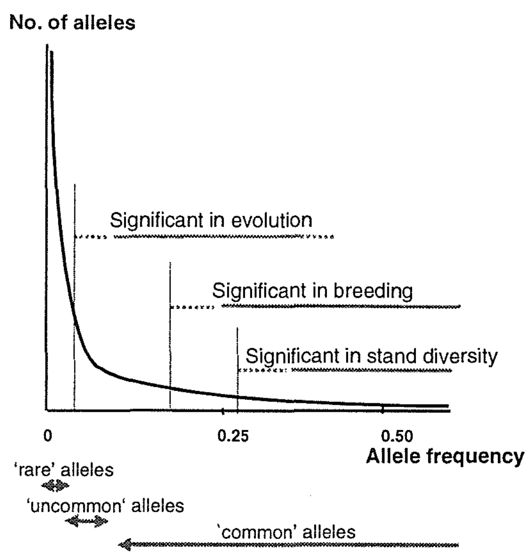

Fig. 2. Distribution of alleles of different types and their significance (Danell 1993a).

Multiple population approach

Both *in situ* and *ex situ* gene conservation of *Fraxinus* spp. should be based on a multiple population approach when the gene resource population is split into small subpopulations located over a range of environments, and thus exposed to natural selection and in turn to evolution in a variety of directions.

The Multiple Population Breeding System (MPBS) concept, first developed for breeding (Namkoong 1976) and then extended to joint breeding and gene conservation (Namkoong 1984b), should be the core of gene conservation. MPBS means that the joint breeding/gene resource population would consist of small subpopulations over a range of environments. The essence of dynamic gene conservation according to the MPBS concept is to promote adaptation by exposing the gene resource population to natural selection and in turn to evol-

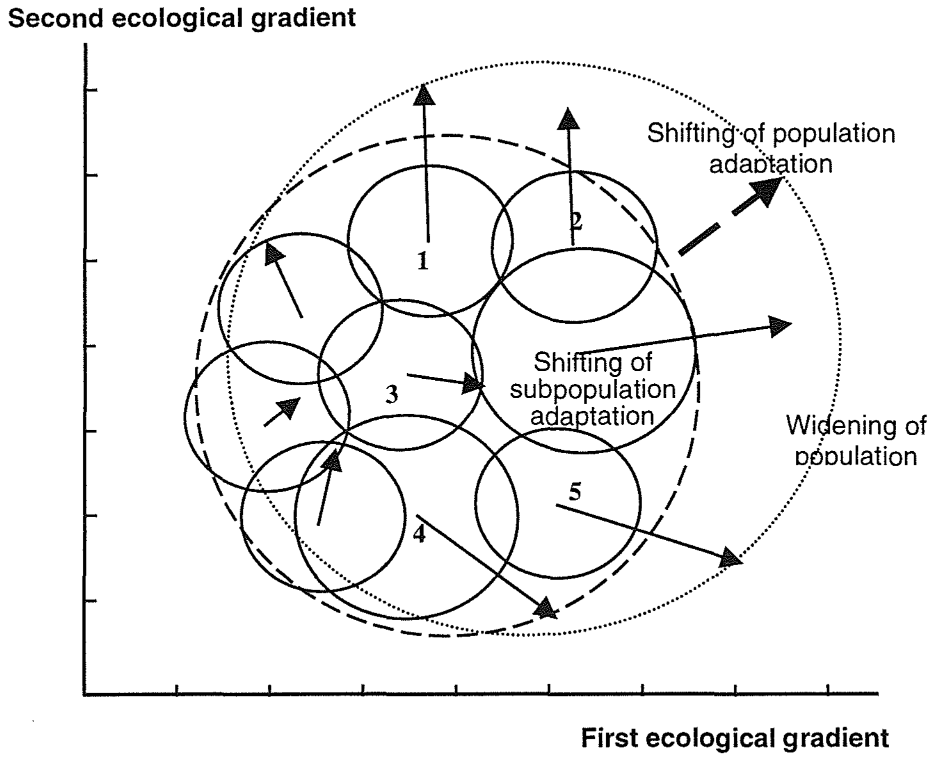

Fig. 3. Changes in distribution of subpopulations over ecological gradients: shifting of their adaptation in a variety of directions, shifting and broadening of population adaptation range.

ution in a variety of directions (Eriksson *et al.* 1993) (Fig. 3). The main principles of dynamic gene resources conservation by applying the MPBS concept are presented in Figure 4.

A prerequisite for natural or artificial selection to be operative is that the gene resource population is large enough to capture high genetic (additive) variation and to avoid genetic drift. According to the MPBS concept, breeding/gene resource conservation population of single species should consist of approximately 10-20 subpopulations, each with an effective population size (N_e) of 50 genetic entries making a total gene resource population of 500-1000 entries. These figures are based on the probability of saving genes at frequencies above 0.01 and of avoiding severe inbreeding in the subpopulations (Danell 1993a; Pliūra and Eriksson 1997). With an effective population size of 50 individuals in a subpopulation, the rate of inbreeding will be 1% per generation ($1/2N_e$) which might be regarded as satisfactorily low. This is also the rate of loss of additive variance (Fig. 5). In order to capture alleles of frequencies above 0.01 with 0.99 probability, the gene conservation population should consist of about 750-1150 individuals (Fig. 6). If we consider capturing alleles of lower frequency, the number of individuals needed increases very rapidly. Because of the risks of natural or man-made disasters, gene conservation populations larger than 1000 trees would be meaningful. The relatively small number of genotypes in subpopulations will help fixation of new genes arisen from mutations and may speed up evolution.

At present, the advantages of the MPBS concept are widely recognized (Barnes *et al.* 1984; Namkoong 1984b; Namkoong *et al.* 1988; Barnes 1995; Williams *et al.* 1995; Koski and Tigerstedt 1996). The most intensive form of MPBS includes planting of regular progeny trials (Danell 1993b; Pliūra and Eriksson 1997). Less intensive forms may be utilized for species not included in extensive breeding programmes (cf. Eriksson *et al.* 1993; Varela and Eriksson 1995).

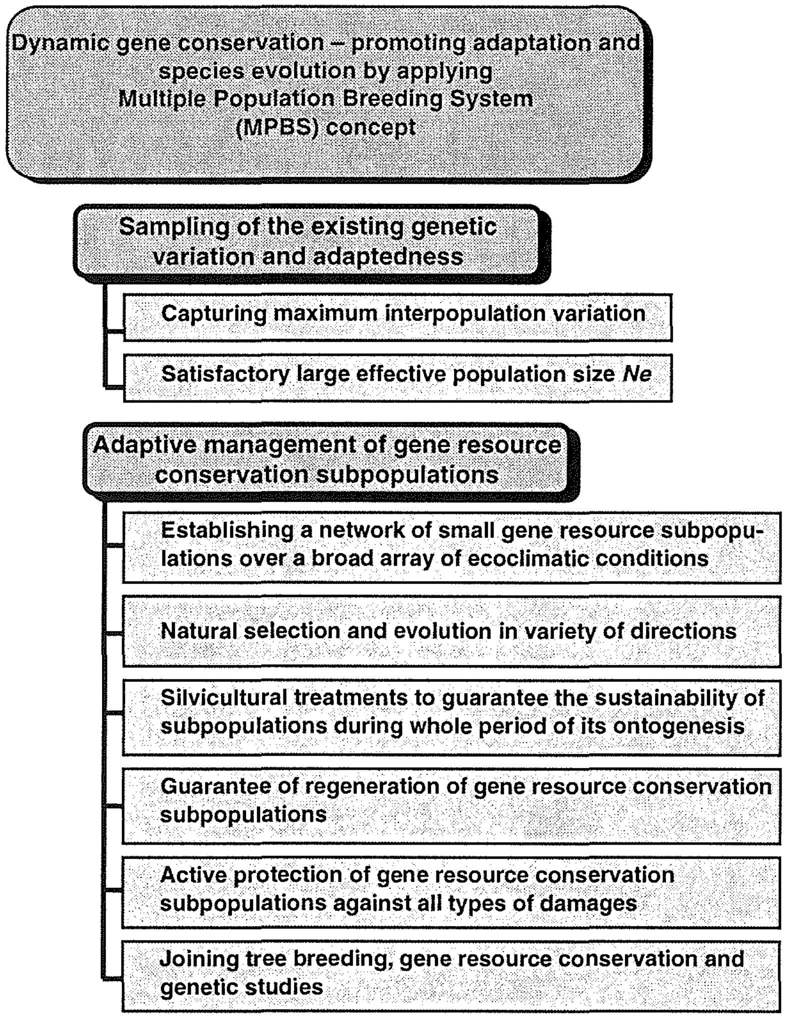

Fig. 4. The main principles of dynamic gene resources conservation by application of the Multiple Population Breeding System (MPBS) concept.

Choice of gene conservation method

Different patterns of genetic variation and therefore different types of adaptability can be noticed both between species and within single species in different parts of the natural range (that is the case with common ash as well). Therefore, gene conservation activities should be different when the species is common over large areas, constituting large randomly mating populations, or when a species is rare along its margin and constitutes small populations, more or less adapted locally, with limited gene exchange. Each country should decide upon what strategy should constitute the core of its national gene conservation of *Fraxinus*.

For many European countries where larger populations of common ash are found on a variety of sites, including optimal ones, *in situ* methods are sufficient for conservation and can constitute the core of national gene conservation programmes. The protected areas for conventional *in situ* conservation (gene reserves, seed reserves, seed stands, etc.) can be used as a base for establishing the network of gene resource subpopulations for *in situ* dynamic gene conservation by applying the MPBS concept. As common ash on many sites constitutes pure stands, the gene conservation programmes can be designated only for the conservation of a single species. However, ash could be jointly conserved with other species *in situ* in the ecosystem in which it exists as well. That would be a low-cost alternative for joint *in situ* gene conservation of some species in mixed stands. To be successful, the joint gene conservation of all species there should be dynamic, evolutionary oriented, and based on the MPBS concept as well.

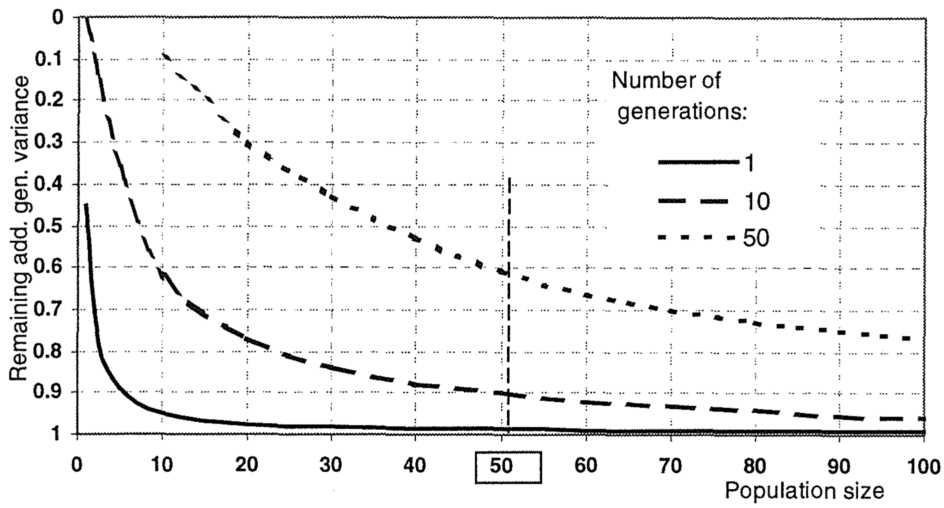

Fig. 5. Remaining additive genetic variance at different population sizes after 1, 10 and 50 generations (based on Danell 1993a).

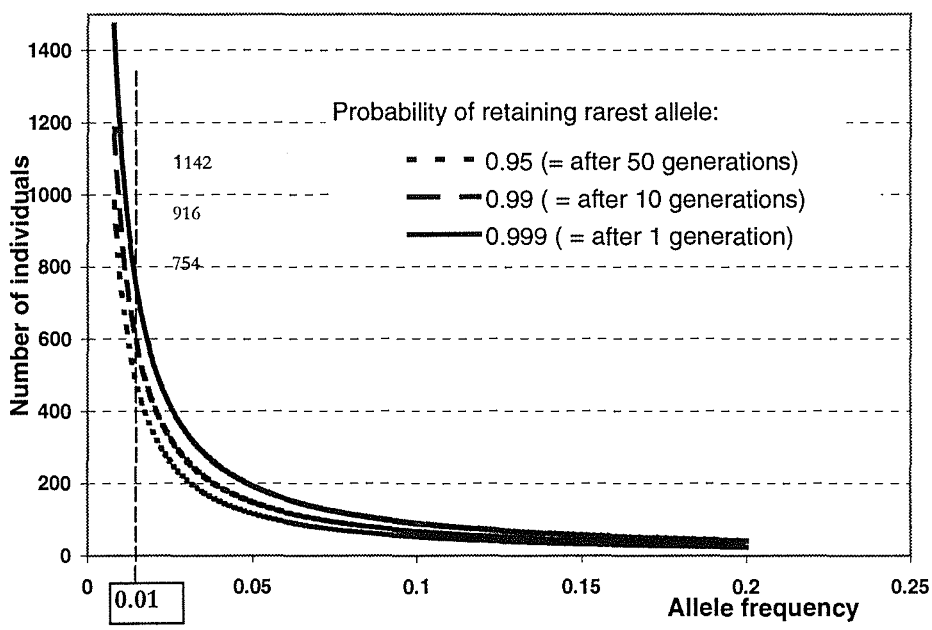

Fig. 6. The number of sampled individuals required to capture low-frequency alleles with certain probability (based on Gregorius 1980).

Ex situ conservation of gene resources in the form of progeny trials as the most active and effective gene conservation method (Eriksson *et al.* 1993) should be defined as the main conservation method for *Fraxinus* as an option for countries that are facing difficulties to conserve *in situ* (where populations are extremely threatened by industrial air pollution or other kinds of irreversible destruction of natural habitat), or which consider *Fraxinus* as an economically important species and are going to have extensive breeding programmes (jointly with gene conservation). This type of conservation provides for fast adaptation of a population by combining natural processes with human management. The *ex situ* method for conservation of gene resources by progeny trials is rather close to the *in situ* method, as it considers establishing plantations in ecological conditions rather similar to those existing in the locations of origin of the planting material.

The establishment of some *ex situ* gene conservation populations in areas of the historical natural range of *Fraxinus* on optimum sites should be encouraged as well, in order to expand the range of environment and in turn adaptation and genetic variation.

For countries where *ex situ* methods constitute a core of gene conservation programmes, *in situ* conservation should serve as a supplementary method that increases safety by decreasing the vulnerability of the whole conservation programme.

Conventional *ex situ* gene conservation based on clonal archives and seed orchards is rather static and does not promote the adaptation and evolution of the species. For more rare species and those with scattered distribution, clonal archives and seed orchards provide an efficient instrument for conserving and even increasing genetic variability. However, clonal archives and seed orchards can be considered only as temporary gene conservation means aimed at generating progenies that would later on become the *ex situ* gene conservation population. In cases where clonal archives are considered as core gene conservation means, that postpones the launching of a dynamic gene conservation system, based on *ex situ* gene conservation subpopulations in the form of progeny test plantations. The clonal archives can serve as supplementary means, aimed at increasing the safety of gene conservation programmes through supplying progenies in cases where regeneration of gene conservation population is not successful. Clonal archives, being established by using full randomization of clones and ramets, can be transformed into conventional commercial seed orchards as soon as a selective thinning is made.

Long-term storage of seed or other kinds of germplasm should also be used to increase the safety of gene conservation programmes.

Minimum requirements for gene conservation of Fraxinus *species from a European perspective*

A sampling of 20 populations based on the existing genetic knowledge or the ecoclimatic conditions in the area of distribution should be carried out. Each population should have at least 50 trees. Whenever possible this sampling can be done in conjunction with sampling of other Noble Hardwoods. The sampled stands will constitute *in situ* subpopulations in a dynamic MPBS type of gene conservation.

Sampling

The number of populations sampled and the number of individuals constituting gene conservation populations must be large enough to include most of the genetic variation that exists both within and between populations. In order to capture the largest possible genetic (additive) variation, which is the main prerequisite for successful natural and artificial selection and in turn for the evolution of species, the sampling should cover a whole range of species distribution, both central and marginal populations on specific habitats (sites). Different types of populations are of importance for conservation and should be sampled: (a) populations representing the main regions of provenance (forest ecoregions or breeding zones); (b) marginal populations; (c) isolated populations; (d) populations growing under specific ecological conditions; (e) endangered populations; (f) populations carrying rare features; (g) populations valuable for breeding. Sampling of different populations increases the probability of capturing the existing adaptedness.

To capture alleles of different types, different sampling strategies are needed. To capture localized alleles (both common and rare) the sampling should cover more populations over a range of environments at the cost of fewer individuals per population.

Sampling should be slightly different (modified) when: (a) the species are common over large areas and there are large populations; (b) a species is rare and of scattered distribution along its margin. The genotypes for each *ex situ* synthetic subpopulation should be sampled in populations of one region of provenance in order to capture the adaptedness existing within that region, not to destroy any co-adapted gene complexes if such exist, and to prevent the potential risk associated with provenance hybridization. The sampling of 10-20 stands within a region of provenance (where the species is common) would provide a representative sample for establishing one gene conservation subpopulation. If there are few populations in a given region (this is the case along the margins of the species' natural range), complementary to marginal populations from the neighbouring regions of provenance should be sampled.

Establishment

A network of gene conservation subpopulations (both *ex situ* and *in situ*) should be created with sufficient geographic coverage of the species' genetic variation and ecological variation within the species' distribution range. The present genetic structure is neither optimal nor stable. However, even if the fitness of populations to ecological conditions of specific ecological regions or regions of provenance does not reach its maximum, it would be meaningful to utilize the existing adaptedness and promote it. Therefore, both sampling and establishment of gene conservation subpopulations should be done on an ecoregional basis.

To conserve gene resources of a single region of provenance *in situ*, 1-3 stands of 5-15 ha should be selected. These stands preferably should be selected within gene reserves, seed reserves or other types of conventional gene or nature conservation areas that already exist in the country.

To conserve *ex situ*, 1-3 progeny conservation/breeding plantations of 2-4 ha each are suggested. An *ex situ* dynamic gene conservation system could be created on the basis of conventional progeny test plantations that were established over a range of environments for tree breeding or genetic study purposes. Two subpopulations of different natures can be established side by side to provide an alternative in the choice of the best method of gene conservation in the future. The first could be composed of progenies from single trees, randomly selected in 10-20 populations within the region of provenance. The second could be established from progenies originating from plus trees, selected within the same region.

The gene conservation of associated species can be done by creating large gene conservation populations, up to 200 ha, one in each main region of provenance per country. Each large gene conservation population can consist of some stands of different species composition, age and site. These populations should be managed to create maximum habitat diversity (different age, species composition, etc.) within the gene resource population.

Management

Gene conservation populations should be intensively managed to improve the adaptedness of each subpopulation and to increase genetic differences between them. The management should guarantee: (a) sustainability of populations during ontogenesis, (b) continuous regeneration of populations of the target species, and (c) protection against all types of damage. Management of each gene resource subpopulation should be done according to individual management plans. The continuous monitoring of natural regeneration and health condition of the population is needed.

Regeneration is a key aspect of gene conservation. To increase the speed of evolution for its better synchronization with fast-changing environment the turnover of generations should be accelerated.

In the case of *in situ* gene conservation, subpopulations should be intensively managed to support the natural regeneration of target species and protect them from competition by other species that may become dominant according to the rules of natural succession. If the subpopulation conserved *in situ* consists of even-aged mature stands, parts of the gene conservation subpopulation should be opened (thinned or logged in narrow strips or gaps) as soon as possible to create conditions for natural regeneration (preferably on the year following the mast). If the population consists of some stands of different age but there is no regeneration, the oldest (but not necessarily mature) part of a subpopulation should be logged as soon as mast years have produced sufficient seed yield or regeneration (first year seedlings) under the stand canopy or in areas being set aside and aimed at the growing of next generation. By increasing the number of stands or demes (groups of trees) of different age that constitute the subpopulation, the total period of regeneration expands. Therefore, the larger the portion of trees involved in regeneration, the larger the within-population genetic variation. In case these regeneration support measures are not successful, artificial planting should be done using planting material that originates from these stands. Bred material originating from *ex situ* gene conservation/breeding subpopulations of the same region of provenance can be used as well. To secure the physical sustainability of each subpopulation, careful tending should be carried out. Thinning should be made by standard silvicultural practices of each country.

The new generation of *ex situ* gene conservation/breeding subpopulations should be created using open pollination of the best individuals selected within each of the families constituting subpopulations as soon as the progenies reach the reproductive phase.

Integration with tree breeding

The *ex situ* dynamic gene conservation system should be integrated with genetic research and tree breeding. The selection criteria for tree breeding are based on developing qualities beneficial for human use. However, the improvement of adaptive properties is as important as in gene conservation. Increasing gene diversity will provide the possibility for increasing the efficiency for both short- and long-term tree breeding. Artificial crossing could be used in combination with breeding if there is an ash breeding programme. An equal number of parent individuals from each family should be used to produce the new generation in order to keep a high effective population size. In total, about 50 best-adapted individuals should be founders of each new gene conservation/breeding subpopulation (within a given region of provenance). The results of selection (tree breeding) within both *in situ* and *ex situ* gene conservation subpopulations could be utilized by establishing seed orchards at the end of each cycle of conservation/breeding – establishing a new generation using cuttings of best individuals selected within each generation.

Supplementary measures

In addition to the specialized gene conservation activities, the following means for reducing the pressures and erosion of genetic resources can be recommended:

- undertake genetic studies and integrate them with demographic and ecological studies
- establish and adopt legal regulations on gene conservation
- establish and adopt regulations on seed transfer and seed trade, control and documentation of seed sources (OECD Scheme)
- control of pollution originating from industry, transport, agriculture, etc.
- education and public awareness of gene conservation, etc.

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Chestnut (*Castanea sativa*)

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Introduction

The overall objective of the conservation of wild chestnut forest genetic resources is the creation of good conditions for the future evolution of populations and the preservation of the present genetic constitution for conservation and genetic improvement purposes.

Local grafted varieties for nut production also represent an important chestnut genetic resource; their importance has been recently highlighted by the fact that traditional varieties are being abandoned and are in danger of disappearing. Thus, while conservation for fruit production is not the focus of the work carried out within the framework of the activities of the EUFORGEN Network, the inclusion of fruit-producing varieties in an overall conservation strategy will be important. Links need to be established between the sectors of forestry and horticulture to further genetic conservation of this multipurpose species for mutual benefit.

Distribution

Castanea sativa is a Mediterranean species. The range of distribution extends from the Caspian to the Atlantic, including Madeira, Azores and Canary Islands, from 51° latitude in southwest Germany and south England, to 37° latitude in Tunisia (Mounts Tlecem). The species is found in north-facing slopes where the rainfall is greater than 600 mm, on moderately acid soils (pH 4.5-6.5) with a light texture. Chestnut needs high air humidity and avoids late frosts, sprouting very late. Chestnut roots are very susceptible to ink disease, caused by several species of *Phytophthora*, a disease which is very important in humid areas. It is also susceptible to *Chryphonectria parasitica*, which causes severe damages in some populations.

Chestnut is an important species, currently occupying more than 1 700 000 ha in southern Europe. It covers important areas in France, Italy, Spain, Portugal, Turkey, the United Kingdom and Greece. It is found mainly as cultivated varieties in grafted orchards to produce nuts, and in coppices to produce small pieces of wood. High forest, to produce high-quality timber, is very scarce but the area is increasing. The species has a discontinuous range, occupying hundreds of hectares on acid soils. In mixed broadleaved forests stands (i.e. with *Quercus robur* as the main species), chestnut could not be considered as a 'social' species, and in some cases it is rare, comparable to *Acer pseudoplatanus* or *Prunus avium*.

The natural or autochthonous origin of *C. sativa* in Europe has been discussed in numerous papers. Some authors assume that chestnut disappeared from southern Europe during the Würm glaciation, surviving only in northeast Turkey and in the Caucasus. From these two areas chestnut was introduced as a cultivated species by the Romans. According to this theory, populations existing in western Europe have a very restricted and unknown origin (either from Turkey or Caucasus or both), and its presence dates back less than 2000 years. Isoenzyme studies have shown that total genetic variability is much higher in East Turkey than in West Turkey, Italy and France (Villani *et al.* 1991a, 1991b; Manchon *et al.* 1996). These authors consider it as a proof of the migration of chestnut into western Europe.

Other authors, however, assume that chestnut remained in several refugia during the glaciations in southern Europe. Several fossils and remains of pollen have been found in the present area of distribution of the species. The species was present at least 2500 to 3000 years

BP (Pitte 1986; Aira-Rodriguez and Ramil-Rego 1995), i.e. before Roman times. Thus, present populations in western Europe are the result of a mixture of native populations with the descendants of cultivated, grafted varieties. For example, in Spain, the continuity of palynological records in the Quaternary sediments precludes the introduction of the material by the Romans as a likely hypothesis (Gómez-Manzaneque 1997). Moreover, isoenzyme studies of material of Spanish origin (varieties and populations) have shown a reduction in allele richness compared with Turkish populations. In general, the number of alleles per locus is higher in Spanish origins than in the Italian and French (Fernández-López 1996; Pereira-Lorenzo *et al.* 1996b). In this sense Camus (1929) pointed out that chestnut is not an autochthonous species in France but it could be native in the northwestern area of Spain.

Multiple use of the species

Chestnut is characterized by the diverse products that can be obtained. One of the most important is the fruit, of great importance in pastries and in human alimentation in the past. For this reason the distribution area of the species was increased. Many varieties have been described and propagated by grafting, most of them for nut production, some for wood or both (Breviglieri 1955; Bergonoux *et al.* 1978; Borghetti *et al.* 1983; Gomes *et al.* 1993; Pereira *et al.* 1996a; Frank and Radocz 1998; Solar *et al.* 1998). Although nut prices are very good, orchards are being abandoned because of rural depopulation.

Chestnut timber is straight-grained, closely resembles oak in colour and texture, and is highly valued, with high prices for big trees free of defects. The traditional use of the species for small pieces of wood, obtained from coppices, was in general associated with vineyards, and presently rotation periods are increasing, as is regeneration from seeds.

An important use of the species is landscaping, mainly as mixed forest, with some other broadleaves such as *Quercus* spp., *Fraxinus* spp., *Betula* spp., etc. In these types of forests, chestnut provides food for many game animals.

The extension of the ink disease resulted in the introduction of the resistant species *Castanea crenata* and *C. mollissima* and further in the use of interspecific hybrids to be used as rootstocks or clonal varieties for wood or nut production.

Objectives of gene conservation

The overall goal of gene conservation in chestnut within the framework of the Noble Hardwoods Network can be divided into four clearly connected objectives.

1. Conservation of the present genetic constitution in clonal archives of plus trees or grafted fruit varieties, seed orchards and progeny tests. The plus trees are selected in seed populations and some grafted varieties of interest for wood production can be included. This conservation is the base for future breeding programmes of the species.
2. Conservation of the present genetic constitution of populations endangered by *Chryphonectria parasitica* or *Phytophthora* spp.
3. Conservation of the species creating good conditions for the future evolution of populations. This third objective would incorporate several populations of the previously described steps.
4. Conservation of the present genetic constitution in clonal archives of grafted fruit varieties.

To reach these objectives, different studies need to be carried out, mainly on the genetic structure of populations, but these are not further described in this paper.

The conservation of chestnut fruit varieties has already been considered by IPGRI and FAO. European chestnut collections are included in the Directory of European Institutions Holding Crop Genetic Resources Collections (Frison and Serwinski 1995).

Genetic knowledge

The multiple use of the species has determined the main genetic characteristics and variability of natural populations. The type and origin of the forest can be divided into the following types, ordered by importance of the resource:

1. Coppices, regenerated by stump shoots after each felling and with different levels of seed regeneration, depending on the density of the stands. Coppicing has been a traditional silvicultural system in many areas for hundreds of years. Depending on the origin of the coppice, cultivated varieties or natural stands, the genetic structure of the populations can be different.
2. Grafted orchards, obtained from a few high-quality wood- and nut-producing genotypes. Grafting has been a method of propagation for several centuries. In this case the level of genetic diversity has clearly changed. The preservation of the most important grafted varieties is the main concern. The type of grafted chestnut for wood production is actually very scarce. The chestnut orchards grafted with fruit varieties are a very important resource to be considered.
3. New natural populations regenerated from seeds: mostly from a few clones, where grafted orchards have been abandoned, a very common event in the chestnut areas; regeneration from seeds transported by birds under plantations of other species such as *Pinus pinaster* or *Eucalyptus globulus*. Genetic drift could be an important evolutionary force in this type of forest.
4. Mixed broadleaved forests, with chestnut as a rare species. These forests are perhaps those in which the genetic diversity has been maintained without human influence. Geneflow among individual trees and inbreeding are not known in this type of forest, but the situation is similar to the hardwoods concept used in the Network. This type of forest is represented by important marginal stands of the species.
5. Plantations, frequently from seeds coming from orchards or unknown provenances. Seed stands selection was made in France (Bilger 1998).
6. Pollen contamination from only one or a few *C. sativa* grafted genotypes, and of *C. crenata* or *C. crenata* × *C. sativa* hybrids, used in North Spain and France, may have affected the genetic structure of the stands.
7. Incidence of ink and canker diseases could be a cause of genetic drift in certain areas.

In conclusion, in the types of forests listed above, the mixed broadleaved forest, seed stands and grafted fruit varieties could be considered as the most important for the genetic conservation of chestnut.

Mating system

Chestnut is mainly an anemophilous species but it is also pollinated by insects. Some biological features force cross-pollination, as male sterility, dichogamy and an important degree of self-incompatibility. Therefore, high levels of heterozygosity and polymorphism have been found in isoenzyme studies.

Geneflow

The weight of chestnut fruits reduces seed dispersion, but dispersion by birds is highly effective, estimated to several hundred metres (Kollman and Schill 1996). The size of chestnut pollen (14-18 microns) permits the transportation of appreciable amounts at distances of about 100 km. Levels of among-population differentiation estimated from isoenzyme data are 0.22, 0.081 and 0.16 for Turkish, Italian and French populations, respectively. These values are similar to those reported in other species of the same family (Villani *et al.* 1991a and 1991b; Manchon *et al.* 1996).

Adaptive variation

Chestnut covers a broad range of site conditions, which may have resulted in adaptation to diverse conditions. Information from provenance tests showing selection responses of the most important traits is not yet published. The first provenance tests, established in south Germany, are still very young (Maurer and Tabel 1997). Important traits are tolerance to drought and to temperature regime, and resistance to *Phytophthora* spp. and *Chryphonectria parasitica*. Selection pressures act in different ways, resulting in different Selective Environmental Neighbourhoods (SENs). Differences in climatic characteristics of the natural range of the species suggest an important variation in these traits; however, the existence of additive genetic variance in the resistance to *Phytophthora* and *Chryphonectria* is not yet known.

Mutations

Mutation rate is supposed to be high, of the same level as in other tree species. Production of seeds starts early, at the age of 5 years, and fruit set is annual.

Genetic drift

Genetic drift is an important parameter in mixed forest, where chestnut is a rare species. Population decline due to diseases (*Phytophthora* spp. and *C. parasitica*) also must have caused genetic drift.

Phenotypic plasticity

Chestnut does not perform as a plastic species with respect to the soil pH and flooding.

Structuration of genetic variability

Genetic variability at isoenzymes along the range of *C. sativa* decreases from East Turkey, through West Turkey, to the western range of the species.

Some adaptive variation among populations located in discontinuous, isolated areas, subject to different ecological pressures, can be expected, but human interventions might have reduced part of the genetic variation. In continuous areas, more homogeneity can be expected owing to the influence of grafted chestnut orchards, the importance of geneflow and the impact on evolution caused by coppicing.

The number of grafted varieties is very high. They differ by size, shape, taste, conservation, peeling, etc. Although they are propagated by grafting, frequently they are polyclonal varieties.

Proposed gene conservation methods

To define the strategy of gene conservation from a European perspective, the following aspects need to be considered:

1. Objectives (breeding, conservation) and the different uses of the populations (timber or fruit production and landscaping) suggest using different populations to reach different goals.
2. Number of populations and genetic entries to be included.
3. Sampling of populations.
4. Activities to develop.

First of all, conservation concerns the species as a whole, and from a European perspective, reduction of the genetic entries needs to be considered.

As demonstrated by Williams *et al.* (1995) the Multiple Population Breeding System (MPBS) is an efficient method to combine both breeding and conservation of wild populations on a long-term scale. The method (Eriksson *et al.* 1993; Varela and Eriksson 1995) is not described in detail here.

In general, several populations will be selected, seed populations or mixed broadleaves forest, each with at least 50 genetic entries, and managed in different ways and with different main objectives. We can define at least 20 populations covering all the main situations to increase the genetic variability to be included. Designation of populations will be guided by discontinuous occurrence of chestnut areas and by ecogeographic gradients. Sampling inside each population will be guided by ecogeographic gradients and by existing knowledge of human influence. The choice of 50 genetic entries in each population will be carried out with the objective to obtain maximum genetic variability within the population. In this sense, a gradient from north to south within the range of distribution, and from east to west is to be distinguished.

Conservation of grafted local varieties for nut, wood production or both will be made in clonal archives. The main questions to design the conservation of fruit varieties are: how many varieties to conserve; what characteristics are the most important; how much 'intracultivar' variability to conserve?

Methods

Clonal archives of plus trees and local fruit varieties. This could be considered as a subpopulation, with the main objective of breeding and preserving the present composition of the chestnut forests and orchards. The main reason is to prevent their disappearance due to diseases or dysgenic selection. Each population will be conserved by the authority responsible for the collection and several copies of the selected plus trees will be established in the field collection. *In vitro* conservation can be considered, especially where *C. parasitica* has an important incidence.

Provenance tests will be established in contrasting environments not affected by any disease for *ex situ* conservation. The first objective is to study the variability of adaptive traits. A second objective is the preservation of the material. *Castanea sativa* shows a high variability in the Caucasus and Turkey, and therefore, some additional provenances should be collected from these regions. Design of the provenance trials will include material from all the populations selected (20). For this purpose, pooled material from 50 trees in each population will be collected. There must be no risk of pollen contamination with local provenances.

Progeny tests of selected plus trees from several populations that will be tested in the sites where a breeding programme will be implemented. One of the populations will serve as a control, to be tested in different environments, and the others will be included depending on the interest of every country.

Managed stands. Conservation of different managed stands, focusing on the conservation of the genetic variation of the populations, will be established on the basis of the selected stands. In this case, a stand including at least 100 individuals will be included in such subpopulation. The subpopulation is the one sampled for the provenance test.

Activities to develop

- Distribution map of the species, including ecogeographic gradients and incidence of diseases.
- Studies of the mating patterns in different populations.
- Introgression with introduced species in *Castanea sativa*.
- Genetic relationship between wild populations and grafted (fruit) varieties.
- Protection of the species in seed populations (managed stands, provenance and progeny tests defining methods, number of populations and sampling of populations) and in clonal archives.

- Establishment of range-wide provenance tests to study the genetic variability of adaptive traits. It may be necessary to standardize the descriptors, methods of seeds conservation and design of field tests.
- Selection of plus trees: spatial distribution, selection methods, descriptors.
- Progeny tests: design, heritability of the main traits.
- Variability among and within fruit cultivars.
- Design of clonal archives: field collections, *in vitro* conservation methods, pollen conservation.
- Descriptors for clonal archives: morphology, phenology, biochemical and genetic markers.
- Promotion of regulations on the transfer of forest reproductive material. The trade with chestnut reproductive material is not regulated at the European level. The use of seeds from grafted trees instead of local provenances and the movement of plants among countries poses certain risks.
- Promotion of the use in reforestation of seeds from seed stands or seed orchards.
- Promotion of *in situ* conservation of fruit varieties.

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Lime (*Tilia* spp.)

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Introduction

Owing to their aesthetic and cultural value as urban trees and as landscape elements, lime trees have become increasingly important in Europe in recent decades. For various reasons, the distribution of *Tilia* in Europe has declined over the last 2000 years. Unless protective measures are taken, the size and constitution of genetic variation of the *Tilia* species which occur in Europe will be significantly reduced.

There is a need for a coordinated effort to secure the genetic resources of *Tilia* in Europe. A coordinated effort can reduce the conservation costs and improve the quality of the conservation activities. A gene resource conservation strategy for a particular species must be based on the available knowledge about the biology of the species and on the basic theories regarding ecology and population genetics.

An approach for gene conservation of the species is outlined, based on an overview of the existing knowledge concerning the geographic distribution, biology and genetic diversity of *Tilia* in Europe, and on widely accepted measures for conservation of forest genetic resources. The approach described should be regarded as the minimum necessary effort required in a European context.

Tilia cordata is considered the most important European lime species. In this paper *Tilia* refers primarily to *T. cordata* except when other species are mentioned. *Tilia cordata* has been subject to many more descriptions and investigations than *T. platyphyllos*, but since the biology and morphology of the two species are similar, information concerning the biology of *T. cordata* can in many cases be applied to *T. platyphyllos*.

Overview of the distribution and biology of the European *Tilia* species

Taxonomy and distribution range

The *Tilia* family includes 400 woody species, among those 30-40 species of *Tilia*, most of them found in the tropics. Ten species are found in the temperate region of the northern hemisphere. In Europe four species are present: *Tilia cordata* Miller, *Tilia platyphyllos* Scop., *Tilia tomentosa* Moench and *Tilia dasystyla* Stev. (Maurer 1995).

Tilia cordata is found in England and its northern distribution limit is at 62°5' in Norway and 63° in Finland. *Tilia cordata* is distributed from the Pyrenees in the west and as far east as Almaty in Kazakstan (Ksembaev and Dragavtsev 1977; Stepanov 1993). The distribution range for *T. cordata* is described in detail in Pigott's botanical monograph for the species (Pigott 1991). The core region for *T. cordata* is central and eastern Europe and the distribution has been described in detail by Pochberger (1967).

In France the distribution of *T. cordata* is scattered toward the west but more dominant in the eastern regions and the Pyrenees. In central Europe the species is common in low mountainous regions (Kleinschmit *et al.* 1996). Also in the Alps, *T. cordata* is mostly absent from lowland valleys, but more common up in the mountains. The occurrence of *Tilia* is limited in Austria (Holzer and Toda 1974) as well as in Switzerland (Trepp 1947; Surber 1951).

In northern Europe, *T. cordata* grows in lowland regions. In Latvia it is reported as a common species by Baumanis *et al.* (1996), but it is uncommon in Estonia and Lithuania. In

Scandinavia *T. cordata* typically has a scattered distribution with small natural stands. The distribution of *Tilia* in Russia is reported by Prokazin *et al.* (1998), in Ukraine by Polyakov *et al.* (1988), in Poland by Bialobok (1991) and Tomialojc (1991), in the Czech Republic by Vancura *et al.* (in Turok *et al.* 1996) and Hynek (1996).

In the Mediterranean and in Georgia and Armenia, *T. cordata* is scattered and grows mostly in mountainous regions. It is absent in Portugal, Ireland and Scotland, and the species is uncommon in Spain, the Netherlands, Belgium (Bart de Cuyper, pers. comm.), Italy, Greece, Turkey, the low and dry plains in Belarus, Hungary, Ukraine and lower Volga region in Russia.

Tilia platyphyllos is rare in northern Europe, but is more common in mountainous regions of central and eastern Europe. The distribution range of *T. platyphyllos* is quite limited in comparison with *T. cordata* and its eastern limit is in Ukraine. However, *T. platyphyllos* is more widely distributed geographically in northern Spain and Italy than *T. cordata*. Inventories of *T. platyphyllos* distribution are sparse in Europe – only a few descriptions exist: for the Macedonian Republic (Andonoski 1974) and for Great Britain (Pigott 1981b). *Tilia platyphyllos* is commonly found on sites containing *T. cordata* (Namvar and Spethmann 1986).

Tilia tomentosa and *T. dasystyla* occur in southeastern Europe and the regions around the Black Sea. The distribution of *T. tomentosa* in Hungary is described by Schmidt *et al.* (1986) and in Romania by Blada (1998). Seven species related to *T. cordata* occur in the Asian region, e.g. *T. mongolia* and *T. japonica* (Maurer and Tabel 1995).

Putative hybrids or intermediate species between *T. cordata* and *T. platyphyllos* have been found in several places (*Tilia* × *europaea*). However, hybridization between the two species is rarely observed, maybe because the flowering time differs. Other examples of hybridization are *Tilia* × *euchlora* which is a cross between *T. cordata* and *T. dasystyla* and *Tilia* × *flaccida*, a hybrid between a European species, *T. platyphyllos* and an American species, *T. americana*.

Historical data

The importance of *T. cordata* in Europe is well illustrated by the common occurrence of its name as part of the names of geographic localities throughout Europe. However, the occurrence of the *Tilia* name within the area of distribution does not necessarily refer to large numbers of *Tilia* trees, but it may reflect the existence of a marketplace for lime-bast (Pochberger 1967). *Tilia* has been used for carving and almost all parts of the tree can be used for fodder, ropes or fuelwood. Lime trees are insect-pollinated, and as such are quite important for honeybees and honey production, especially in eastern Europe (Endtmann 1990).

Between 6000 BC and 500 AD a warmer climate favoured *Tilia* species in northern Europe. They were dominating species in the forests of England and southern Scandinavia. Even the rarely found *T. platyphyllos* was more commonly distributed in northern Europe than it is now, as shown by pollen analysis (Huntley and Birks 1983). The occurrences of *T. platyphyllos* in northern Europe today are suggested to be ancient relics.

Climatic conditions and human impact have been a serious threat to the distribution of *Tilia* in most European countries (Turner 1962). In some regions forest areas were reduced to 2-4% in the year 1800. Another factor is the competitive effect of beech (Koss 1982). Beech has slowly invaded Europe after the last glacial period, and the species has become dominant in central Europe within the last 2000 years. Despite these conditions, *T. cordata* and to some extent *T. platyphyllos* have managed to survive.

As the present distribution of *Tilia* does not seem to be clearly related to climatic or edaphic conditions, conclusions concerning optimum growing sites for *Tilia* in specific regions should be drawn carefully. In many lowland areas, *Tilia* may have disappeared when humans included these areas for agriculture, and the species only remains on marginal sites. In northern Europe *Tilia* may have disappeared on many sites because of low seed fertility. On the other hand, as *Tilia* is easily propagated, some stands have evidently been established by humans.

In recent centuries, *Tilia* has been widely spread in landscape and urban areas. Reproductive material has been moved, especially in northern Europe where it was imported from the east European countries.

Growth and site requirements

Tilia cordata and *T. platyphyllos* are tall trees reaching a maximum height of 35-40 m. Tilias can become very old, more than 500 years. Large coppice stumps, where the centre core disappeared several hundred years ago, have been reported from England (Pigott 1991). The ecological range for *T. cordata* is wide. The trees favour good loamy site conditions, but they can be found on sandy infertile soils as well. Next to oak, *T. cordata* is supposed to be one of the most drought-resistant species. Dormant shoots of *T. cordata* are reported to resist winter frost temperature down to –34°C (*T. platyphyllos* to –25°C) (Till 1956). *Tilia* is not troubled by spring frost or autumn frost, as flushing is late and budset early. *Tilia* has been found in regions in Russia with a short frost-free period (105 days) (Pigott 1991).

In some forests in eastern Europe, *T. cordata* is found as a dominating species within the canopy layer, but in most other places in Europe, *T. cordata* grows in several types of mixed forest, i.e. commonly in the Oak-Hornbeam forest type. *Tilia* is quite shade-tolerant, and on some locations competitive with oak and ash.

Many insects and fungi may be associated with *Tilia* (Pigott 1991), but none of them seriously affects the vitality and distribution of the species.

Reproductive biology

General reproductive and flowering biology of *Tilia* is described by Eisenhut (1957), Anderson (1976), Pigott (1991) and Chistyakova (1982).

Tilia flowers at the end of June and the beginning of July. *Tilia cordata* flowers later than *T. platyphyllos*. Mast years are not frequent. *Tilia* sets flowers at the age of 30, and at least 10 years earlier on solitary trees. In northern Europe, seed regeneration is sparse, e.g. Pigott (1981a). The problem of regeneration in England and northern France is assumed to be caused by low temperatures at the time of flowering and by too low temperatures to permit complete development of the embryo (Pigott and Huntley 1981). In other countries *Tilia* also shows poor seed regeneration: Finland (Pigott 1981a; Ranta 1996), Denmark (Skov- og Naturstyrelsen 1994).

At least part of the individuals within a population are self-sterile (Pigott and Huntley 1981), and *Tilia* species are outcrossing. General seed properties have been described by Suszka *et al.* (1994). One kilogram contains 25 000-30 000 seeds of *T. cordata* and 15 000-20 000 seeds of *T. platyphyllos*. The germination is around 45% in central Europe. The fruit is a nut and water can hardly enter it. The maturation of the seed and germ is slow and normally the seed germinates 2 years from harvest (Møller 1977). Seed from older trees has a higher germination rate than seed from younger trees (Eisenhut 1957). Seeds should be dried and stored at 5°C and can be stored no longer than 2-3 years (Barton 1934; Golosov 1938).

Within the sympatric range, hybrids between *T. cordata* and *T. platyphyllos* have been observed several times (Pigott 1969; Maurer 1995; Wicksell and Christensen 1998). Hybridization and introgression are expected to take place rarely, but possibly to an extent where the genetic structure of the two species is affected. Like *Quercus robur* and *Q. petraea*, leaf, flower and fruit morphology can be used for identification of the species. However, no single morphological trait alone can separate the species owing to large variation within the populations for the single trait (Maurer 1995). Several traits need to be investigated at the same time in order to separate the species and to detect hybrids. Different variants of multivariate statistics have proven to be efficient tools for such analysis (Maurer 1995; Wicksell and Christensen 1998).

Tilia cordata and *T. platyphyllos* can easily be reproduced by vegetative propagation through cuttings and root layers. Cuttings can easily be propagated even from old trees. As *Tilia* formerly was extensively used for bast and honey production, this may have been an important factor in the spread of *Tilia* and its use as a typical agroforestry species in the Middle Ages (Pochberger 1967). Vegetative propagation of *T. cordata* is reported by Sekowski, Hrynkiewiecz and Sudenik (Bialobok 1991; Howard 1995). Somatic embryogenesis has been carried out both for *T. platyphyllos* and *T. cordata* (Chalupa 1990). Grafting and layering of *Tilia* in Holland are described by Koster (1977).

Genetic variation

Investigations of morphological characters of *T. cordata* have shown little variation between populations (Pigott 1991). Leaf variability has also been recorded by Czekalski and Kaczmarczyk (1978). Other studies of morphological traits have been reported by Scheller (1972).

Descriptions of genetic properties have rarely been reported. However, general genetic properties have been described by Giertych (*in* Bialobok 1991). Further, a small Danish provenance trial from 1954 with two Danish and three Swiss provenances revealed provenance variation, but surprisingly no groupwise differences in growth (or quality) between the provenances. In Germany, several provenance and progeny trials were established in 1978, 1979 and 1982 including provenances from several countries (Namvar and Spethman 1986). Results from these trials have not been published (Kleinschmit, pers. comm.). However, the trials have been used for provenance recommendations for the northern German region (Anonymous 1995).

No provenance studies based on the use of biochemical markers have been reported, but isoenzymes have been successfully applied on specific genetic material (Maurer 1995), including more than one species and hybrids. Some studies concerning identification of clones by isoenzymes have been reported by Maurer and Tabel (1995). Cytology in *Tilia* has recently been examined by Jonsson and Eriksson (1989).

Since lime trees are insect-pollinated, relatively large between-population variation is to be expected (Hamrick *et al.* 1992), as demonstrated for *Acer saccharum* (Perry and Knowles 1989). The extensive fragmentation and destruction of the biotopes of the species in some European regions would also be expected to contribute to large variation between populations. Inbreeding is expected to have an impact on both *T. cordata* and *T. platyphyllos* (Kleinschmit *et al.* 1996). In view of their reproductive biology and the distribution of small populations, a small within-population variation can be expected. Hybridization and widespread domestication of foreign species and provenances may very well have an impact on the existing genepool.

Ongoing gene resource management of *Tilia* spp. in Europe

Many countries have adopted gene resource conservation strategies for *Tilia*. Table 1 shows information collected from reports of the first and second meetings of the EUFORGEN Noble Hardwoods Network (Turok *et al.* 1996, 1998). The table indicates where actual progress is going on, but it does not reflect the magnitude of the effort. The records concerning *in situ* stands indicate plans for establishment of gene reserves, nature reserves, seed stands or other *in situ* conservation activities. Some data may be missing as several countries had not concluded their report at that stage. For other countries *in situ* efforts are included in other strategies and reserves. In Denmark, a common strategy for gene resource conservation has been adopted, but part of it still needs to be implemented. A similar situation seems to exist in Switzerland (Rotach 1996). Clonal or seedling seed orchards (*ex situ* reserves) have been established in several places in Europe.

Table 1. Existing *ex situ* and *in situ* efforts for gene resource conservation of *Tilia cordata* in Europe (data extracted from EUFORGEN reports and literature studies)

	***In situ* conservation activities**	***Ex situ* conservation activities**
Austria	Müller 1996	Müller 1996
Switzerland	Not implemented	Not implemented (Rotach 1996 †)
Denmark	Not implemented	Yes – Unpublished
France		
Germany	Kleinschmit *et al.* 1996 †	Rau *et al.* 1980, Piper 1981; Maurer and Tabel 1995; Kleinschmit *et al.* 1996 †
Slovakia	Longauer and Hoffmann 1996 †	Labanc 1992, 1994; Longauer and Hoffmann 1996 †
Czech Republic	Vancura *et al.* 1996 †	
Lithuania	Baliuckas *et al.* 1996 †	
Latvia	Baumanis *et al.*1996 †	
Sweden	Ackzell and Eriksson 1998 ‡	Ackzell and Eriksson 1998 ‡
Finland	Rusanen 1996 †	Rusanen 1996 †
Slovenia		Pavle *et al.* 1996 †
Hungary		Tompa 1992
Croatia	Gracan 1996 †	Gracan 1996 †
Poland	Korczyk 1998 ‡	Bialobok *et al.* 1991; Czart *et al.* 1989
Ukraine	Mazhula *et al.* 1998 ‡	
Russia	Prokazin *et al.* 1998 ‡	
Romania	Blada 1998 ‡	Vancura *et al.* 1996 †

† In Turok *et al.* 1996.
‡ In Turok *et al.* 1998.

In Denmark two clonal seed orchards have recently been established (Jensen, unpublished) and a small-scale breeding programme is planned. No specific information has been available from France, Italy, Spain, Belarus, Estonia, Norway, Holland and Belgium. Some countries lack necessary inventories of potential stands. In other countries *Tilia cordata* is a low priority species, and for that reason no action has been taken. In some countries *Tilia* is not considered to be endangered, it is of limited economical interest, and as such not subject to gene resource conservation (i.e. Norway, ICPPGR country report on forest genetic resources, 1997).

A gene conservation strategy for *Tilia* spp. in Europe

Objective of the strategy

Gene conservation of Noble Hardwoods species should be carried out to secure their ability to adapt to environmental changes and the conservation activities should cover the existing genepool, including both the central distribution area and marginal sites. Conservation should guarantee the evolutionary potential for the species as the existing genepool only can be regarded as a transient stage of evolution.

Securing the basis for future sustainable use of genetic resources is also an important objective. Gene resource conservation does not *per se* secure long-term sustainable forestry. Gene conservation activities should be combined with ongoing or planned commercial breeding and improvement programmes to secure the sustainable use of the reproductive material.

Rare alleles should hardly be targets for a common gene conservation strategy for *Tilia*: conservation of rare alleles requires very large population sizes, which give rise to practical problems. Further, rare alleles are not likely to contribute to the evolutionary potential of the species in question (Graudal *et al.* 1995).

The Multiple Population Breeding System (MPBS)

The overall principle for gene conservation, within both the central core region of the present distribution and the marginal areas, should be the Multiple Population Breeding System

(MPBS). In order to cover the genetic variation of a target species, where genetically different populations have evolved through adaptation to different ecological and environmental conditions, it is necessary to establish a network of conservation stands (Graudal *et al.* 1995). The network should cover the spectrum of ecological variability within the area of distribution.

Within each country a national strategy should be implemented. Programmes related to conservation and breeding in all countries can contribute to conservation of the total genepool. Relevant programmes include nature protected areas and reserves, gene conservation areas, improvement programmes, genetic trials etc. As the objective for conservation is dynamic, the strategies should be flexible and be geared to cope with adaptation and evolution (Eriksson *et al.* 1993).

Practical application of the MPBS concept has been proposed for *Quercus suber* by Varela and Eriksson (1995). A strategy of this type could also be developed for *Tilia* spp. in Europe where it could efficiently protect existing genetic variation and secure adaptive and evolutionary processes.

Sampling strategies for gene conservation of Tilia

The different patterns of distribution and biology of *Tilia* in Europe call for different gene conservation actions. In some areas *Tilia* is a dominating species, but on many other sites *Tilia* is rare and threatened. Both *T. cordata* and *T. platyphyllos* vary in terms of rareness, distribution pattern, reproductive biology and in vulnerability with regard to threats from pollen pollution from exotic seed sources. In general *Tilia* occurs in mixed forests and can even be an indicator for ancient forest. A number of different tree species, e.g. *Quercus* spp., *Carpinus betulus, Ulmus* spp., *Acer* spp. and several shrubs and herbaceous plants, coexist with *Tilia*. Hence, *in situ* conservation of *Tilia* may in many areas be carried out together with associated species and gain from other ongoing or planned conservation activities.

A preliminary step in preparing a sampling strategy is the definition of regions in which there is no ranking change between genotype with respect to fitness (Eriksson 1998). In other words there should be no genotype by environment interaction for a sample of populations and sites within the region. These regions should ideally be defined on the basis of tests concerning several traits, but for most Noble Hardwoods species, that type of research would be out of proportion with the economic importance of the species. For practical purposes, the regions can instead be identified on the basis of ecogeographic variation which should be modified to take into account either expectations of geneflow or general knowledge about regional genetic variation within different species (Graudal *et al.* 1995).

In some marginal regions *Tilia* species are rare, and conservation activities have to be targeted toward single trees. This is the case in northern Europe for *T. platyphyllos.*

Central core regions

Large gene reserves within the central core of distribution will be very efficient for gene conservation purposes and should be a first priority goal, as large genetic variation is expected to be present in the core distribution area.

Existing nature protected areas (e.g. national parks) will only partly serve as gene conservation areas, because national gene reserves often consist of noncommercial, high-elevation forest (Ledig 1986) and are normally not selected at random. Further, *Tilia* may in some cases have disappeared from national gene reserves. Establishment of additional conservation stands will therefore be necessary.

Marginal regions

In some regions, large gene reserves of *Tilia* are not present at all, and the source may be strongly fragmented. At the same time the occurrences may also be subject to pollen contamination from new plantations originating from non-local seed sources. *In situ* conservation *per se* may not be effective or desirable. In some of the marginal regions the regeneration of *Tilia* is missing or weak. The existing genepool of *Tilia* is slowly but constantly declining. The genepool is plastic and varying and the existing genetic variance should generally be regarded as a transient stage.

In areas where *Tilia* is no longer adapted to the prevailing climate, the relevance of gene conservation efforts can be questioned. Still most countries have decided to carry out gene conservation, presumably because *Tilia* has significant historical value and the climate may change again (Ledig 1993).

In the marginal regions where situations with many small populations and risk for genetic drift are typical, *ex situ* conservation of the genetic resources of *Tilia* is recommended. Preferably *ex situ* conservation stands should be established on the basis of reproductive material from within the local regions, and as such the conservation efforts will be related to *in situ* principles. *In situ* conservation in marginal regions may include a larger number of populations.

Other conservation activities

A precise overview of the status for gene conservation of *Tilia* in Europe is lacking.

The further work of the EUFORGEN Noble Hardwoods Network should include exchange of knowledge about existing work being carried out and promotion of new initiatives and projects. Limited research on genetic properties of *Tilia* is also a constraint for the preparation of an efficient gene conservation strategy. It is especially important that the different ecological zones for the *Tilia* species be identified.

Ecogeographical zones may cross borders between countries and many breeding and gene conservation projects should therefore be carried out in close cooperation between neighbouring countries. Coordination and optimum use of resources will allow for more conservation activities to be implemented. These considerations are particularly relevant for *Tilia* species, and the Network is an important tool to promote such common actions.

Use and management of genetic resources of *Tilia*

Breeding, improvement and management of genetic resources of *Tilia* should be combined with gene conservation. Combining use and conservation is especially necessary for species of low economic interest, as it is unlikely that sufficient resources will be made available for conservation alone. Furthermore, the combination of conservation and use would allow the evolutionary forces to work. *In situ* stands should be maintained until they are able to regenerate. Some stands, especially within the marginal parts of the distribution area, will probably be very low in effective population size, and as the geneflow between stands of *Tilia* will be limited, the next generations could possibly be affected by inbreeding.

At some locations the lime trees will be eradicated, if expensive precautions are not taken. Alternatively, resources could be used to promote establishment of new populations constructed from local seed collections. At other sites, *Tilia* may be regenerated through coppice forest management, and a large number of individuals can be kept alive this way. However, this approach will allow some directional selection to occur (for successful vegetative reproduction), and the conservation is therefore quite static by nature.

A policy for sustained management of areas with *Tilia* is complicated, as the species generally occur in mixed stands. Choice of species which should be removed or promoted is one problem. Another problem is the timing and strength of thinning and general management practices, which balance gene resource management and low cost (Rotach, p. 39, this volume).

Stands used for seed production can contribute to conservation of genetic variation. However, the stands will often be based on progenies from selected trees, which in turn will influence gene conservation.

In special situations where ecological regions cross country borders, seed transfers may be necessary. International cooperation will be very valuable. Eriksson (1996) has suggested international cooperation regarding gene conservation of *T. platyphyllos*. This is also proposed by De Vries (1996), as the species is very rare in the Netherlands.

Public awareness regarding management of *Tilia* resources may promote local or national gene conservation programmes. Forest owners may be quite active in participating in such programmes, but often they are neither aware of the biological value of their forest, nor of the possibilities for economic support for conservation activities.

Legislation and seed transfer rules

It should be ensured that reproductive material for forestry and open landscape plantings is used in a proper way, and the origin of the material well documented. *Tilia cordata* has recently become part of the OECD scheme, which has improved this important aspect of gene conservation. Furthermore, national rules have been implemented in different countries. *Tilia cordata* was enrolled in the German regulations in 1979, and before that time most plantings are assumed to have been established with material from southeastern Europe (Namvar and Spethman 1986). Still many countries have adopted a rather liberal legislation in this field and reproductive material of *T. cordata* has evidently been widely moved from one country to another.

Concerning certification in general, there is an increasing public awareness, and many people require reproductive material of local origin. It is obviously an important task for each country to promote the use of the most suitable genetic material.

Conclusions

In many places in Europe, *Tilia* species are vulnerable to human impact and their genetic variation may be endangered unless gene conservation activities are undertaken. In most European countries, gene conservation activities are taking place, and *Tilia* species are often considered as very valuable - mostly for landscaping or cultural and historical reasons. However, international cooperation is important because the distribution of the *Tilia* species is fragmented, and because borders of the distribution areas do not follow country borders. The use of the Multiple Population Breeding System (MPBS) is recommended.

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In situ conservation and promotion of Noble Hardwoods: silvicultural management strategies

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Introduction

Most of our autochthonous Noble Hardwood species are relatively rare, some are even endangered. Hence, conservation as well as efforts to promote these species in order to increase their proportion in the forests are desirable. The importance of minor and rare species is increasing because they represent a natural variation. Since the Earth Summit in 1992, biodiversity, sustainability, stability and adaptability of ecosystems and their components are perceived as being highly important for further development and survival of human beings. The management strategies in forestry need to incorporate such new objectives. Furthermore, to stay competitive, forest enterprises will need to comply with certain objectives imposed by society. Conformity with these objectives will be surveyed and certified, a process which has already started. Certification requires management strategies which protect and support natural processes (implying due attention to close-to-nature silviculture, mixed and uneven aged stands, and the protection of rare species) and which implement a variety of objectives other than wood production. Noble Hardwoods and other minor or rare species will most certainly benefit from this new development. Besides all this, Noble Hardwoods are highly interesting for wood production. Timber prices are increasing continuously and are less susceptible to fluctuations on the global timber market. A high economic value is an important stimulus for forest owners to promote certain species. This can support conservation activities rather efficiently.

Conservation and promotion of Noble Hardwood species is most successful within the frame of forestry. Hence, it is the primary objective of this paper to develop strategies for the conservation of genetic resources in managed forests. The strategies try to respect and implement important practical aspects of forestry. An important objective for Noble Hardwoods silviculture is the production of high-quality timber. Management strategies thus need to incorporate the production aspects (site requirements for optimal performance, educational needs, choice of provenances and breeding). Additional instruments for *in situ* conservation such as gene reserves, protected areas, seed stands, old growth stands or nature reserves which may also be important for gene conservation, are not discussed here. Conservation of most Noble Hardwoods ideally combines both *ex situ* and *in situ* measures. Especially for rare species and those with scattered distribution, artificial breeding populations, such as seed orchards, provide a very efficient instrument for conserving or even increasing genetic variability. In this paper we primarily concentrate on *in situ* activities; *ex situ* measures are mentioned only if they relate to *in situ* activities.

The physiological optimum of most Noble Hardwoods is found on sites where beech or other climax species (oak, spruce) dominate naturally. Therefore, competition is the most decisive factor for the existence and survival of Noble Hardwoods on these sites; they naturally survive only under conditions which are not optimal for the climax species. Consequently, measures for *in situ* conservation of minor species theoretically are straightforward and easy. For survival and adequate development, Noble Hardwoods need sufficient light and space, especially in the older age classes. On most sites, silvicultural interventions thus need to regularly control competition from other species by thinning. However, three prerequisites are necessary if *in situ* conservation measures are to be successful in practical forestry:

1. Sufficient demographic data are needed. Efficient conservation measures can be implemented only if populations, population structures or, in some cases, even individuals are known.
2. Since Noble Hardwoods often occur as single individuals in mixed stands and since their competitive ability is generally low, periodic interventions over time are needed.
3. The financial possibilities of the forest owners need to be sufficient to pay for a forestry organization and for the necessary, relatively cost-intensive thinning and planting operations.

The last point is very valid since increasing economic problems in forestry may drastically limit conservation efforts applied in the practice. Effective conservation and promotion measures depend on the existence of a forest organization with sufficient qualified personnel and financial means. In the long run, conservation and promotion may only be possible if the highly valuable Noble Hardwoods contribute to the revenues of forest enterprises. This means that mature individuals of sufficient quality need to be harvested to pay for the interventions in the young stands. Short-term conservation objectives and long-term promotion efforts are sometimes conceived to be contradictory. Therefore, conservation and promotion can only be successfully implemented in a dynamic fashion and over a long period of time. A central problem in this context is the rarity of some of the species. With the exception of *Fraxinus* and *Acer*, populations are often too small to allow for genetic diversity in natural regeneration. In these situations, natural regeneration needs to be accompanied by planting material with high genetic diversity. Hence, in a dynamic approach, sufficiently broad populations need to be established *ex situ* in order to produce the required planting material.

Promotion efforts are less straightforward than conservation activities. Although Noble Hardwoods may frequently be established by natural regeneration or may be planted when natural regeneration is not possible, these measures alone do not guarantee a higher proportion of such species in the future. In contrast to climax species, Noble Hardwoods dominate only under very special conditions.[1] In undisturbed forest ecosystems they either occur on very special 'niche' sites or in mixed broadleaved forests, especially during certain stages of succession. In undisturbed forest ecosystems on beech-dominated sites, mixed stands or stages are rather an exception than a rule (Korpel 1995). While Noble Hardwoods may show higher proportions in early stages of development, their proportion drastically decreases in later stages owing to the strong competition of beech. In late stages of natural development they occur only occasionally and in very low proportions.

Consequently, management strategies need to consider the competitive environment as well as the special properties and requirements of these species. In this paper we try to summarize some silvicultural considerations and to outline some general management strategies for a successful conservation and promotion of Noble Hardwood species in multifunctional forests. Since these strategies may differ according to site conditions and vary for the individual species, and because rarity and needs for conservation vary widely between species and from one part of Europe to another, generally valid guidelines are difficult to develop. Consequently, the considerations outlined here cannot be very specific. Moreover, because many factors may influence management decisions, different optimal strategies are conceivable or necessary under differing conditions. Our experience is primarily based on sites which offer excellent growing conditions for all Noble Hardwoods, i.e. rich, young soils, a favourable climate with sufficient precipitation and excellent conditions for natural regeneration. Strategies as well as the examples given are primarily valid for conditions found in Central Europe and for sites where beech is the main competitor. Strategies may somewhat differ and may need to be adapted for other competitive environments, site conditions, situations of rarity and threats. Adaptation is

[1] With few exceptions such as *Fraxinus*, *Acer*, *Ulmus* species.

especially important in marginal areas on the northern and southern border of the species distribution areas.

General management strategies: potential solutions

The following characteristics, essential for both conservation and promotion efforts, are common to all Noble Hardwoods as defined by the EUFORGEN Network:

- with some exceptions, these species rarely dominate under natural conditions
- the species mostly occur as single and scattered individuals in mixed stands or on special sites, where they may be slightly more abundant owing to reduced competition from their major competitors
- the species are mostly light demanding and consequently do not survive shade and strong competition
- the species have a low ability to recover from unsatisfactory growing conditions, especially in the second half of their life span
- compared with beech, the species have a low competitive ability
- sociability (social behaviour in mixed stands) of these species is related to site conditions.

From these general characteristics it follows that strategies for the conservation and promotion largely depend on site conditions.[2] Site conditions greatly influence natural stand development, competition between species, behaviour of species in mixtures, types of mixed stands, value production and silvicultural intensity needed to conserve or promote these species. On certain sites, conservation and promotion efforts have to be considered inefficient, expensive and are most likely to be unsuccessful in the long run because regular human interventions would be necessary to continuously correct an "unfavourable" natural development.

Recommendation 1

As a first priority, conservation and promotion efforts should concentrate on ecologically optimal[3] sites, natural niches[4] or special habitats. Efforts placed on physiologically optimal[5] sites are reasonable only in situations where a high silvicultural intensity can be guaranteed.

There may, however, be situations or conditions where it might be reasonable or even necessary to undertake conservation measures regardless of site conditions, especially in marginal areas where species are rare or in situations where species are severely threatened.

Noble Hardwoods are generally rather demanding species with regard to site conditions. Their physiological optimum is found on highly productive sites, i.e. in the center of ecograms (Ellenberg 1986). In nature, however, they hardly ever occur in their optimum. Because of competition, they naturally occur only on suboptimal sites, either in special habitats where competition is reduced artificially (due to human activity), or during certain stages of succession when the competitors are absent or not yet fully developed, or in niches where competition is less vigorous. Conservation and promotion efforts are most efficient on sites where the species occur in their natural ecological optimum (only *Fraxinus* and *Alnus*) or where they have their natural niches. A low competitive ability combined with low tolerance to competition, and a habitat preference which they share with their major

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2 We define site as soil conditions and the biotic and abiotic environment (climate, natural forest vegetation, competition etc.).

3 Sites where a species dominates naturally.

4 Sites where a species occurs naturally without being dominant (but survives competition).

5 Sites where a species would show optimal development if there were no competition by other species.

competitors, are major causes for the natural rarity of these species (Gaston and Kunin 1997). Consequently, conserving or promoting these species on sites outside their ecologically optimal range actually means enlarging their natural distribution. Although this is possible, it requires much greater effort, investment and more continuity to be successful. Economically it can only be justified if the expected qualitative value of production is higher than the investments, which certainly is the case for some of the Noble Hardwoods like *Sorbus torminalis, Juglans regia* or *Prunus avium.*

Concentrating the efforts on ecologically optimal sites has two advantages. First, silvicultural interventions need to be less intensive and less regular over time (continuity) to guarantee success. Second, we increase the chance of concentrating our efforts on the genetically most important natural populations, the so-called 'core populations', which are most important for the survival of the species (if they still exist). This essential consideration illustrates the differences that exist between climax species and Noble Hardwoods. Climax species such as spruce, fir or beech do not only form extended populations, they also differ from Noble Hardwoods with respect to management strategies. While gene conservation of climax species can be accomplished in unmanaged stands (or stands which require minimum management interventions to ensure health and regeneration), and since natural development does not endanger the survival of such a population or its genepool (only of certain individuals), the *in situ* conservation of Noble Hardwoods primarily means managing the survival of the species in a given location. Hence, gene conservation programmes for these species not only require a different concept, they also require more effort and investment than climax species. *In situ* conservation of Noble Hardwoods should thus concentrate on sites where they are in their ecological optimum or they should be grown in special habitats.

Another possible concentration of efforts could be achieved by limiting *in situ* measures to populations of more than 20 individuals as proposed in the report of the first meeting of the Noble Hardwoods Network (Turok *et al.* 1996). This strategy may, however, be questioned for several reasons. Population genetic considerations clearly indicate that the minimum viable population size for genetic conservation purposes needs to be much larger than 20 individuals (Lawrence and Marshall 1997). Moreover, for many of the species in question it would be impossible to find *in situ* populations in the sense of interbreeding individuals that fulfill this condition. For example, for *S. domestica, Pyrus pyraster, Malus sylvestris, J. regia, Ulmus laevis* or *Ulmus minor,* such effective populations are very rare. In addition, to define a population in a genetic sense, we would need to know the distances of effective geneflow. Owing to fragmentation, geneflow may be rather restricted. Hence, in such species, genetic differentiation may be higher than in other species and a large part of genetic diversity may thus reside among the single fragments. Furthermore, it is generally agreed that *in situ* gene conservation should respect the 'metapopulation structure' of these species. In the metapopulation model (Levins 1970), in which a number of local demes interact through geneflow and migration, local extinction may occur but may not be decisive for the survival of the species since the genepool is maintained, as a whole, through recolonization of new habitats from certain 'core' populations. If we accept this model, then the demography, the patterns of distribution and the interaction of the single demes are essential for conservation rather than the size of the single demes. From this model it also follows that only a dynamic conservation over a large area (essentially over the complete metapopulation) will be successful. In this sense, a small but genetically effective deme may eventually be more valuable for gene conservation than a group of 20 or more trees because the effective population size of such a group is not necessarily larger (especially in species which frequently regenerate vegetatively and which often are dominated by competitors and thus hardly fructify). Even if metapopulation structures are disturbed for most species as a consequence of human activity, it would be counterproductive, especially for the rare species, to limit *in situ* conservation to groups of more than 20 individuals. It is doubtful whether generalized population genetic principles can be applied to rare species with a scattered distribution. Drift, inbreeding and geneflow may play a different role in naturally rare and dispersed species than in species which occur in extended populations. For example, species which occur naturally in low densities (such as tropical species with less than one individual per ha), show a surprisingly high genetic diversity (Bawa 1992; Loveless *et al.* 1992; Hamrick *et al.* 1994). The same can be observed in very rare autochthonous species such as *S. domestica* or *S. torminalis* (Wagner *et al.*, Menn *et al.*, in preparation). As long as we do not have a better understanding and knowledge about the demography, the genetic structure and geneflow patterns, conservation measures for the rare species should include as many individuals as possible, regardless of their association with certain genetic demes. Even if genetic drift and inbreeding may occur in small demes, a lot of among-deme variation or certain rare or interesting genotypes may be conserved this way. In contrast, for hardwood species which still occur in larger populations such as *Fraxinus excelsior, Acer pseudoplatanus* and *Prunus avium,* a concentration of conservation efforts on stands with populations size between 20 and 50 individuals seems reasonable.

Recommendation 2

For rare and very rare species, all individuals on their ecologically optimal sites or niches should be conserved. For species that still occur in larger populations such as *Fraxinus*, *Acer* and *Prunus*, a concentration of efforts on demes with more than 20 individuals seems reasonable.

Growth and quality are not optimal on sites where the species have their ecological optimum. With few exceptions,[6] optimal growth and quality production are encountered on highly productive sites, i.e. where beech is in its optimum. From a production point of view, Noble Hardwoods should be managed on the most productive sites, either riparian (*Fraxinus, Acer, Ulmus, Prunus*) or optimal beech sites. In most cases, however, this means promoting the species on sites where they do not occur naturally. Although populations of Noble Hardwoods can be established easily, either from natural regeneration or by planting on most of the beech-dominated sites, the high competitive ability of beech has important consequences for a successful promotion. Success primarily depends on two factors: the possible silvicultural management intensity and the type of mixture.

Mixed stands of these species have many advantages, i.e. higher stability with regard to the effects of abiotic and biotic factors and associated lower risks, higher adaptability, higher biological diversity, better quality, better growth in some cases, flexible timber marketing (Lanier 1992; Schütz 1994). Noble Hardwoods are prime candidates for admixtures with beech since they may increase the qualitative value of production considerably. It has to be realized, however, that highly diverse mixed stands do not occur naturally on these sites. An active silvicultural management is thus necessary in order to guarantee a substantial proportion of Noble Hardwoods at maturity and to attain reasonable silvicultural objectives (final diameter, quality, rotation age). Hence, only where a certain silvicultural intensity and continuity can be guaranteed should hardwoods be promoted on beech-dominated sites.

Recommendation 3

If a high silvicultural intensity is guaranteed, valuable Hardwoods may also be promoted on highly productive sites. Growth and value production will be optimal on such sites and return of investments will be high for many of the species.

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6 *Fraxinus excelsior* is such an exception as it also grows optimally on moist riparian sites where it can dominate naturally because these sites are too moist for beech. The same is true for *Alnus glutinosa* and *Ulmus glabra.*

Competition in mixed stands depends on the type of mixture and the social behaviour of the species. Several factors are important (Schütz 1994):

- growth dynamics of the species over time on a given site. Relationships in height growth between species change over time and in relation to site conditions. Competitive ability and survival largely depend on these growth relationships
- light demand or shade tolerance determine the reaction of a species in a competitive environment
- capability to expand the crown in a competitive environment is essential for competitive ability
- ability to restore the crown after release from competition reflects tolerance to competition and determines silvicultural intensity which is necessary to conserve the species in a mixture
- final height determines survival, growth capacity and vitality in older age classes.

Most decisive factors for competition in mixed stands are height/growth relationships among species and shade tolerance of the respective species.

Recommendation 4

On beech-dominated sites, Noble Hardwoods should be mixed in patches (groups of trees) rather than as single trees. The hardwoods are either planted in patches or they are favoured by means of the first interventions.

In most cases, single-tree admixtures of Noble Hardwoods are not stable and depend on periodic, intensive silvicultural interventions. Growth rhythms of these species differ considerably from that of beech or oak and competitive ability is generally rather weak for most of the species in question. Even if some of the Noble Hardwoods may outgrow beech in the first 30-40 years, they are all clearly dominated by beech in the second half of the rotation period. In groups of trees, growth differences are less important since competition is restricted to the contact zone between the species. If the patches are chosen such that their size at least equals the necessary growing space of an adult tree, at least one individual of the less competitive species should survive without human intervention even under severe competition. Occasionally, single mixtures are possible, for example for *Fraxinus*, *Acer* and *Ulmus* on humid, riparian sites where they dominate naturally and integrate well in mixtures. For all other sites and species, group mixtures are recommended since they are more stable, silviculturally less intensive and thus more efficient than tree-by-tree mixtures. Patch size should be chosen according to 'sociability' and rotation age of the species and with respect to the possible silvicultural intensity. Patches should, however, not be smaller than 10 m in diameter. Even when Noble Hardwoods occur as patches, attention has to be paid to the choice of the accompanying species. Depending on the site, suitable species need to be selected. Two considerations are important. First, if patches are small, growth rhythms and final height should not differ too much. Second, rotation age should be similar for reasons of future regeneration. If rotation age differs considerably, patches of the species with short rotation should be very small. Otherwise, when they need to be harvested, unproductive gaps will result.

Some Noble Hardwood species cannot be integrated into high forest stands, not even as groups. For example, *Malus*, *Pyrus* and certain *Sorbus* species have considerably slower height growth than any other species and generally reach final heights of less than 20-25 m. An integration in closed, high-stand structures is therefore hardly successful. These species need special stand structures or habitats where they find optimal growth and light conditions.

Recommendation 5

Species that are difficult to integrate with other species should be favoured in special stand structures or habitats which are especially favourable. Such special habitats should primarily be managed for the endangered minor or rare species.

The following are interesting special habitats for species with a very low competitive ability, i.e. species which are light-demanding, slower growing and of small stature, such as *Malus, Pyrus* or *Sorbus aria, S. aucuparia* and *S. torminalis.*

- **Forest margin.** A special treatment of the margin is necessary in order to promote these species. A zone of 20-30 m in depth should be reserved for these minor species. In most cases they need to be planted. Patch size planting is again the favoured solution since competition from shrubs will be severe in the phase of stand establishment. The border zone needs to be managed with low standing volumes which should not be higher than 150 m^3/ha. Locally, all trees should be removed to create small patches with ideal light conditions.
- **Hedges or small 'forest patches' scattered within the agricultural land.** It is well known that such forest patches are not only important elements of the landscape, they are also valuable as retreats for plants and animals, as wind barriers and much more. Regarding the conservation of rare and disseminated species, hedges and scattered forests are especially important because they may serve as "stepping stones" for geneflow, linking fragmented core populations.
- **Coppice with standard.** Many of the rare and endangered hardwood species used to be relatively abundant in special stand structures such as coppice with standard. This management system was practised all over Europe until around the turn of the century. It was especially suitable for the less competitive species for several reasons. First of all, standing volumes were very low (in order to allow a sufficient development of the coppice that produced the highly important fuel wood; Schütz and Rotach 1993), which provided excellent growing conditions for all light-demanding species. Secondly, competition of beech was absent because beech normally was not tolerated (since it produced a less valuable timber than oak, pine or spruce and had negative effects on development of the coppice; Mathey 1998). Finally, every 20-30 years, the coppice was removed but the valuable fruit trees and hardwoods were kept (for different reasons) and allowed to grow freely without any lateral competition. Since coppice with standards type stands show a considerably lower qualitative value of production than high forests, this ancient system cannot be reintroduced in larger areas. As long as it is feasible from an economic standpoint, all remains of old coppice stands should be conserved and heavily thinned to standing volumes below 150 m^3. Interventions should favour all the existing hardwood species. Eventual natural regeneration of these species needs to be protected from deer and to be supported periodically from competitive shrubs and stool-shoots.
- **Pine stands.** *Sorbus aria, S. torminalis, S. domestica, Pyrus* and *Malus* are often relatively frequent in the understorey of older pine stands. Mature pines provide favourable growing conditions even if stands are closed because light penetrates the crowns easily. The mentioned species can grow and survive in the understorey for a rather long time. If sites are not too poor, such stands offer good conditions for these species. The hardwoods often show insufficient quality, however, because they have been suppressed for too long. Even if these species may be quite frequent, such populations commonly are of little value for gene conservation. In most cases, they do not contribute genes to future generations since they hardly fructify in the understorey. In general, however, pure pine stands offer excellent possibilities to favour the mentioned species. Natural regeneration is rather abundant. Moreover, *S. torminalis* (and to a lesser degree also *S. domestica*) generally develop a better form if they are tended under a light canopy for the first 10-20 years

(Drapier 1993). Crown cover should not be too dense, and young trees finally need to be completely released when a straight axis of 6-8 m has been formed. Hence, to obtain good phenotypes and individuals that fructify, rather heavy interventions are necessary, removing older pines in the upper storey.

Experiences in Switzerland indicate that the personnel in the field are hardly aware of some of the species. Inventories where the 'populations' that were known to the forest service were compared with the actually existing ones in the field, have clearly shown that rare species are perceived quite differently. While the local forest service[7] knew nearly all of the existing *Taxus baccata* populations and even individuals, only about 20% of the actually existing *Sorbus torminalis* individuals were known to them. Obviously, *Taxus* is easily recognizable and/or it is perceived either as rare, as special or as especially valuable. *Sorbus torminalis,* on the other hand, is hardly "noticed". Evidently it is not perceived as a valuable species, although market prices have been extremely high in the past, much higher than for any other species. It is our experience that perception or awareness seems to correlate with knowledge, information and motivation. Consequently, promotion of rare species will neither be efficient nor successful unless the personnel working in the field are trained, motivated and committed.

Recommendation 6

For a successful conservation and promotion of minor hardwood species, the perception of most of these species needs to be improved. People working in the field need to be better trained and motivated.

In most cases, the proportion of minor hardwood species could be increased considerably just by changing habits, perception and objectives. It is our experience that all Noble Hardwoods, even the rare ones, are very often found in certain proportions in natural regeneration (only *S. domestica* being an exception). The proportion of most Noble Hardwoods could thus be considerably increased by training and supervising field staff and by giving clear directives for early interventions in young stands.

If mature stands contain a certain proportion of the desired hardwoods, natural regeneration should be possible for many of the Noble Hardwoods. On suitable, fertile sites, for example, *Fraxinus* and *Acer* can be easily established by natural regeneration. Since these species are light-demanding, and since they need to have a head start over beech, fast regeneration techniques are the method of choice in order to favour their proportion in future stands. On suitable sites, shelterwood regeneration, removing 60-70% (or less if weed competition is important) of the standing volume in a first cut and a second and final cut following after 4-6 more years, should produce a natural regeneration with a rather high proportion of the desired species. Alternatively, a direct and complete removal of the stand is possible in cases where sufficient hardwood seedlings are already established, which is very often the case on beech-dominated sites.

On suitable sites, single individuals of other Noble Hardwoods are rather frequent in most of the natural regeneration (for example *Prunus avium, Acer platanoides, Acer campestre, Ulmus glabra* and *Tilia* species). Even species with heavy seeds such as *J. regia* may be found in astonishing quantities where there are old trees nearby (due to bird seeding). A successful integration of such species in future stands would need little effort in many cases.

Promotion of some species primarily depends on vegetative propagation. Species such as *S. torminalis, S. aria* and *S. domestica* and *Prunus avium* frequently produce root suckers. Early interventions and regular tending could thus produce stands with rather high proportions of these minor species without the need for plantations. In contrast to *P. avium* which also regenerates from seed, *Sorbus* species only occasionally occur as seedlings established from

[7] Including different foresters with different times of service in the area (up to 30 years of local experience).

seed.[8] If they do, seedlings are not vigorous, are slow growing and thus do not withstand competition as well as root suckers (Drapier 1993; Germain 1993). Vegetative propagation is an easy way to regenerate these species naturally and to avoid plantations that are rather expensive. Consequently, promotion of *Sorbus* species is especially promising in stands where a certain number of mature individuals occur. Root suckers can develop as far as 25 m from the trunk. Since root suckers are produced without the mother tree being cut (Germain 1993), immature individuals should not be cut but kept as standards until they reach maturity. Sufficient light, however, is necessary for the propagation and development of the root suckers. Protection against browsing is necessary in most cases since the minor species are especially vulnerable.

Many of the hardwood species have been considered as economically unimportant in the past. Even worse, the so-called minor species have primarily been perceived as competitors for the main species and have been actively eliminated early on. The proportions found in the younger stands today do not reflect the potential proportions of these species. The naturally occurring proportions of most of these species can be rather high and can be increased by tending operations.

For certain species, natural regeneration may, however, not be sufficient for gene conservation. Some of the species, especially *Pyrus pyraster, Malus sylvestris* and *Prunus avium* may, owing to their occurrence in small demes, primarily mate with domesticated individuals outside the forest. Because of a high degree of introgression from cultivated forms, it is for example doubtful if *Malus* and *Pyrus* still exist as wild forms (Kleinschmit 1998). Some introgression may also occur in *Sorbus* and *Ulmus* species. For gene conservation, these species need an enrichment with genetically diverse material, containing a high proportion of undomesticated genotypes. A reasonable solution for the mentioned species thus is the establishment of seed orchards, followed by the reintroduction of the desired material in plantations. Hence, regarding regeneration, two different strategies, depending on the species and the actual situations, are necessary. For species which still occur in larger populations and which do not suffer from introgression by domesticated material, the following recommendation is given.

Recommendation 7

If species still occur in large, wild populations, efforts and financial means should primarily be invested into supporting natural regeneration and early interventions. Planting for these species should be restricted to the most productive sites where value production can be expected to be highest. For these plantations, only improved material with the best phenotypic quality should be used.

Breeding and conservation are often considered contradictory. We do not see any contradiction if minimum requirements for the breeding populations are respected. On the contrary, we consider *ex situ* breeding populations as an ideal supplement to *in situ* measures. The value of production can be extremely high for most Noble Hardwoods if quality is sufficient. Quality primarily depends on stem form and branching habit. For many Noble Hardwoods, these traits are often unsatisfactory in average populations. *Prunus avium*, for example, very often shows an insufficient qualitative value of production due to poor form caused by frequent forking and sinuous stem form. Improving these traits by breeding would thus considerably enhance the value of the products of certain species. Since conservation and promotion of Noble Hardwoods in practical forestry is probably most successful if owners and foresters are convinced that these species produce highly valuable timber, improved reproductive material should be used for all plantations. Genetic improvement and seed production are efficiently achieved in seed orchards containing selected and tested clones. If appropriate breeding programmes are used, improved material

[8] With the exception of *Sorbus aucuparia*.

may be genetically as diverse as material collected in the wild. Considering the difficulties of collecting seed from a large number of trees in mature stands, orchard seed may even be more diverse since genes of more trees may be represented in the offspring. Moreover, compared with *in situ* populations where individuals may be scattered over a large area, chances for random mating in the orchard populations are increased over natural conditions. In addition, within the artificially formed orchard population, individuals are allowed to exchange genes that would never have had a chance to mate in the wild. Breeding orchards may thus also serve as *ex situ* instruments for gene conservation. This is especially so if they contain a sufficient number of clones, if several (regional) breeding populations are established and/or if multiple population breeding concepts (Eriksson *et al.* 1993) are used.

For certain species or situations, natural regeneration is not sufficient for gene conservation and additional planting is not only optional but necessary.

Recommendation 8

For species which occur only in small demes and which are endangered by introgression from domesticated material, natural regeneration needs to be accompanied by planting. Planting is also necessary on sites where they are economically not very efficient. Material should be highly diverse and contain a large proportion of wild genotypes from the respective provenance.

Conservation of species such as *Pyrus, Malus, Ulmus, Sorbus* or *Prunus avium* may thus require more effort and financial means. The only reasonable solution for the conservation of *Malus* and *Pyrus* seems the establishment of seed orchards which contain wild, natural genotypes and which produce genetically diverse material that can be reintroduced on their original sites. In situations where sufficiently large demes are no longer available, additional plantations may also be necessary for *P. avium, Ulmus* or *Sorbus* species.

In the context of *in situ* gene conservation, two primary objectives are important for tending operations:

- a maximum number of individuals should survive until fructification, and
- individuals should be able to transfer as many genes as possible into the next generation.

Silvicultural interventions thus need to control competition in order to guarantee the survival of as many individuals as possible and to provide for a sufficient crown development and vitality for a regular fructification at the end of rotation.

Without interventions, most of the Noble Hardwoods will disappear from natural regeneration, even on sites where beech is less vigorous. With the exception of *Fraxinus, Acer* and *Ulmus*, most hardwoods lose competition within the first 20-30 years. Early interventions are thus essential for their survival and their integration into future stands. At least one intervention in the thicket or pole stage is necessary to regulate the mixture and to favour all minor species.

Recommendation 9

The first 20-30 years are decisive for the survival of most Noble Hardwoods. At least one intervention in the thicket or pole stage is necessary in order to conserve and favour existing minor species. All minor species should be favoured in natural regeneration, regardless of their quality, occurrence in mixed stands and length of rotation period.

In the past, young stands were regulated in order to obtain silviculturally 'ideal' mixtures. The regulation of the mixture was an important silvicultural objective. The ideal mixture was based on site requirements of the species, their 'sociability', value production and rotation length. Interventions often reduced diversity, since they favoured primarily species which could easily be mixed with the major species (commonly beech). Slower-growing species which are difficult to integrate into the stand structure or species with a shorter or longer rotation period were not chosen as plus trees and thus were not favoured. Silvicultural objectives aimed primarily at highest possible value production.

Today, biological diversity as an objective is equally important as production. Consequently, all minor species should be favoured, even if mixtures are not ideal from a silvicultural perspective. This also holds from a purely economic point of view. The economic potential of most minor species is very high. Prices for *Sorbus*, for example, reached new records last year. We believe that future perspectives are even better, considering that certification should increase the demand for locally, ecologically and sustainably produced wood products. Noble Hardwoods should especially profit from certification because of their highly useful, precious timber produced in a sustainable way. Minor species such as *Juglans*, *Sorbus* or *Prunus* commonly are more valuable than the dominant species (*Fagus*, *Pinus* or *Quercus*) even if their volume production is lower. Economically, final dimensions of minor species may be smaller and logs may be shorter than what is expected for the common species. Consequently, interventions in favour of these species are economically worthwhile even if better and bigger individuals of the common species need to be sacrified.

Because of financial constraints, early interventions need to be kept to a minimum. Today, the first interventions are frequently postponed until the revenues from the removed products cover thinning costs. Since this break-even point is not reached before age 40-50, most minor species will disappear from the stand in this case. In this situation, two strategies are feasible. A first strategy is to limit early interventions to stands with high proportions of minor species. A second strategy is the early selection of plus trees (Z-trees) at a final spacing. If minor trees are selected as a first priority, their chance of survival can be increased considerably with little investment. Both strategies may, of course, be combined to further reduce tending costs.

Recommendation 10

In young stands with a high proportion of minor species, the first interventions should primarily favour minor species, using early plus tree (Z-tree) selections already in the thicket stage, followed by at least one heavy intervention. Although early plus tree selections bear a certain risk, they are the most efficient strategy to guarantee the survival of minor species until the first thinning interventions.

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Progress made in the national gene conservation strategies on Noble Hardwoods

(1997 - June 1998)

Introduction

This section provides an overview of the progress made in national forest genetic resources strategies and programmes with regard to Noble Hardwoods. It covers the period approximately between mid-1997 and mid-1998.

The information provided follows introductory country reports which were published in the Reports of the first and second Network meetings. A synthesis of the overall progress made since the establishment of the Network will be prepared.

The updates from individual countries focus on several main points: current threats to Noble Hardwoods genetic resources, research, applied gene conservation measures and public awareness. The order of countries follows the previous Reports and does not imply any order of importance or priorities.

The Mediterranean Zone

Spain

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Activities carried out in Spain follow from the participation in research projects dealing with the most important Noble Hardwoods species. The first step in genetic resources conservation is to increase our knowledge and to select material of the different species.

Ulmus spp.

Organizations involved:
- Servicio de Material Genético, Dirección General para la Conservación de la Naturaleza, Madrid
- Unidad de Fisiología y Genética, Escuela Técnica Superior de Ingenieros de Montes, Madrid

The activities are included in a national project on Conservation and breeding of *Ulmus* species resistant to Dutch elm disease, connected to the European project on this theme (GEN RES 78: "Coordination for conservation, characterization, collection and utilization of genetic resources of European elms").

The activities carried out are the selection of 220 trees (*Ulmus minor, Ulmus pumila* and hybrids), establishment of clonal archives and progeny tests. In the last year the main works related to EUFORGEN activities were:
- implementation of the database on characterization and evaluation of the selected trees (morphological characters, growth, propagation ability and resistance to diseases and pests); 48 genotypes have been characterized and constitute the breeding population
- studies of native vs. introduced populations at isoenzyme markers
- vegetative propagation of selected trees.

Castanea sativa Miller

Organization involved:
- Centro de Investigación Forestal, Lourizán.

A draft strategy has been prepared for the genetic resources conservation of the species, and is to be discussed. The activities comprise:
- selection of trees for conservation, selection and breeding of forest genetic resources of chestnut
- micropropagation of chestnut.

During the year, the second COST G4 meeting on Multidisciplinary Chestnut Research was organized in Santiago de Compostela (Spain), including the working groups on Tree physiology and Genetic Resources.

Juglans regia L.

Organizations involved:
- Centro de Investigación Forestal, Lourizán.
- IRTA, Tarragona.

Activities deal with the study of genetic resources of the species in Spain, mainly in connection with walnut as a forestry species: selection of trees, propagation methods.

Other species

Organizations involved:

- Centro de Investigación Forestal, Lourizán.
- Escuela Tecnica Superior de Ingenieros Agrónomos, Madrid.

Activities deal with the study of genetic resources of the species in northern Spain, mainly with *Prunus avium*, *Fraxinus* spp. and *Acer* spp.

In 1998 Spapin started participating in a European Union project dealing with the genetic variability of the Noble Hardwood species in Europe (FAIR/CYTOFOR – "Measuring molecular differentiation of European deciduous forests for conservation and management"). At present, material has been collected from one stand (Hayedo de Montejo, Madrid), covering all the hardwoods present in the forest.

Portugal

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Research projects

- European project for gene conservation of *Ulmus* (GEN RES 78: "Coordination for conservation, characterization, collection and utilization of genetic resources of European elms").
- Portuguese project under the programme "PAMAF" for *Castanea sativa* - "Influência das interacções solo-vegetação herbacea-árvore, na valorização dos sistemas agro-florestais do Nordeste Trasmontano" [Influence of soil-herbaceous vegetation-trees interactions in the valorization of agroforestry systems of the Nordeste Trasmontano].

Bibliographic database

An updated database on articles and grey literature on Noble Hardwoods important for Portugal is under preparation. It will be available in Excel or Access during 1998.

Protection measures for Noble Hardwoods in Portugal

The area of Noble Hardwoods in Portugal is increasing after the financial support coming from the EU regulation 2080, conferring subsidies if these species are used in agriculture set-aside programmes under the new Common Agricultural Policy. Species benefiting from this regulation are *Castanea sativa, Fraxinus angustifolia, Fraxinus excelsior, Juglans nigra* and *Prunus avium.*

New issues in the Noble Hardwoods gene conservation in Portugal

- **Research project for the study of reproductive behaviour:** We plan to participate in the project proposal for the study of some Noble Hardwoods in Portugal.
- **Inventory:** Contacts have been made with forest enterprises in order to get more accurate data about the size and state of the Noble Hardwoods populations in Portugal.
- **Origin of reproductive material:** An overview of the origin of seed and other reproductive material used for afforestation of Noble Hardwoods is also planned.

The Temperate Zone

Slovenia

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During the last 2 years the conservation of forest genetic resources in Slovenia followed the recommendations and the national strategy, which were presented at the first EUFORGEN meeting on Noble Hardwoods (held in Germany, March 1996). The activities described below were carried out in collaboration by the Slovenian Forestry Institute, the Forestry Department of the Biotechnical Faculty, University of Ljubljana, the Slovenian Forest Service and the Ministry of Agriculture, Forestry and Food.

Detailed inventories of forest genetic resources

Locations of wild service tree and service tree have already been recorded. The inventory of wild cherry is under way.

Conservation and enriching of Noble Hardwoods genetic resources

- The second revision of forest seed stands on the basis of new criteria was completed in 1997. There are 404 seed stands in the new register with an area of 2703.90 ha. 137 seed stands (mostly beech) are of broadleaved species, among them 37 stands of Noble Hardwoods and 10 of minor species.
- In the last year 430 seedlings of service tree and 600 seedlings of wild service tree were planted in the forest, outside of the forest and at the forest edge. It is planned for 1998 to plant 500 seedlings of service tree and 1000 seedlings of wild service tree.

Development of the national programme for conservation of forest genetic resources

The national strategy is being further developed for the preparation of the National Strategy for Conservation of Biodiversity and is better placed within the new Act on Forest Reproductive Material. The basis for this new Act is in the EU Council Directives with their modifications from 1997. The new Act has already been exposed to the first public reading.

Extension of the network of forest reserves

Forest reserves might be considered as a combination of 'living museums' and forest gene reserves, which could exceptionally also be used as a source for collecting reproductive material. In 1997 they comprised 10 880 ha of forest land. It is proposed to protect additionally 3540 ha of forests, thus the total area would rise to 1.34% of all forest land.

Future work

The following activities in conservation of Noble Hardwoods genetic resources are planned:
- further mapping of rare tree species
- supplementing the register of seed stands by adding individual trees, populations and gene conservation stands
- raising public and professional awareness about Noble Hardwoods genetic resources: for forest owners through information on the value of wood and seed, for wildlife management (hunters) through the value of fruit-producing species, and for forestry and nature conservation by recommendations on forest management

- harmonizing the legislation (Act on Forest Reproductive Material) with the newest EU Council Directive and broadening of the list of species included.

Austria

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In situ conservation

Enlargement of the gene conservation stands with seven Noble Hardwoods species, with a current total area of 960 ha.

Ex situ conservation

Clonal archives and seed orchards currently consist of 28 plots and 11 species of Noble Hardwoods, with a total area of 41.2 hectares.

Emphasis was given to the conservation of genetic resources of wild pear (*Pyrus pyraster*) and wild apple (*Malus sylvestris*). In order to distinguish between wild forms and hybrids with cultivars, a score system for morphological traits of twigs, leafs and fruits was developed, and the inventory of remaining individuals has been initiated. The future conservation strategy includes the establishing of seed orchards and artificial seed stands for regeneration, which should be distributed using different utilization strategies.

Slovakia

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Main current threats

Main threats for the conservation of the Noble Hardwoods genepool in Slovakia are:

- low silvicultural interest in the Noble Hardwoods. If occurring as an admixture in forest stands, they are frequently not included or are referred to as unspecified "other species" in the forest management plans
- extensive damage by ungulates (especially red deer), insufficient care about these tree species in young growth phases of forest stands (maples, common ash)
- partially uncontrolled transfer of reproductive material
- possible contamination of genepool by crossing with domesticated relatives (wild cherry, apple, pear)
- diseases (elms).

Research activities

Forestry Research Institute, Zvolen

- continued breeding of elms for resistance to Dutch elm disease, testing of resistant elm hybrids
- research projects aimed at the genepool conservation of sycamore and common ash (inventory, provenance research, gene bases) have started.

Technical University in Zvolen, Faculty of Forestry

- a research project on wild cherry (inventory, phenotypic variation, yield tables) has been completed
- testing of isoenzyme systems for the population genetic studies of wild cherry and Norway maple
- research on black alder phenotypic variation, especially wood properties.

Agricultural University, Faculty of Landscape Management, Nitra

- in collaboration with the Faculty of Forestry, Zvolen: testing of open-pollinated progenies and seed-quality testing of wild pear, service tree, wild service tree.

Pavol Jozef Šafárik University, Faculty of Sciences, Košice

- taxonomic studies in the genus *Sorbus*, including genetic variation.

Applied gene conservation activities

Forestry Research Institute, Zvolen

- selection of plus trees (Wych elm, common ash, wild cherry)
- delineation of gene bases with Noble Hardwoods
- continuous establishment of regional seed orchards (Wych elm, common ash)
- delineation of the gene reserve forests with Noble Hardwoods
- inventory of white elm and Hungarian ash occurrences in lowland forests of southwest Slovakia.

Ukraine

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The introductory country report presented at the last Network meeting dealt with the occurrence, conservation of genetic resources and breeding of Noble Hardwoods species. Conservation of these species includes *in situ* conservation (single trees and stands of *Alnus glutinosa, Carpinus betulus, Fraxinus excelsior, Fraxinus angustifolia, Tilia cordata, Acer platanoides, Acer pseudoplatanus, Sorbus torminalis*) and *ex situ* conservation (seed orchards, experimental plantations). These measures were implemented some years ago.

Update on the current situation and possibilities for further activities

The difficult economic situation in Ukraine, and the difficult state of research in general and of forestry research in particular, must be strongly emphasized.

Because of the economic crisis, financial support for research was reduced to a minimum. Our Institute received practically no means for official travel during the last 5 years. Scientists often had to go on official trips at their own expense. Therefore breeding research is reduced to a minimum and concerns only the main species: *Pinus sylvestris, Quercus robur*, and among Noble Hardwoods, *Fraxinus excelsior*. The best trees and stands are logged because of the current demand for wood of high quality. We try to select the best trees in those stands and to propagate them by seeds and cuttings, but this is realized only on a small scale and concerns only the main species.

An article on international collaboration aimed at ensuring the effective conservation of forest genetic resources and seed legislation of Noble Hardwoods, to raise the awareness about genetic resources of these species, was sent to a Ukrainian forest journal last summer.

Literature reviews have been started but are not yet finished.

Unfortunately it was not possible to start more detailed inventories of the ecogeographic distribution of Noble Hardwoods.

Czech Republic

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The national strategy for Noble Hardwood species is being developed in the frame of the new state forestry policy (adopted by the Goverment in 1995). Most of the work and its implementation in forestry practice is done by the Forestry and Game Management Research Institute (FGMRI) in Strnady near Prague.

The new broad project dealing with conservation and breeding of Noble Hardwood species was started last year, but most of the work in this field is currently considered as activities of maintenance owing to limited research capacities and adequate funds. It is necessary to concentrate on several tree species and regions. This project also covers inventories. Nine test plots with 30 ash provenances from the whole Czech Republic will be established in 1999. Standard criteria for plus tree selection and approved stands for all Noble Hardwoods species growing in the Czech Republic were developed.

A project dealing with "Genepool conservation of selected tree species in Natural Forest Regions of Southern Moravia" is underway at the research station Uherské Hradiště. It covers mainly wild fruit tree species (cherry, pear, apple, service trees) but also ash, elm species and Norway maple.

"Biotechnological methods of breeding and multiplication of tree species" is another project covering hardwoods (lime, service tree, elm). *In vitro* propagation methods are carried out for gene conservation of some rare species. On request of the forestry practice, species and individuals are propagated *in vitro* as well as by cuttings. The establishment of a tissue bank and cultivation of material suitable for plantation of clonal archives and seed orchards are also practical applications of these methods.

The population structures of forest trees will be tested and the origin of gene resources verified by isoenzyme analysis (DNA analysis, prospectively) based on the setting of the characteristics of genetic variability. Gene markers will also be used for clone identification, studying variation in endangered populations, and studying the resistance of threatened species to biotic and abiotic enviromental factors.

Several permanent activities of the Institute which have been assigned by the Forestry Department of the Ministry of Agriculture should also be mentioned. These are seed material control, registration and certification of reproductive sources (according to the Forest Act), preservation and reproduction of gene resources (mainly in connection with Regional Plans of Forest Development and Forest Management Plans), and consultation and control activities in forest nurseries.

The Forestry Faculty of the Czech Agricultural University continues research activities in breeding of wild cherry. This project deals with tree selection in forest stands, grafting of clones from Germany and establishment of seed orchards.

In many regions, especially in national parks and landscape protection areas, specific breeding programmes including different methods of vegetative reproduction have been implemented. Many practical activities are supported by the Ministry of Environment or by local institutions.

The status of Noble Hardwoods genetic resources in the Czech Republic (as of 1/1/1998) is summarized in the following table.

Species	No. of gene reserve forests (= gene bases)	Selected (plus) trees	*Ex situ* stands	Forest stands approved for seed collection (ha)	
				1/1/96	1/1/98
Acer platanoides	3	9	1	5.91	14.85
Acer pseudoplatanus	58	235	–	132.20	180.93
Alnus spp.	–	–	–	186.94	188.99
Alnus glutinosa	6	80	1	–	–
Betula spp.	1	–	–	205.58	217.98
Betula pendula	–	140	–	–	–
Carpinus betulus	6	–	–	35.79	34.67
Prunus avium	1	239	–	–	–
Fraxinus spp.	–	–	–	723.25	816.67
Fraxinus excelsior	22	131	–	–	–
Sorbus aucuparia	1	–	–	14.68	19.33
Sorbus torminalis	1	50	1	–	0.60
Tilia spp.	27	–	–	158.17	220.56
Tilia cordata	–	313	1	–	–
Tilia platyphyllos	–	49	–	–	–
Ulmus spp.	17	–	–	–	–
Ulmus glabra	–	169	3	9.56	2.33
Ulmus laevis	–	86	1	3.63	10.54
Total	**85 (45 389 ha)**	**1501**	**12.49 ha**	**1475.71 ha**	**1707.45 ha**

Switzerland

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Research activities

- A genetic survey with isoenzymes of all currently known *Sorbus domestica* individuals in Switzerland has been completed. Results will be published shortly.
- A first isoenzyme genetic survey of *Sorbus torminalis* in northeastern Switzerland was completed this spring.

Applied gene conservation

The Federal Office of Environment, Forests and Landscape has recently formulated general strategies concerning biodiversity in our forests. These newly formulated strategies will have direct or indirect implications for the long-term situation of Noble Hardwoods in Switzerland. Conservation and promotion of biodiversity in Swiss forests will be based on the following three general objectives:

1. Close-to-nature silviculture applied to the total forest area, with special emphasis on:
   - conservation and promotion of site-adapted species and mixtures, and
   - conservation and promotion of highly structured and diverse forests.
2. Protection of genetic resources of all tree species, with a special emphasis on:
   - establishment of gene reserves for species occurring in extended populations,
   - creation of conservation and seed orchards for rare species, and
   - promotion and utilization of genetically diverse, site-adapted seed and planting material from either approved seed stands or seed orchards.
3. Creation of a network of forest reserves, in order to:
   - protect ecologically valuable sites and vegetation units,
   - protect rare species, and
   - protect valuable forest associations and forest types, including old management forms.

These newly adopted strategies in national forest policies are certainly a major breakthrough for the conservation and promotion of Noble Hardwoods. They are more than just a verbal statement. Besides indirect effects which may certainly be expected in the long run, several direct effects are already observable.

A new project, designed by the Swiss Federal Institute of Technology in Zürich, has been approved and funded by the federal government. This 3-year project, which started recently, has a number of different objectives:

- to establish country-wide demographic data for 10 hardwood species (inventory)
- to evaluate the current status of these species and their eventual risk level
- to gather information and practical experience which may help to conserve and promote these species
- to gather information on plus trees or particularly suitable material which may be used to establish breeding and conservation orchards
- to develop strategies for practical application of the conservation and promotion measures
- to motivate the forest service for the species and the conservation and promotion tasks
- to distribute the new information to the forest service by training sessions and information material.

The following 10 species have been selected by a scientific committee which is supervising the project: *Sorbus domestica, Sorbus torminalis, Pyrus pyraster* and *Ulmus laevis* as rare or very rare species and *Acer platanoides, Tilia platyphyllos, Tilia cordata* and *Prunus avium* as moderately rare species.

The two seed orchards (*S. domestica* and *S. torminalis*) which we reported on last year will be installed during 1998. About 100 clones for each species were collected and grafted and plants are ready to be planted. Clones of both species were assessed genetically. The results obtained provide important information: (1) all selected clones are genetically unique, and (2) both selections (which were based on form and quality traits in both cases) represent the overall genepool of the species very well, better than any of the surveyed demes. Moreover, gametic multilocus diversity, i.e. the potential to produce different genotypes, is highest in the orchard collections. Both orchards will thus produce offspring with the highest possible genetic diversity.

Germany

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In situ and *ex situ* measures

A report on the situation of Noble Hardwoods species and measures for the conservation of their genetic resources was given at the first Network meeting (Kleinschmit *et al.* 1996). The activities were continued under coordination by the Federal - Laender Working Group on the basis of the "Concept for the conservation of forest genetic resources in the Federal Republic of Germany" from 1987. The English version was published in 1997 (BLAG 1997). The actual state of *in situ* and *ex situ* conservation measures for Noble Hardwoods is summarized in Table 1 according to the activities report for the period 1996-97 (BLAG 1998). Meanwhile a considerable number of *in situ* stands was selected for Noble Hardwoods species. For the rare species *ex situ* stands, seed orchards or clonal archives were established, particularly for those species where only very few stands or scattered individual trees could be found. In addition, seed material has been stored, where possible, from stands, seed orchards or single trees.

Research

Biochemical (isoenzymes) and/or molecular genetic (DNA) investigations about the genetic variability and the population structures were continued in several Noble Hardwoods species. Evaluations were intensified and supported by research grants. Special emphasis was given to the problem of pollen contamination and hybridization of pure species by cultivated varieties, e.g. in wild fruit trees. For most Noble Hardwoods, the storage of seeds is possible only over a short period. Studies are under way to improve the long-term storage, e.g. by special preconditional measures and cryopreservation methods.

Public awareness

Ten years ago a committee started to elect each year a "Tree of the Year". The aim is to focus the public on endangered species and ecosystems. Among the species were several Noble Hardwoods: 1991 lime (*Tilia* spp.), 1992 elm (*Ulmus* spp.), 1993 service tree (*Sorbus domestica*), 1995 Norway maple (*Acer platanoides*), 1996 hornbeam (*Carpinus betulus*), 1997 mountain ash (*Sorbus aucuparia*), 1998 wild pear (*Pyrus pyraster*). Various leaflets and articles were published about the respective tree species. Elm and wild pear, for instance, were also topics of special meetings. The papers and posters presented were published in proceedings (Kleinschmit and Weisgerber 1993; Kleinschmit *et al.* 1998).

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Table 1. *In situ* and *ex situ* conservation measures for Noble Hardwoods in Germany (as of 31.12.1997) (source: BLAG 1998)

	In situ			*Ex situ*								
	Stands		No. of	Stands		No. of	Seed orchards		No. of	No. of	Clonal archives	
Species	No.	Area (ha)	single trees	No.	Area (ha)	single trees	No.	Area (ha)	families	clones	No.	No. of clones
Acer campestre	10	19.85	1236	–	–	–	–	–	–	–	–	–
Acer platanoides	14	4.69	692	–	–	–	2	4.40	–	110	–	–
Acer pseudoplatanus	68	68.09	226	6	10.45	–	17	29.60	–	781	3	58
Acer spp.	–	–	4	–	–	50	–	–	–		–	–
Alnus glutinosa	84	234.13	216	–	–	–	19	37.97	–	822	1	21
Alnus incana	–	–	–	–	–	–	2	0.99	–		–	–
Betula pendula	32	59.75	32	–	–	37	1	0.60	–	29	3	427
Betula pubescens	29	376.54	124	3	4.50	–	1	1.64	–		1	72
Carpinus betulus	81	134.48	117	2	0.90	–	2	4.40	–	157	–	–
Fraxinus excelsior	101	141.49	145	–	–	–	11	23.80	–	719	1	52
Malus sylvestris	2	1.10	2024	20	4.40	1985	22	21.05	232	514	1	28
Prunus avium	40	21.66	620	6	2.6	700	18	33.6	1	1069	8	205
Pyrus pyraster	6	2.75	967	1	0.1	400	16	12.9	40	400	2	57
Sorbus aria	1	0.20	259	4	2.60	–	3	2.00	53	50	–	–
Sorbus aucuparia	4	3.50	251	7	2.30	–	4	3.60	48	111	–	–
Sorbus domestica	1	0.10	1928	7	2.80	4243	6	4.80	128	236	2	76
Sorbus torminalis	244	4.80	1661	13	6.20	4707	8	9.60	100	282	2	41
Sorbus spp.	–	–	–	2	0.20	–	–	–	–	–	–	–
Tilia cordata	122	124.75	204	–	–	–	19	39.40	–	582	2	102
Tilia platyphyllos	125	21.19	198	–	–	–	2	4.10	–	191	1	11
Ulmus glabra	90	49.63	3189	7	6.65	4625	9	11.10	37	287	18	688
Ulmus laevis	82	50.78	3598	13	4.13	120	1	2.00	–	109	3	80
Ulmus minor	30	10.16	671	–	–	270	1	1.50	–	50	1	21

Belgium

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Flanders

The progress made in the gene conservation strategy of some Noble Hardwoods species such as common ash, wild cherry and sycamore maple, resulted from the continuation of the long-term breeding programme: new plus trees and seed stands were selected (Table 1).

Table 1. Selection of seed stands and plus trees in Flanders since the second Noble Hardwoods Network meeting

Species	Seed stands		Plus trees
	Number	Area (ha)	
Prunus avium	1	1.00	9
Fraxinus excelsior	1	0.35	3
Acer pseudoplatanus	1	0.50	4
Total	**3**	**1.85**	**16**

In addition, the follow-up of existing provenance trials (common ash) and progeny tests (wild cherry) was assured. Following the evaluation of genetic resources (i.e. plus trees) of common ash on the basis of resistance to ash canker, 29 bacterial isolates were obtained from newly located infected trees.

Five ecological territories (river basins) were surveyed in search of autochthonous trees of 14 Noble Hardwoods species, resulting in the recording of 482 individuals.

In the framework of the EU programme "Coordination for conservation, characterization, collection and utilization of genetic resources of European elms" (GEN RES 78), the *ex situ* conservation programme of autochthonous elms continued during 1997-98. In 1997, 67 genotypes were successfully propagated and are held in the clone genebank. All the clones are registered with passport data. Forty-six percent of the genebank consists of clones of *Ulmus minor* Mill. or intermediate forms between *U. minor* and *U. glabra* Huds. Seven percent of the genotypes are *U. glabra* Huds. and 10% are *U. laevis* Pall. A selection of 30 genotypes will be tested for tolerance against *Ophiostoma novo-ulmi* in a field test in 1999.

Wallonia

Within the scope of the selection and breeding programme of forest tree species, 17 seed stands were selected (Table 2), together with three plus trees of *Acer pseudoplatanus*.

Table 2. Selection of seed stands in Wallonia since the second Noble Hardwoods Network meeting

Species	Seed stands	
	Number	Area (ha)
Prunus avium	3	22.94
Alnus glutinosa	7	5.23
Fraxinus excelsior	2	40.79
Acer pseudoplatanus	2	1.80
Betula pubescens	1	0.40
Betula pendula	2	6.19
Total	**17**	**77.35**

The Netherlands

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In relation to the nationwide inventories reported at the (second) Network meeting, further activities can be mentioned. Some of the areas that were planned to be investigated for autochthonous reproductive material of trees and shrubs have been monitored. These inventories were funded not only by the government, but also by private nature conservation organizations.

Collecting of the material took place in all investigated areas and an increasing amount of plant material became available for trade.

The government has commissioned a group of organizations to make a proposal for the establishment of genebanks for a great number of tree species. Some of these should be established at the same time as seed orchards in order to be able to collect highly valuable genetic material at reasonable prices. This is considered the best possible option to compete with relatively cheap basic reproductive material from undesired origins. This proposal is still under negotiation, but many Noble Hardwoods species are on its priority list.

Funds for implementation will have to be found at government level. The State Forest Service will be involved in the establishment of genebanks on its properties, while administration will be a task for the Institute for Forestry and Nature Research. Private organizations will cover collecting and growing of the material needed for these genebanks.

An Advisory Board was set up to accompany both planning and implementation of the process.

Poland

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According to information received from the State Forest and Environment Protection National Fund, chief sponsor of the forest research, it appears that in 1997 and 1998 no new projects concerning the conservation of Noble Hardwoods in Poland were accepted. The government budget also reduced the financial means for all scientific investigations in 1998, in comparison with 1997. These are the costs of our economic transformation. Additionally, the great flood disaster in 1997 entailed large expenses, not only from the government budget, but also from other economic and aid institutions.

Inventory of old trees in Poland

Old trees are of great value for scientific research, as well as for forest husbandry. They are remnants of the native wild populations shaped by natural selection, their genotypes belong to preindustrial times and they show high adaptation capacity since they have survived to reach their age. Because of their genetic value and advanced age (they can perish at any time), inventory of these trees should be made and their genes should be preserved (in clonal archives and genebanks).

In northeast Poland's forests (798 100 ha), trees older than 200 years can still be found. The inventory of old trees was made according to the following criteria: the tree should grow in the forest and should not be younger than 150 years. The age of a considerable number of trees cannot be estimated because their stems are decayed.

The following Noble Hardwoods were recorded in northeast Poland:

Fraxinus excelsior	84 trees with dbh between 71.7 cm and 159 cm (77 trees in Białowieża Forest). The oldest tree was 249 years
Tilia cordata	39 trees with dbh between 82.9 cm and 143.9 cm (36 trees in Białowieża Forest). The oldest tree was 165 years
Acer platanoides	23 trees with dbh between 50.5 cm and 72.18 cm (22 trees in Białowieża Forest). The oldest tree was 149 years
Ulmus glabra	20 trees with dbh between 30 cm and 142 cm (18 trees in Białowieża Forest). The oldest tree was 142 years
Carpinus betulus	8 trees with dbh between 55.6 cm and 136.9 cm, all in Białowieża Forest

The Boreal Zone

Lithuania

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The main threats to Noble Hardwoods genetic resources in Lithuania are forest management practices that give preference to other species in the planting, tending and thinning of forests; competition by other species; loss of habitat due to agriculture and forest land reclamation; damage by fungal diseases, game and insect outbreaks. The resources that are provided for both research and applied gene conservation activities are insufficient to cover the measures needed for species of current minor importance.

In 1997, research activities and applied gene conservation were carried out on the basis of three national projects financed by the Fund of Science and Education, the Ministry of Agriculture and Forestry, and the Ministry of Environment of the Lithuanian Republic.

Under the project "Resources of cultivated plants" (1994-97) and based on up-to-date concepts, aims and methods of gene conservation and tree breeding, new criteria for the assessment, selection and conservation of forest genetic resources were defined. Plans have been made for the modernization of the conventional system of forest gene conservation. Based on international recommendations and descriptors prepared within EUFORGEN, the databases of Lithuanian forest genetic resources conserved *in situ* and *ex situ* have been updated; data on Noble Hardwoods have also been compiled and/or updated. A catalogue of forest genetic resources was issued.

It is also foreseen to develop genetic studies and activities on gene conservation and tree breeding of Noble Hardwoods within the new project on plant gene conservation for the coming 5 years. This project, which has a State Programme status, is being initiated. Special efforts will be made to extend the gene conservation of *Fraxinus excelsior, Tilia cordata* and *Acer platanoides*.

In the framework of the "Programme for forest genetics and tree breeding" (1997) the gene conservation and tree breeding strategies and programmes were elaborated for the main tree species of the country, including *Alnus glutinosa* and *F. excelsior*. They foresee the transformation of the conventional, static forest gene conservation into a dynamic Multiple Population Breeding System (MPBS) concept, aiming at the creation of good conditions for the continuous evolution of species, and combining secure and sustainable conservation of forest genetic resources, in view of possible ecoclimatic changes, and efficient tree breeding. Efforts are made to include dynamic gene conservation activities in the national forestry policy. The proposed programmes were approved as recommendations for practical gene conservation and tree breeding in the country. Within this project, new plus trees of *A. glutinosa* were selected. In greenhouse experiments the growth of progenies from 135 plus trees was studied. Three progeny test plantations (3 × 2 ha) were established in three different forest ecoclimatic regions in the country. All 135 half-sib families were planted in each test plantation. The establishment of a clonal archive/seed orchard (4 ha) was completed.

Within the project "Effects of individually growing broadleaves on forest biodiversity and stability, inventory of their genetic resources, selection and reproduction" (1997-2000), an inventory of rare Noble Hardwoods has been started. Habitats of Noble Hardwoods, their distribution, biocoenotic and economic role, significance and reproduction potential were assayed. A strategy for investigation, phenotypic assessment, conservation and protection was set up. Plus trees and/or representatives of local populations of *Acer platanoides, Ulmus laevis, Malus sylvestris* and *Pyrus communis* were selected in the southwest of Lithuania. In the coming years, the inventory of gene resources to be conserved will be expanded to the rest of the country.

Much effort is expended to introduce and advertise new concepts of gene conservation among forestry officials and foresters, and to raise general public awareness in order to guarantee the success of the new national gene conservation and tree breeding programmes.

Finland

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Applied conservation activities

The *ex situ* action plan, presented in Table 1, was carried out intensively. However, the outcome was again less than planned, owing to practical obstacles such as insufficient seed crop due to the cold period during flowering of maple, and lack of autochthonous stock for the grafting of lime. The setting aside of land for the planting of the collections is completed and soil preparations are under way.

Table 1. *Ex situ* collections: goals and situation as of 1 January 1998

	Goal				Implemented	
Species	Populations	Trees/ Families	Area of the collection planted (ha)	Finished by	Populations	Trees/ Families
Acer platanoides	50	290	1.0	2005	28[†]	187
Fraxinus excelsior	20	170	0.6	2005	13[†]	
Tilia cordata	70	400	2.0	2003	35	162
Quercus robur	20	170	0.6	2000	19	126
Ulmus glabra	40	250	1.3	2000	30	180
U. laevis	30	200	1.0	2003		

[†] Plots sown in autumn 1997 are included.

The area of *in situ* gene reserve forests of Noble Hardwoods has not increased since 1995, and is not likely to grow much from its present 62 ha, which consists of four stands of maple, lime and ash.

Research activities

- Isoenzyme studies on maple and European white elm (Foundation for Forest Tree Breeding, Finnish Forest Research Institute)
- Hardening process and frost tolerance studies which include Wych elm (University of Joensuu)
- Distribution and dynamics of genetic variation of minor tree species (The Academy of Finland, Research programme on biological diversity).

Introductory country reports

Noble Hardwoods genetic resources in Bulgaria

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Although Bulgaria is smaller in territory than a number of European countries, its biodiversity is rich: about 3600 species of higher plants, 52 species of ferns, 670 species of mosses, 600 species of lichens and about 4000 species of algae (Peev *et al.* 1993), and about 35 000 animal species (Nedialkov 1994). This diversity is due to the influence of three phytogeographic regions: European Deciduous Forest, Mediterranean Forest and Euroasian Steppe, and to the diversity of climatic and edaphic conditions determined by the relief, bedrocks, soils, hydrothermic regime and other factors.

Biodiversity in Bulgaria is determined to a great extent by the existing forest ecosystems. Until the beginning of the present millenium, over two-thirds of the territory were covered with forests.

The three forest vegetation districts: "Misian", "Southern By-Frontier" (each with five subregions) and "Thracian" (with six subregions); the three forest vegetation belts determined by altitude: the Lower Plain-and-Hilly and Hilly Foothill Belt of the Oak Forests; the Middle-Mountain Belt of the Oak and Coniferous Forests; and the High-Mountain Belt, each with three sub-belts; the climatic and edaphic conditions; and the main forest tree species determine 147 types of forest ecosystems. These are identified according to the classification scheme of the types of forest sites in Bulgaria (Agrolessproekt 1983).

In 1995, the forest lands occupied 3 876 272 ha, i.e. 34.9% of the country's territory. The area covered with forests was 3 334 256 ha, with 2 265 582 ha of these (76.9%) under deciduous forests composed mainly of oaks (1 092 475 ha - 48.22%), followed by beech (557 742 ha - 24.62%), hornbeam (304 228 ha - 13.43%), false acacia (103 811 ha - 4.58%), poplars (25 870 ha - 1.14%) and other species covering the remaining 8.01%.

The total number of autochthonous tree and shrub species in the forests of Bulgaria is about 290, including 110 trees and 180 shrubs distributed in 93 genera and 42 families. Approximately 380 introduced species occur, represented by 200 trees and 180 shrubs distributed in 281 genera and 65 families. Most of the introduced species comprise small groups or occur as single trees, including individuals grown in arboreta and botanical gardens. Therefore it is more realistic to consider that only about 100 tree species and 80 shrub species are introduced. The phanerogamous flora in Bulgaria can be approximately estimated at 460 species, including 210 species of trees and 250 of shrubs. The families richest in genera are the Rosaceae (17 genera), Fabaceae (7), Ericaceae (6), Betulaceae and Oleaceae (5 genera each). The genera with the highest number of species are *Rosa* (32 species), *Quercus* (17), *Salix* (15), *Sorbus* and *Rubus* (5 species each), *Juniperus* and *Acer* (7 species each).

The other kind of biodiversity is intraspecific diversity, which has been studied in Bulgaria for 32 of the forest tree species with greatest commercial value. About 50 ecotypes, 80 varieties and 360 forms constitute a great genetic resource.

The composition of species belonging to the category Noble Hardwoods, as defined by the EUFORGEN Network, is not unique and identical in all European countries. Some deciduous species are "noble" in a certain region in Europe, but not in another; they often differ even for adjacent countries. There is only a limited number of tree species with the common properties of Noble Hardwoods throughout Europe. In Bulgaria, 52 forest tree species may be referred to as the Noble Hardwoods. These belong to 13 families and 24 genera (see Table 1).

Table 1. Noble Hardwood species in Bulgaria

Family	Genus	Species
Aceraceae Juss.	*Acer* L.	*A. campestre* L.
		A. heldreichii Orch.
		A. hyrcanum Fisck. et C.A. May
		A. monspessulanum L.
		A. platanoides L.
		A. pseudoplatanus L.
Aquifoliaceae Bartl.	*Ilex* L.	*I. aquifolium* L.
Betulaceae Gray	*Alnus* Gaertn.	*A. glutinosa* (L.) Gaertn.
		A. incana (L.) Moench.
		A. viridis (Chaix)DC.
	Betula L.	*B. pendula* Roth.
	Corylus L.	*C. colurna* L.
	Ostrya Scop.	*O. carpinifolia* Scop.
Cornaceae Dum.	*Cornus* L.	*C. mas* L.
Fagaceae Dum.	*Castanea* Mill.	*C. sativa* Mill.
Hippocastanaceae D.C.	*Aesculus* L.	*A. hippocastanum* L.
Juglandaceae Lindl.	*Juglans* L.	*J. regia* L.
Oleaceae Hoff. et Link.	*Fraxinus* L.	*F. excelsior* L.
		F. ornus L.
		F. oxycarpa Willd.
Platanaceae Dum.	*Platanus* L.	*P. orientalis* L.
Rosaceae Juss.	*Prunus* L.	*P. avium* L.
		P. cerasifera Ehrh.
		P. padus L.
	Laurocerasus Roem.	*L. officinalis* Roem.
	Malus Mill.	*M. dasyphylla* Borkh.
		M. praecox (Pall.) Borkh.
		M. sylvestris Mill.
	Mespilus L.	*M. germanica* L.
	Padus Mill.	*P. mahaleb* (L.) Borkh.
		P. racemosa (Lam.) Gilib.
	Pyrus L.	*P. amygdaliformis* Vill.
		P. communis L
		P. elaeagnifolia Pall.
		P. nivalis Jacq.
	Sorbus L.	*S. aria* (L.)Crantz.
		S. aucuparia L.
		S. austriaca (Beck.) Hedl.
		S. domestica L.
		S. graeca (Spach.) Kotschy
		S. torminalis (L.) Crantz.
		S. umbellata (Desf.) Fritsch.
Staphyleaceae Lindl.	*Staphylea* L.	*S. pinnata* L.
Tiliaceae Juss.	*Tilia* L.	*T. cordata* Mill.
		T. platyphyllos Scop.
		T. rubra D.C.
		T. tomentosa Moench.
Ulmaceae Mirb.	*Celtis* L.	*C. australis* L.
		C. caucasica Willd.
	Ulmus L.	*U. glabra* Huds.
		U. laevis Pall.
		U. minor Mill.

The species with relatively great commercial importance are the representatives of the genus *Tilia* occupying 47 222 ha or 2.08% of the deciduous forest area: *Fraxinus* (12 780 ha - 0.56%), *Betula* (9577 ha - 0.43%), *Juglans* (9435 ha -0.42%) and *Acer* (3748 ha - 0.16%). The total area occupied by the other genera is 94 570 ha (4.17%).

Depending on their genetic basis, Noble Hardwoods are adapted to particular environmental conditions where they realize their growth potential (Stefanov and Ganchev 1958; Delkov 1988). Their characteristics are given below.

Acer campestre	Very plastic, not demanding for soil and drought. Distributed from sea level up to 1600 m asl. Dimensions: height - up to 25 m; diameter - up to 60 cm.
Acer platanoides	Demanding for nutrient richness and moisture of the soil. Distributed from 500 up to 1500 m asl. Dimensions: height - up to 30 m; diameter - up to 1 m.
Acer pseudoplatanus	Occurs in the middle mountain belt, up to 1300-1400 m asl. Prefers fertile, deep and nearly moist soils. Dimensions: height - up to 40 m; diameter - up to 3 m.
Alnus glutinosa	Distributed up to 1000 m asl., by rivers, on rich and moist soils. Dimensions: height - up to 35 m; diameter - up to 1 m.
Betula pendula	Not demanding for soil conditions but adapted to colder and humid climate at 1000 up to 2000 m asl. Dimensions: height - up to 30 m; diameter - up to 50-60 cm.
Castanea sativa	Moisture- and warmth-demanding species growing from 250 up to 850 m asl. in Belassitsa Mountain and in the Berkovitsa spur of the Balkan Range. Dimensions: height - up to 30-35 m; diameter - up to 2 m.
Corylus colurna	Prefers nearly moist and rich soils in mountains, at altitudes up to 1200 m. Dimensions: height – up to 25 m; diameter - up to 50-60 cm.
Fraxinus excelsior	Demanding for richness and moisture of soils, but resistant to polluted air. Occurs in mountains at altitudes up to 1300 m. Dimensions: height - up to 40 m; diameter - up to 1 m.
Fraxinus ornus	Grows under various soil conditions, up to 1200 m asl. Resistant to drought. Dimensions: height - up to 20 m, diameter - up to 50-60 cm
Fraxinus oxycarpa	Warmth-demanding species occurring by rivers, on moist and rich soils, but also on stony terrains. Dimensions: height - up to 43 m; diameter - up to 1 m.
Juglans regia	Prefers nearly moist and rich soils and occurs up to 1100-1200 m asl. Dimensions: height - up to 35 m; diameter - up to 2 m.
Ostrya carpinifolia	A species growing at many sites and distributed up to 900 m asl, with preference for warmer climate and higher humidity of air. Dimensions: height - up to 20 m; diameter - up to 30 cm.
Platanus orientalis	Grows mainly on alluvial aerated soils, in warm climate, in the southern part of the country where there is Mediterranean influence, and reaches up to 600 m asl. Dimensions: height - up to 50 m; diameter - up to 4 m.
Prunus avium	Distributed up to 1000-1200 m asl and requires fertile and nearly moist soils. Dimensions: height - up to 35 m; diameter - up to 60 cm.
Tilia cordata	Adapted to nearly moist and rich soils, at altitudes up to 1500 m. Dimensions: height - up to 30 m; diameter - up to 1 m.
Tilia tomentosa	Drought-resistant species occurring from 700-800 m up to 1400 m asl. Dimensions: height - up to 25 m; diameter - up to 1 m.
Tilia platyphyllos	Distributed in warm and moist defiles, from 500 up to 1500 m asl. Dimensions: height - up to 40 m; diameter - up to 1 m.
Ulmus glabra	Demanding for nutrient richness and moisture of the soils, and reaches up to 1300 m asl. Dimensions: height - up to 40 m; diameter - up to 1 m.
Ulmus laevis	Occurs in the mesophilic forests of eastern Bulgaria and the Tracian Lowland. Dimensions: height - up to 35 m; diameter - up to 1 m.
Ulmus minor	Demanding species growing on nearly moist, aerated soils, up to 1300 m asl. Dimensions: height - up to 40 m; diameter - up to 1.5 m.

The conservation of Noble Hardwoods genetic resources in Bulgaria is carried out in several ways:

- Since 1991, the felling of forest fruit trees and rare forest trees is prohibited.
- Seed stands of Noble Hardwoods have been selected (total area 2751.4 ha) and the possibilities for expanding their areas are being investigated. Their total area and percentages according to species vary strongly. The seed stands of the species belonging to the genus *Acer* amount to 85.4 ha, those of the genus *Betula* to 354.5 ha, those of *Castanea* to 118.2 ha, *Fraxinus* 402.1 ha, *Tilia* 1721.7 ha. However, the seed stands selected for certain species, such as *Alnus glutinosa, Corylus colurna, Juglans regia, Prunus avium* and *Sorbus* spp. are still insufficient.
- The 12 national parks (total area 282 765 ha), 85 reserves (total area 79 474 ha) and protected territories (total area 15 000 ha) represent a safe measure for the conservation of Noble Hardwoods.
- As a result of the implementation of a programme for breeding forest fruit tree species, about 19 400 ha of plantations have been established over 20 years (Bouzov 1993), including 13 970 ha of *Juglans regia,* 3560 ha of *Castanea sativa,* 1100 ha of *Amygdalus communis* and 760 ha of *Corylus* spp.

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Present status of Noble Hardwoods in Estonia

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Introduction

About 6500 to 3000 years ago, broadleaved nemoral forests were quite common in Estonia, but as the climate became more severe and the fertile forest soils were changed into fields, their area decreased to a minimum (Valk 1974).

The total area of forest lands in Estonia is 2 015 500 ha; 47.6% of the mainland territory is covered with forests (Anonymous 1998). Lately this area has been increasing, including the area of broadleaved forests, as a result of the afforestation of former pastures and meadows, and also the planting of artificial stands.

According to the list of species published at the first meeting of the Noble Hardwoods Network (Turok *et al.* 1996), the following tree species growing in Estonia belong to this group: birch (*Betula pendula* and *Betula pubescens*), alder (*Alnus glutinosa* and *Alnus incana*), ash (*Fraxinus excelsior*), lime (*Tilia cordata*), Norway maple (*Acer platanoides*), Wych elm (*Ulmus glabra*), white elm (*Ulmus laevis*) and rowan (*Sorbus aucuparia*), which cover altogether 38.7% of the total forest area.

The average age of the Noble Hardwoods stands in Estonia is 43 years in private and 46 years in state-owned forests, which more or less corresponds to half of the rotation age, whether taken as an average or separately for each tree species. Naturally the rotation age depends not only on the main tree species, but also on the aims of the forest management and on soil conditions. It is 101-140 years for ash, 71-80 years for birch stands and 41-80 years for other broadleaves stands (Anonymous 1995).

Noble Hardwood tree species

*Birches (*Betula *spp.)*

Two birch species out of four growing in Estonia are important from the forestry point of view: silver birch (*Betula pendula*) and pubescent birch (*Betula pubescens*). They have been considered together in the forestry management.

The area of the birch stands in Estonia takes second place after Scots pine, making up 27.7% of the state-owned forests (Fig. 1) and 31% of the private forests (Fig. 2) (all stands included) (Anonymous 1998). The average age of the birch stands is 47 years.

The distribution of birch stands on the territory of Estonia is quite irregular. There are quite a number of them in Tartu County, in the northeast and southwest of Estonia. The stands of silver birch produce most of the birch timber and three-quarters of them grow in the site types of *Filipendula*, *Myrtillus*, *Aegopodium* and *Oxalis*. The stands of silver birch are particularly productive in Estonia (Siimon and Tamm 1996).

According to the data given by the forest management, the mean growing stock per hectare reaches 166 m^3/ha in state-owned forests (Table 1) and 159 m^3/ha in private forests (Table 2). The mean current annual increment of the growing stock is 4.8 m^3/ha. The birch timber yield from final cuttings makes up 25%, sharing second and third place with the Scots pine after Norway spruce.

Most of the birch timber is used as pulpwood, which is exported due to the temporary depression of the Estonian pulp industry. Birch timber is also used in furniture and ski factories.

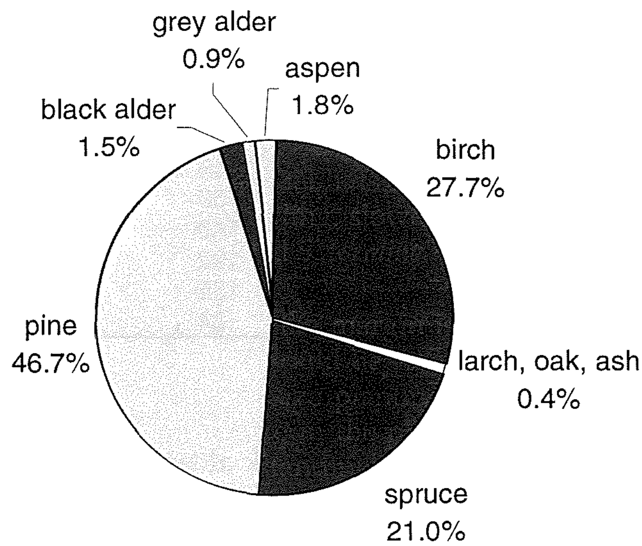

Fig. 1. Tree species dominance in state forest stands (01/01/1997).

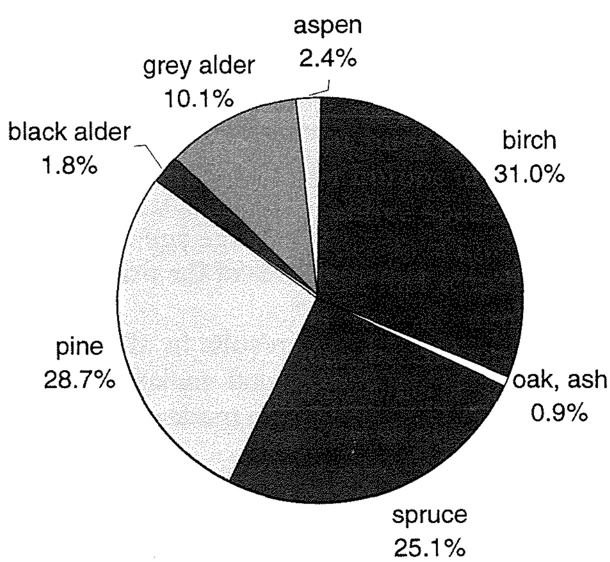

Fig. 2. Tree species dominance in private forest stands (01/01/1997).

Table 1. Area, age, growing stock and increment of Noble Hardwoods stands in state forests

Dominant tree species	Area ('000 ha)	Average age	Mean growing stock (m^3/ha)	Current annual increment (m^3/ha)
Alnus glutinosa	12.653	48	162	4.6
Alnus incana	7.592	30	133	7.9
Acer platanoides	0.018	51	95	3.5
Betula spp.	233.652	47	166	4.6
Fraxinus excelsior	1.687	45	149	4.7
Tilia cordata	0.122	72	188	3.4
Ulmus glabra	0.042	67	127	2.7
Ulmus laevis	0.002	36	116	5.5

Table 2. Area, age, growing stock and increment of Noble Hardwoods stands in private forests

Dominant tree species	Area ('000 ha)	Average age	Mean growing stock (m^3/ha)	Current annual increment (m^3/ha)
Alnus glutinosa	2.814	50	172	4.8
Alnus incana	15.789	31	153	7.6
Acer platanoides	0.009	71	149	2.8
Betula spp.	48.464	46	159	5.2
Fraxinus excelsior	0.782	57	148	4.0
Tilia cordata	0.023	94	192	3.1
Ulmus glabra	0.005	54	155	4.1
Ulmus laevis	0.001	61	84	3.2

*Alders (*Alnus *spp.)*

Two alder species grow naturally in Estonia: black alder (*Alnus glutinosa*) and grey alder (*Alnus incana*). Their hybrid (*A. hybrida*) is seldom found in Estonia. It exceeds the speed of growth of both the black and grey alder and is able to survive more easily in unfavourable growing conditions.

Black alder (*Alnus glutinosa*)

The stands of black alder grow in lowlands on wet soils with high and medium fertility. These areas are flooded during spring months and water movement in soils is fast (Hainla 1996). The best forest site types for black alder are *Filipendula*, Alder swamp forest, *Dryopteris* and *Aegopodium*. Black alder stands in Estonia make up 1.5% of the state forest area (Fig. 1) and 1.8% of private forest area (Fig. 2) (Anonymous 1998). The black alder stands are more common in eastern and southwestern Estonia. According to the mean growing stock per hectare (169 m^3) black alder takes fourth place after aspen, spruce and pine. The current increment of the growing stock is 4.7 m^3/ha. The average age of the black alder stands is 48 years; 37% of the state-owned forests (Fig. 3) and 49% of the private forests (Fig. 4) are 41–60 years old.

The utilization of alder has yielded very good results in afforestations of exhausted oil-shale and sand mines and sand dunes. Alder wood makes our wood utilization more diverse; furniture, musical instruments and veneer are made of it.

Grey alder (*Alnus incana*)

The grey alder is distributed over the continental part of the country, while rare on the islands. It grows better on fertile soils and is the first tree species to start growing in the fields which are no longer cultivated. On the basis of the database of survey results of the Forest Management Centre, 0.9% of state forests (Fig. 1) are grey alder stands (as the main tree species), but in nature the situation is different; many grey alder stands are not considered as forest lands. More accurate data come from private forest land owners, from a special inventory made for them: the grey alder forests constitute 10.1% of all private forests (Fig. 2), and from all cuttings in private forests, 25% is grey alder timber (Tullus *et al.* 1995). The mean annual volume increment is 7.7 m^3/ha, which shows that it is one of the fastest growing tree species in Estonia.

Considering that a lot of the grey alder is also growing outside forest lands, e.g. in unproductive farmlands, by drains, in small grasslands, etc., we may state that it is extremely important as firewood. The grey alder stands are common in *Aegopodium*, *Filipendula*, *Oxalis* and *Dryopteris* forest site types.

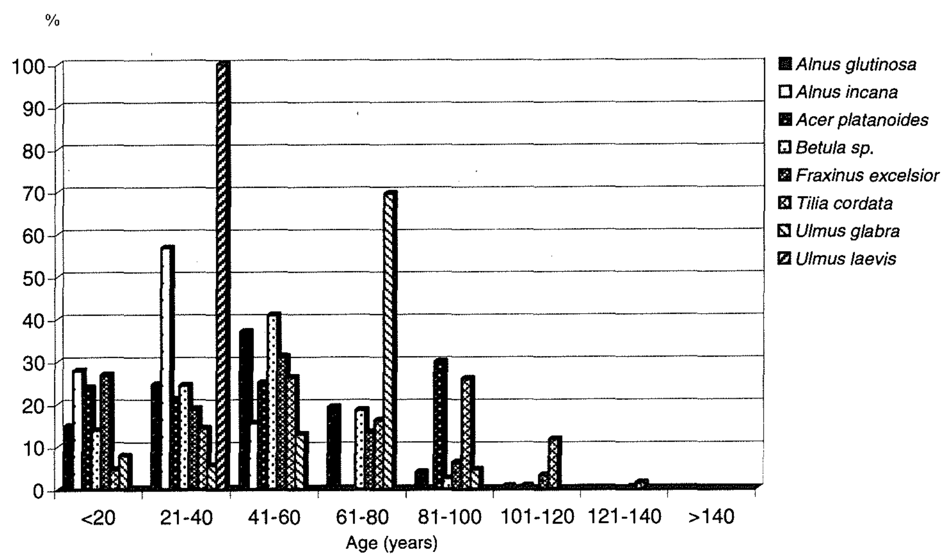

Fig. 3. Distribution of stands (%) according to age groups in state forests.

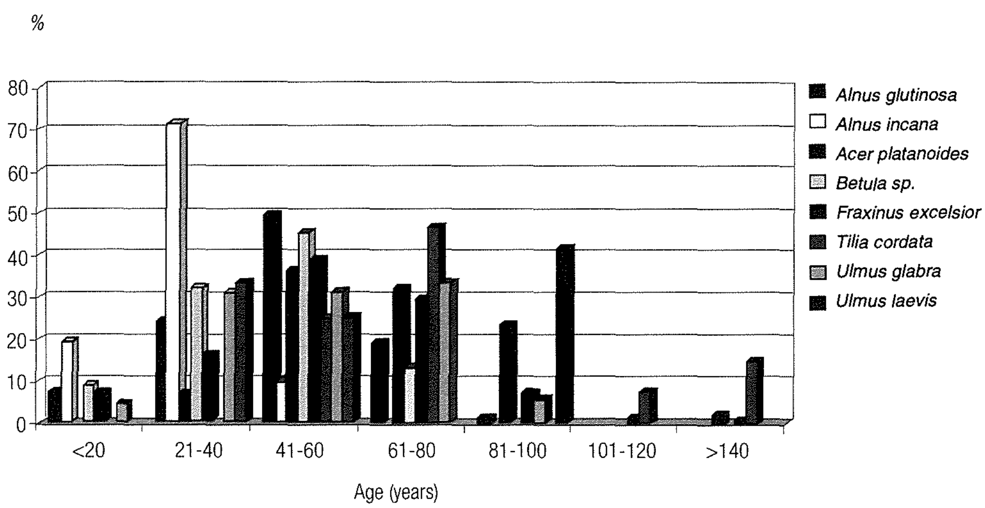

Fig. 4. Distribution of stands (%) according to age groups in private forests.

*Ash (***Fraxinus excelsior***)*

Ash stands make up 0.2% of the area of the state forests and 0.5% of the private forests (Anonymous 1998). Most of them are situated in East and South Estonia. There are also ash stands in the neighbourhood of Tallinn and Pärnu and on the island of Saaremaa. The majority of ash stands belong to the category of production forests although quite a number of them should be among protected and protection forests. Ash stands prefer *Aegopodium* site type but *Filipendula, Carex* and *Equisetum* site types are also quite common.

The average age of ash stands is 45 years (Table 1) in state-owned forests and 57 years (Table 2) in private forests. The forests, which are over 100 years old (the oldest is 140 years) can be found mainly in East and South Estonia (Figs. 3 and 4). In Estonia, 40 to 60-year-old ash stands dominate. The mean growing stock per hectare is 149 m^3. The ash regeneration is quite abundant almost everywhere, which guarantees the establishment of the new forest generation.

Lime (*Tilia cordata*)

Lime is one of the favourite trees in the yards, parks and stands in Estonia. It has been considered a sacred tree. According to the data of forestry management there are 145 ha of stands where lime is dominating in Estonia. This tree prefers fertile soils that are rich in humus. The small-leaved lime grows in fertile sites in numerous stands of different composition as the second layer, making the forests more diverse. The average age of the lime stands is 86 years. Lime stands 61 to 80 years old make up 47% of all the age groups in private forests (Fig. 4). The stands aged 41–60 years make up a quarter of the stands in the state-owned forests, and the same is true for stands 81 to 100 years old (Fig. 3). There are 100-year-old stands in East Virumaa and in the neighbourhood of Elva. The mean growing stock is 192 m^3/ha in private (Table 2) and nearly 188 m^3/ha in the state-owned forests (Table 1). The timber is used in veneer and match industries. Toys and musical instruments are also made of it. Small-leaved lime is highly appreciated in Estonia as a valuable herb and also as a plant where bees can find a lot of honey.

Norway maple (*Acer platanoides*)

There are 27 ha of stands in Estonia where Norway maple dominates according to the data by the forest management. There are also 21 ha of artificial maple stands (Kalda 1995). The forests where maple dominates in small groups are mostly situated in East and West Virumaa, also in the neighbourhood of Võru and on the island of Saaremaa. Most of the maple stands belong to the *Hepatica* and *Oxalis* site types, and to a smaller extent, also to the *Aegopodium* and *Oxalis-Vaccinium* types. The age of maple stands in private forests is 41–60 years (Fig. 4), but in state forests they are 81 to 100 years old (Fig. 3). The oldest maple in North Estonia is 100 years; originally it was in a park that has changed into a forest in the course of years. There is also one maple stand over 90 years old in Lahemaa, which also contains spruce and some other deciduous trees; the most common are oak, ash and birch. The mean growing stock of maple stands makes up about 149 m^3/ha in private forests (Table 2). The maple helps to diversify Estonian forests; apart from that the maintenance of varied broadleaved forests and the creation of stable forest associations are also valuable.

Elms (*Ulmus *spp.)

Wych elm (*Ulmus glabra*)

There are 25 natural stands (Kalda 1995) and nine planted stands in Estonia. The biggest natural elm forests grow along the slope of the North Estonian Clint. Another area of elms is South Estonia, near Viljandi and Otepää.

At Altnurga, 2 km from the Tallinn–Tartu highway, there is a unique 15-ha forest. It can be considered as a "natural memorial" – vigorous forest, but typical of one of the earliest periods of our natural history. This is the only forest in Estonia and maybe also in Nordic countries where the life of a broadleaved forest in a river valley goes on ruled by the laws of nature only (Parmasto 1998).

One of the oldest and most beautiful in South Estonia is the elm stand growing on the slope of the valley at Heimtali, where some trees are 250 years old. According to the data published by the forestry management the average age of natural elm stands is 66 years. It should be stated that the regeneration of elms in nature is strong enough to guarantee the survival of the species. Elm stands usually grow in *Hepatica, Aegopodium* site types. The other favourable growth site for them is on the slopes of the ancient valleys in South Estonia (*Aegopodium* site type). The mean growing stock is 155 m^3/ha and the current increment 4.1 m^3/ha in private forests (Table 2). In state-owned forests the corresponding figures are 127 m^3/ha and 2.7 m^3/ha (Table 1).

White elm (*Ulmus laevis*)

White elm is one of the most uncommon natural tree species in Estonia. It has been recorded in the Red Data Book of Estonia and belongs to the third category of the protected species of Estonia. White elm, with some other broadleaved tree species, belongs to the trees of the past, which started spreading in our forests about 7000 years ago and were most abundant during the Atlantic climatic period. In connection with the constant process of climate changes toward more continental and with the increasing human influence on forests, nemoral forests have had to withdraw. Consumption was faster than the self-regenerative ability of the trees. The white elm can have a lot of stump shoot and grows quickly when young but it has one "inborn" shortcoming – its seeds lose their germinative capacity very quickly, often before reaching a suitable site. Therefore their seed propagation is really scarce.

A few viable populations of white elm (about 3 ha) can be found north of the nature preserve of Alam-Pedja and in South Estonia. Small groups are also occasionally encountered on the banks of bigger Estonian rivers. Thus, the white elm has grown originally in the forests of the river valleys, preferring fertile soils in flooded areas. It can survive also in the lower tree layer. *Aegopodium* site type and *Filipendula* site types are common for it. The average age of white elms in private forests is 61 years (Table 2) and in state-owned forests 36 years (Table 1). The mean growing stock is only 105 m^3/ha.

Rowan (Mountain ash) (*Sorbus aucuparia*)

The rowan tree can be found mainly as underwood in the stands of other tree species, in surroundings of settlements and roads. Therefore there is no information in the reports of forestry management and we have no data on its area either.

Rowan tree has been appreciated in Estonia as a decorative tree especially its weeping form (f. *pendula*) and the form with palmate leaves (f. *laciniata*).

Research

There is no intensive breeding programme in Estonia for Noble Hardwoods. In the summer of 1989 **birch** seed was collected from 111 mother trees of three birch stands (enjoying the best qualities), the seedlings of which were used to found progeny trials both in Estonia and Finland.

Different forms of birch have been investigated in Estonia (Ott 1969). Taking into consideration the colour of the bark of the stem, two different forms of both the silver and downy birch have been distinguished: a fair-barked form and a dark-barked one. After measuring the trees it was found out that the fair-barked silver birch is the fastest growing and that its growth increment exceeds the increment of the dark-barked form by 16%; the increment of the diameter was also the best for the fair-barked silver birch, exceeding the dark-barked form by 32% on the average of the four years of observation.

Besides other hardwoods, the breeding of **black alder** (Hainla 1996) has continued since 1973. First, an attempt was made to find out if there are any differences in the growth rate of the individuals of generative progeny and if any attributes of parent trees can be associated with the growth rate of the progeny. It appeared that the influence of the site is much stronger than the influence of the mother tree. The second series of experiments was established to study the geographical variation of black alder in Estonia, and the possibilities of using the seed from one region in some other places of the country.

Twenty years later the authors of another research work (Tamm and Vares 1997) continued the experiment. They wanted to know whether the offsprings with an initial high growth speed retained it later, and whether the offsprings with a low initial speed of growth retained it continuously.

From the total of all the factors the impact of mother trees on the height growth of their offspring was 1/2, on their thickness-growth 1/10 and on the length of the terminal of the tree up to 1/3. In all experimental areas the variation in height decreased and the influence of mother trees increased.

Compared with other tree stands the **grey alder** stands are much younger; their average age is 30 years, whereas the average age of all the stands is 58 years. In connection with the economic and political changes in the Estonian society, the use of local renewable resources has become an issue, especially the use of wood for heating.

In Estonia it was essential for the research that silvicultural, ecological and economic aspects of management of grey alder stands were analyzed (Tullus *et al.* 1996). The influence of different cutting systems on natural regeneration and soil fertility were and are being examined. The aim is to create the yield tables and to determine the rotation period for grey alder stands as energy forests depending on site types (Tullus *et al.* 1997) .

Ash stands have been studied by many scientists in Estonia at different times. Many articles have been published. The survey of the research concerning ash stands is one of the recent publications (Põntson 1997).

National conservation activities

Research in the field of forest typology and regular forest inventories carried out over 100 years provided detailed information on the distribution of forest trees. This allowed application of concrete means to protect forest trees genetic resources. The basis was set by the Decree of the Minister of Forestry and Nature Conservation No. 183 on 20 December 1985. The following means are stated in this Decree: (1) establishment of genetic reserves, and (2) protection regime for certain noteworthy and rare stands.

There is one conservation area of birch (417 ha, or 12% of the genetic forest reserves) and two nature reserves of nemoral forests (Abruka Island, area 103 ha) in Estonia. Great forest areas are protected in national parks. There are other nature conservation areas with different protection regimes. The maintenance of these forests is warranted by the Act of Protected Nature Units (accepted by Estonian Parliament on 1 June 1994).

Plus trees are important units among protected stands and trees: 23 birch plus trees were selected in Estonia earlier; 13 new ones were added in 1996.

Among plantations to protect and maintain the genetic resources, seed orchards are most important. The establishment of birch seed orchards was started in 1998. We have one ash seed orchard.

This overview has shown that the distribution of Noble Hardwoods in Estonian forests is quite diverse. This diversity must be preserved and increased.

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Noble Hardwoods in the United Kingdom: genetic resources and genetic improvement

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Introduction

The UK is one of the most deforested countries in Europe with only about 10% of the land area covered by woodlands and forests. Excluding Northern Ireland, there are 641 000 ha of broadleaved woodlands (England 461 000, Scotland 115 000, Wales 65 000) including species not considered as Noble Hardwoods. This accounts for about 30% of the total forest area, the remaining 70% being coniferous.

In the UK, there are 15 species which EUFORGEN designates as native Noble Hardwoods: *Acer campestre, Alnus glutinosa, Betula pendula, Carpinus betulus, Fraxinus excelsior, Malus sylvestris, Prunus avium, Sorbus aria, Sorbus aucuparia, Sorbus torminalis, Tilia cordata, Tilia platyphyllos, Ulmus glabra, Ulmus minor* and *Ulmus procera*. All of these, with the possible exception of *F. excelsior*, are now considered to be ecologically important. Only four of the native species (*A. glutinosa, B. pendula, F. excelsior* and *P. avium*) are thought to be economically important nationally, together with two introduced species (*Acer pseudoplatanus* and *Castanea sativa*) and, potentially, *Juglans regia*. *Ulmus glabra, U. procera, T. cordata* and *T. platyphyllos* are economically important locally. Table 1 summarizes the status of Noble Hardwoods in the UK. There is a view that conservation should concentrate on the rare native species such as *Sorbus, Tilia* and *Ulmus* species. It is also recognized that it is important to conserve those economically important species for which the genetic resources can form the basis of improvement programmes.

Distribution of native Noble Hardwoods

Acer campestre

The field maple is common in the south, east and central England, especially on basic soils, becoming rarer westwards and northwards. It is rare in Scotland where it is considered introduced. It is found in hedgerows, old scrub and in woodlands, sometimes as coppice, and is an ecologically important species.

Alnus glutinosa

Common alder is common throughout the UK, favouring wet habitats, where it often forms pure woods in succession to fen or marsh. It can be found up to 500 m above sea level and is valued economically as a timber tree and as a nitrogen-fixing plant.

Betula pendula

Silver birch is found in woodlands throughout the UK, but is rare in the north of Scotland. It favours lighter soils, with the exception of chalk, and is able to colonize heathland as a successional stage to sessile oak woodland. In Scotland especially, birch is an economically important timber species. Pure birch woods occurring in the Scottish Highlands are recognized as being very important ecologically, having adapted to local photoperiod and temperature conditions, and are reputed to improve soil conditions. Though not recognized as a Noble Hardwood, *B. pubescens* is thought to be ecologically important in the UK and could be considered with *B. pendula*.

Table 1. Summary of the status of Noble Hardwoods species in the UK

Species	Common name	Native	Ecologically important	Economically important	Improvement programmes
Acer campestre	field maple	Yes	Yes	No	No
Acer lobelii		No	No	No	No
Acer platanoides	Norway maple	No	No	No	Yes
Acer pseudoplatanus	European sycamore	No	No	Yes	Yes
Alnus cordata	Italian alder	No	No	No	No
Alnus glutinosa	common alder	Yes	Yes	Yes	Yes
Betula pendula	silver birch	Yes	Yes	Yes	Yes
Carpinus betulus	hornbeam	Yes	Yes	No	No
Castanea sativa	sweet chestnut	No	Yes	Yes	No
Fraxinus angustifolia	narrow-leaved ash	No	No	No	No
Fraxinus excelsior	common ash	Yes	No	Yes	Yes
Juglans regia	English or Persian walnut	No	No	No	Yes
Malus sylvestris	wild crab apple	Yes	Yes	No	No
Prunus avium	wild cherry	Yes	Yes	Yes	Yes
Pyrus amygdaliformis		No	No	No	No
Pyrus pyraster	wild pear	No	No	No	No
Sorbus aria	whitebeam	Yes	Yes	No	No
Sorbus aucuparia	mountain ash	Yes	Yes	No	No
Sorbus domestica	service tree	No	No	No	No
Sorbus torminalis	wild service tree	Yes	Yes	No	No
Tilia cordata	small-leaved lime	Yes	Yes	Yes	No
Tilia platyphyllos	large-leaved lime	Yes	Yes	Yes	No
Ulmus canescens		No	No	No	No
Ulmus glabra	Wych or Scotch elm	Yes	Yes	Yes	Yes
Ulmus laevis	European white elm	No	No	No	No
Ulmus minor	European field elm	Yes	Yes	No	Yes
Ulmus procera	English elm	Yes	Yes	Yes	Yes

Carpinus betulus

Hornbeam is thought to be autochthonous to the southeast and east of England but is widespread across lowland Britain. It is often grown as coppice in oak woods on sandy or loamy clays and can be found planted as far north as Sunderland.

Fraxinus excelsior

Ash is common in woodlands and hedges across the UK up to 370 m asl and is one of the UK's most economically important hardwoods. It prefers calcareous soils in the wetter parts of the UK.

Malus sylvestris

The crab (wild) apple is usually found in hedgerows, copses and oak woodlands and is frequently found in lowland Britain, becoming rare in central and northern Scotland. It can grow up to altitudes of 400 m asl and often hybridizes with cultivated apples.

Prunus avium

Wild cherry is a widespread native species, typically found as small groups of trees or individual trees on the edges of woodland in lowland Britain. In central and northern Scotland it is rare. It is valued for its timber and environmental benefits.

Sorbus* species: *S. aria, S. aucuparia* and *S. torminalis

Whitebeam, *Sorbus aria,* is native in southern England and as far west as Dorset, the Wye Valley and Worcester. It is common on chalk and limestone soils but tends to be more localized on sandstone hills. It is frequently planted elsewhere and has become naturalized outside this region. Mountain ash, *Sorbus aucuparia,* is widely distributed, growing up to 1000 m asl, typically in woodlands and scrub. It is common in the north and west but is rare or absent on clays and soft limestones of east and central England. Wild service tree, *Sorbus torminalis,* is usually found as individual trees or only a few trees in any locality. It is distributed southwards from Lincoln in woodlands, growing on clay and sometimes on limestone soils. It is used as an indicator species of ancient woodlands. All three are considered to be of high conservation value. There are a number of other native *Sorbus* species present in the UK, including several endemics, which are not considered by EUFORGEN.

Tilia* species: *T. cordata* and *T. platyphyllos

In the UK, the small-leaved lime, *Tilia cordata,* and large-leaved lime, *T. platyphyllos,* are important ecological species in native woodlands. The small-leaved lime is often coppiced and is largely confined to England and Wales. It has a scattered distribution, being found mainly in woodlands growing on fertile soils in limestone areas. It can be found growing southwards from the Lake District and is planted as far north as Perth. The large-leaved lime is found in woods on good calcareous or base rich soils. It is thought to be endemic to limited areas such as the Wye Valley and on the magnesium limestone in South Yorkshire. There is an old established plantation north of Perth.

Ulmus* species: *U. glabra, U. minor* and *U. procera

The Wych or Scotch elm, *Ulmus glabra,* is common in woodlands, hedges and along streams in Scotland and on high ground in the north and west of England. It occurs less frequently in the south and east of England and Wales, typically as isolated trees. The European elm, *Ulmus minor,* is confined to eastern England from Norfolk to the River Thames. The English elm, *Ulmus procera,* is thought to be endemic to central and southern regions of England, though it is widely planted elsewhere. It is a common tree, especially in hedges, but the vast majority of mature trees have been lost to Dutch Elm Disease. It is almost invariably infertile and propagates freely by suckering.

Distribution of introduced Noble Hardwoods of economic importance

Acer* species: *A. platanoides* and *A. pseudoplatanus

The Norway maple and sycamore have become widespread and naturalized in woodlands and hedges across the UK over several centuries. Sycamore is an economically important timber tree, valued for its ability to grow on exposed sites and sites affected by salt spray. It is commonly established in plantations and can be found up to 500 m asl.

Castanea sativa

Sweet chestnut was introduced to the UK by the Romans and is now widespread. It is grown intensively as pure stands of coppice in the south of England where it has become naturalized. In Britain, it is considered as the most successful and profitable coppice crop. Its timber is highly valued but large trees are often prone to shake.

Juglans regia

Introduced many centuries ago and valued for its fruit as well as its highly prized timber. Good timber trees are scarce and need to be conserved, preferably *ex situ* as well as *in situ.* Found across lowland Britain, particularly central and southern England where it has more or less become naturalized.

Genetic resources

Ex situ *conservation*

Representatives of all the Noble Hardwoods, native and introduced, with the possible exception of *Ulmus canescens*, can be found in Westonbirt Arboretum, in other arboreta or in national collections coordinated by the National Council for Conservation of Plants and Gardens (NCCPG) across the UK. Collections often include cultivars and foreign material as well as wild native accessions. Details regarding the origin of accessions range from complete to unknown, but in most cases only a small fraction of genetic diversity is represented in these collections as there are often few accessions for each species. There are national species collections for *Acer* (2), *Alnus* (3), *Betula* (3), *Carpinus* (2), *Castanea* (2), *Fraxinus* (2), *Juglans* (2), *Prunus* (2), *Pyrus* (2), *Sorbus* (3), *Tilia* (3) and *Ulmus* (3). The Tree Register of the British Isles (TROBI) provides a useful reference for the tallest, widest and oldest examples of trees for most or all of the Noble Hardwoods in the UK, whether in collections or in the wild. The Tree Improvement Branch of Forest Research has seed-source trials of *A. pseudoplatanus*, *A. glutinosa*, *B. pendula* and *F. excelsior* that can be considered to serve as *ex situ* conservation trials. About 60 UK clones of *P. avium* have been established in a genebank at HRI-East Malling.

In situ *conservation*

The *in situ* conservation of Noble Hardwoods is in effect the responsibility of individual landowners, the principal woodland/forest owner being the Forestry Commission, but much restocking is based on planting seedlings rather than on natural regeneration. The Forestry Commission is responsible for identifying and registering seed stands of species. Five seed stands of *B. pendula* have been registered in Scotland. Individual trees of particular interest in collections or in the wild can be protected by Tree Preservation orders.

Improvement programmes

Until recently, there has been little systematic improvement of any of the Noble Hardwoods. Improvement programmes (summarized in Table 2) are concentrating on species considered to be economically important and are undertaken principally by Forest Research (FR), Horticulture Research International (HRI) and the Oxford Forestry Institute (OFI), funded variously by the Ministry of Agriculture, Fisheries and Food (MAFF), Forestry Commission and charitable trusts.

An excellent framework for this work is provided by the British Hardwood Improvement Programme. Formed in 1996, BHIP is an association of landowners, research institutes (FR, HRI and OFI) and professionals who aim to improve significantly the quality of UK broadleaved timber trees through selection, breeding and silviculture. BHIP has improvement programmes on *F. excelsior*, *P. avium* and *J. regia*. These programmes are at an early stage; the programme on *P. avium*, which started in 1988, is the most advanced. The programmes are not concerned exclusively with UK material.

The Tree Improvement Branch of Forest Research has improvement programmes on *A. pseudoplatanus*, *A. glutinosa*, *B. pendula* and *F. excelsior*. These are mainly seed-source trials to investigate the degree of adaptive genetic variation in these species, established since 1992, and can be also considered to serve as *ex situ* conservation trials. There are five Registered Seed Stands of *B. pendula* in Scotland, consisting of autochthonous material, and two trials of 45 seed sources (most autochthonous) collected from throughout the range of *B. pendula* in Scotland and northern Britain. The use of local provenances is recommended. Native birch seed-sources, collected throughout northern Britain, are being compared with material from seed orchards (Forestry Commission and commercial) in extensive genetic field trials.

Table 2. Species and research organizations involved in UK tree improvement programmes

Species	Institute[†]	Species	Institute[†]
Alnus glutinosa	FR	*Fraxinus excelsior*	FR, HRI & OFI
Acer platanoides	HRI	*Juglans regia*	HRI & OFI
Acer pseudoplatanus	FR & HRI	*Prunus avium*	HRI
Betula pendula	FR		

[†] FR: Forest Research; HRI: Horticulture Research International; OFI: the Oxford Forestry Institute.

Typically, native birch of good form is uncommon. There are ten seed-source trials of ash comparing 11 British seed sources with 11 continental seed sources. Nine of these trials have been established in England and Wales, and one in Scotland. Forest Research has established five seed-source trials for *A. pseudoplatanus* consisting of six seed sources from England and Wales and four from continental Europe. Forest Research has three collections of elms established in England and an advanced programme investigating sources of resistance to "Dutch Elm Disease" using molecular techniques.

HRI has a large improvement programme on *P. avium*, minor crossing programmes on *A. platanoides*, *A. pseudoplatanus* and a clonal selection programme on *J. regia*. At HRI-East Malling, the *P. avium* programme involves the selection of plus trees, raising progenies from controlled crosses, selection and trials, and the development of molecular markers. A clonal seed orchard using 17 selected plus trees was planted in 1998. Seedling progenies of *A. platanoides* and *A. pseudoplatanus* have been raised, from controlled crosses, for resistance to Verticillium wilt and for genetic mapping studies respectively. A walnut collection (*J. regia*, *J. nigra* and their hybrids) at East Malling consists of about 30 genotypes selected for timber production, and 35 cultivars for fruit production. The aim is to test them for adaptability to UK conditions. At HRI-Wellesbourne, techniques for the micropropagation of mature *Fraxinus excelsior* have been developed for four clones supplied by FR and a start has been made to establish a collection of UK plus trees.

In 1993, OFI, in collaboration with FR, established eight breeding seedling orchards of *F. excelsior* consisting of 36 UK provenances and these are being recorded for form and vigour. The work on *J. regia* began in 1997 with the collection of seed from 22 provenances in Kyrgyzstan and 15 European provenances. The seedlings have been germinated and will be planted out in three provenance trials in winter 1998-99.

Conclusion

In the UK, work on the genetic conservation of most Noble Hardwoods of ecological and economic importance is at a very early stage. Work on *Betula pendula* and *Prunus avium* is the most advanced. There is still much work needed to understand the patterns of genetic diversity of the different species and the best approach to conservation. Molecular markers are useful tools for studying genetic diversity. It would be interesting to investigate the amount of genetic diversity found within the UK compared with that on the Continent. Conservation efforts should concentrate on the rarer native species, especially those of *Sorbus*, *Tilia* and *Ulmus*.

Acknowledgements

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Inventories and documentation on Noble Hardwoods genetic resources

Concept note for the establishment and maintenance of databases at national level

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Introduction: definition of a computer database

A database is a well-organized dataset held in one or more interrelated files which can be managed by the same software. Files managed by different software are completely separated databases.

Methodology: the four steps

First step: preliminary study

Description phase: This step is fundamental in the elaboration of the databases. It is the description of the present situation. A diagnostic is made and different solutions can be imagined. At this step we must answer the following questions: Which kind of data are available, what are you looking for, which kind of descriptors do you have? How can they be linked together? Which kind of sorting do you need? What links do you need with other software? What do you want to do with your database?

This step should always be the longest in the project timetable.

Result phase: specifications to respect.

Secondary step: detailed study

Description phase: During this step one solution must be chosen for the organization of the databases. We must answer "Who, Where, When, and How"?

Result phase: function specification in details.

Third step: implementation

Description phase: During this step the scheme elaborated in the previous phases is implemented using the software. Tests must be completed with few data to improve the database structure. When the database is available, data can be entered in the different tables.

Result phase: software, testing and utilization manual.

Fourth step: management

Description phase: update of the databases.

Result phase: report of the use of the database and update of the data.

The importance of a good structure

The creation of files which have a clearly defined purpose and a logical structure is fundamental to an efficient database design.

Different descriptors which are used in conjunction with each other in a given procedure, or related to each other in some way, can normally be grouped together in a single database file.

Each file must have a clearly defined structure for data storage, facilitating editing, updating and retrieving. A badly designed structure will result in an inflexible, inefficient and problematic system.

Files records and fields
Your database will have identified descriptors which are practical in terms of recording of the data and editing of information.

A field is the section of the file (or the table) which always holds the same descriptor.

A record is a set of different fields which is handled as a unit. A record holds different descriptors which relate to a single element.

Organizing your files

Identifying fields: It is important to clarify which field or combination of fields are needed to identify the records you wish to work with. Such fields are called identifying fields and are used to link different files together. How links are set up will depend on whether the identification of a specific record is required or whether you wish to work with a group of records.

Guidelines for design of data file structure: Sets of descriptors identified should be used as a basis for building the documentation system. However you must decide carefully which fields are used to link files in order to avoid unnecessarily duplicated data. Unlinked fields containing redundant data which occur in two or more files will occupy valuable space on the disk. Also if such fields need updating at any time, you must remember to update each in turn, otherwise paradoxes will occur because of duplicate unlinked fields in separate files. For successful file management you need to create an identifying field with an identifying number which is necessarily unique for each file. Fields which are logically related to each other and to the identifying field should be grouped together in one field.

Sorting: Records must be stored in an order that will help subsequent information retrieval. To have access to specific data, the most useful order for storage is the order of the identifying number. With a computerized system, when new records receive an identifying number, they are simply added to the end of the file. This means that records can theoretically appear in any order. Records can be sorted in different ways. Commonly they are sorted in alphabetic, numeric or chronological order.

Importance of the software

The performance of the database depends on the capacities and the features of the management software used. Since the capacities can vary considerably among different software packages, it is vital to spend time studying available software to ensure that it suits your needs. Of course the quality and capacity of your hardware are also very important. If many people will use the database, the interface must be user-friendly.

Features of database management systems

Most database management systems permit the following basic activities:

- enter new data
- modify or delete data
- search and retrieve data for reports
- sort data
- import or export data
- modify the structure of a file in response to changing information needs.

One example

The Microsoft Access database for the ONF ALISIER conservation project has been conceived according to a number of specific purposes, namely:

1. A clear support providing an easy **input**.
2. An easy **access** to the database.
3. A powerful tool providing multiple options to **analyze** and **sort** the data.
4. A possibility to integrate the data into a GIS (MAPINFO).

The database is founded on a basic level, providing a file which concerns the sampling **site** and all its relevant information (geographic location, administrative details).

The printed output of this basic file can be used as a **form**. The form can be distributed to local foresters for input.

Access to the database is made simple in order to allow verification and updating.

Inventories of Noble Hardwoods genetic resources: basic requirements

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Introduction

Forest inventories usually cover principal timber species, but they contain no or only scarce information concerning rare species. Most of the Noble Hardwoods belong to this group. They are scattered, and even at the local level, knowledge about the occurrence of the species is often missing. The knowledge of the present range of natural distribution is based more or less on random information. It is often better for state forest land than for private ownership. However, since the state forests usually have been managed intensively owing to the prevailing management rules which concentrated on economically important principal tree species, the habitats for rare species were more reduced than on most of the small, privately owned lands.

The knowledge of the present range of distribution and status of most of the rare Noble Hardwoods is based on general botanical knowledge, sometimes accompanied by local, more intensive studies, and on the individual knowledge of particularly interested foresters. In the following chapters the inventory requirements for these species will be discussed. We are aware that the situation is quite different from one country to another. Therefore we will concentrate more on the basic principles and procedures which have to be followed for inventories, depending on the degree of precision desired.

It is very important to differentiate the approach to inventories according to the frequency of a species' occurrence. For very rare species, every tree above a certain dbh (e.g. >10 cm) has to be recorded, for more frequent species it may be regularly populations. However even in those species outstanding individuals should be registered. A minimum population size should be at least 20 individuals in reproductive age forming a mating unit.

The rarity of a species depends on its geographic range, its habitat specificity and its local population size. Several forms of rarity or frequency, respectively, can be distinguished according to Rabinowitz (1981) and Rabinowitz *et al.* (1986). The status of some tree species in Switzerland regarding their respective form of rarity is given as example in Table 1.

Inventory requirements

The lack of information is a limitation for conservation planning as well as for the use of a species. Data sources can be found from:

- literature
- forest inventories
- plant geographic information systems and maps
- habitat mapping
- files of forest tree breeding organizations
- files of nature protection organizations
- experience of local experts and foresters.

Table 1. Forms of rarity of some tree species in Switzerland

Form of rarity	Geographic range	Habitat specificity	Local population size	Examples for Switzerland
1	small	narrow	small	*Acer opalus*
2	small	narrow	large	*Quercus cerris, Q. pubescens, Ostrya carpinifolia*
3	small	wide	small	*Sorbus domestica, S. torminalis, Malus sylvestris, Pyrus pyraster*
4	small	wide	large	–
5	large	narrow	small	*Populus alba, P. nigra, Ulmus laevis, U. minor*
6	large	narrow	large	*Betula pubescens, Pinus mugo, Taxus baccata, Alnus glutinosa*
7	large	wide	small	*Prunus avium, Acer campestre, A. platanoides, Sorbus aria, Ulmus glabra, Tilia cordata, T. platyphyllos*
8	large	wide	large	*Picea abies, Fagus sylvatica, Abies alba*

Since these sources do not give complete information, they have to be supplemented by inquiries and local inventories.

The **inquiries**, addressing foresters, forest owners, farmers and nature protection organizations, will give some additional information. They have, however, the weakness of depending on the local interest, the knowledge and the time of the addressed person.

Local inventories in cooperation with experienced local people give the most complete information. They are time-consuming and expensive. Combined procedures are possible and they allow concentration of efforts on the most promising points. However, even this information will not be complete for a larger area.

What information is needed from inventories?

The most relevant information is location, health and threats, population structure including size of a stand or number of individuals, and genetic structure.

Information about the location

The aim is to identify locally the occurrence of the respective species, to register the site conditions (e.g. structure, profile and reaction of soil), ecological data (e.g. composition at shrub and herbaceous levels), the ownership, the possibilities for protection, and to code this information for an information system, which later on allows control and evaluation of the inventory results.

The geographical coordinates (latitude, longitude, Gauss-Krueger coordinates with seven digits, elevation above sea level) have to be as precise as possible. Global positioning systems (GPS) are an excellent support to locate and re-identify the position.

The area of the respective population or individual trees should be drawn on a map.

Climatic data (e.g. mean temperature, mean precipitation and their monthly distribution, snow cover) are important ecological information.

Descriptions of the type of location (field, forest, protected area) and ownership (public or private) are important and facilitate determining the possibility of *in situ* conservation. An identification code has to identify the specific object clearly, to prevent duplication and to enter all relevant information into an information system.

The Lower Saxony Forest Research Institute, Department of Forest Tree Breeding Escherode (Germany), uses an 11-digit code (see Annexes):

- digits 1 to 3 for tree species identification
- digits 4 and 5 for year of first registration
- digits 6 to 8 are current numbers for a stand within the year
- digits 9 to 11 are current numbers for single trees within the year.

It would be desirable to agree on a minimum common identification code for the Noble Hardwoods Network.

Health and threats

The vitality of a particular unit is relevant for conservation decisions. The following information is necessary and should be registered.

- Diseases or attacks by fungi, insects, etc. The periodic epidemics of insects or other organisms can be decisive for the health of a tree population. Recording historical information about this aspect is important.
- Damage by deer, especially in natural regeneration.
- Site degradation (drainage, soil erosion, emissions).
- Adaptation to local environment (to be judged by vitality).
- Plantations of hybridizing species or cultivars in the vicinity. Their presence can be a limiting factor and can affect the survival of a pure species population and its further evolution.
- Competition by other species.
- Logging operations (e.g. clear-cutting might eliminate a population).

Population structure

This includes the botanical identification, the size of the population (stand = more than 20 individuals in reproductive age within pollination distance thus forming a mating unit), the structure (pure stand, mosaic or single tree mixture in mixed stands, even-aged or uneven-aged stands, or populations outside of forests) and the regeneration status of the species. The maximum distance between individual trees depends on the pollination vector. The frequency of occurrence at local and regional levels, the occurrence of varieties or hybrid forms (especially the occurrence of hybrids between closely related species) and the potential for seed collecting (including stand quality) are relevant information. Additional information about: origin, stand history (old forest site, stand type), silvicultural status (competition, survival without human interference, thinning methods), type of regeneration (generative or vegetative), and dendrometric characters (height, diameter, length of trunk, form) can be important and should be registered.

Genetic structure

All the information described above can be collected locally. Information on the genetic structure needs additional efforts with field testing, laboratory work, etc. Relevant information includes morphological, phenological, biochemical or molecular genetic (isoenzymes, DNA) traits.

Introgression between species or cultivars, which is important in Noble Hardwoods, can be judged from morphological traits only, if the material is grown *ex situ* under equal experimental conditions.

This type of species inventory has a precondition that at least a rough knowledge of the local occurrence of a species is available. It is, however, an important condition for well-founded gene conservation planning.

The genetic structure of Noble Hardwoods populations can change according to ecological succession. Therefore, phyto-ecological traits or other indicators can be useful in order to define different situations, e.g. regarding subspecies, varieties, races, etc.

Discussion

A good inventory is the basis for the knowledge about species in a region. It has been shown that in particular the knowledge of local people (e.g. foresters, forest owners, nature conservationists) can contribute significantly to the inventory. Personal contact can create and promote interest in activities to conserve these species. A part of this work has to be formalized to obtain comparable results. In Annexes 1 and 2 the inventory sheets of the Lower Saxony Forest Research Institute, Department of Forest Tree Breeding are given as an example for such a formalization. This may serve as standardized information which can be directly entered into a database.

The main problems for wide application are time and money. If we take the resolution of the Rio Conference and the European Ministerial Conferences in Strasbourg, Helsinki and Lisbon seriously, we have to invest time and money. Noble Hardwoods are important components of mixed hardwood forests, their regular management can increase the biodiversity of forests and the economic return from these forests as well. The best conservation of these species is their regular, sustainable use in forest management. To be able to do this, we require reliable inventory data. Therefore, more efforts are necessary to obtain these data.

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Annex 1. Example of a **Registration Form for Gene Conservation Subjects** (form used by the Lower Saxony Forest Research Institute, Department of Forest Tree Breeding; see Annex 2 for explanations of superscript numbers)

tree/shrub species[1] ______ kind of subject[2]

registered by ______ date ______ data base

common information

state ______ district ______ ownership[4]

forest district ______ owner ______

local place ______

site name/compartment ______ provenance region[5] ______ state of area[6]

geopraphic coordinate ______ tree number[7] ______

site information[14]

ecological region[8] ______ autochthony[9] ______ precipitation (mm): year ______ growing season ______

altitude (m) from ______ to ______ average ______ temperature (°C): year ______ growing season ______

area (ha) ______ species area[10] ______ number[11] ______ site description ______

age[12] ______ kind of establishment[13] ______

location/information for refinding ______

comment ______

sketch/map on backside

special information

occurrence: code[15] ______ remark ______

kind of mixture ______

association ______

reason for conservation[16] ______ grade of injury[18] ______ priority[20]

kind of threat[17] ______ grade of risk[19]

possibility for seed harvest[21] ______ suitable for seed harvest: yes ______ no

measures for conservation

measure		remark
in situ[22]		
ex situ[23]		

For this subject there are still following data forms: breeding tree / seed (underline where applicable)

Annex 2. Example of a **Code for the Registration Form for Gene Conservation Subjects** (code used by the Lower Saxony Forest Research Institute, Department of Forest Tree Breeding)

1 tree/shrub species — scientific name

2 kind of subject
- B stand, usually >20 individuals, tree species ≥0.1 ha, shrub species ≥0.01 ha.
- E single object ≤20 individuals.

3 data base
- GE gene conservation
- GDS gene information pool, no measures planned

4 type of ownership
- 1 state forest
- 2 federal forest
- 3 corporation forest
- 4 private forest
- 5 other ownership

5 provenance region — registration number of seed stands

6 state of the area
- ND natural monument
- NW natural forest
- NG nature protection area
- NP national park
- WS forest reserve
- BR biosphere reserve
- SB selected stand
- GB tested stand
- IB stand under examination
- KV Control Association (Kontrollvereinigung)
- AW old woodland
- EX *ex situ* conservation object
- ST special site
- ÜB stand or tree above average
- XX note under "comment"

7 tree number — see 4.3.2.4 internal working instruction

8 ecological region — see special code

9 autochthony
- 1 autochthonous
- 2 not autochthonous
- 3 unknown/not sure

10 species area — for stands

11 number — for single objects, number of trees/shrubs

12 age — also period possible

13 kind of establishment
- 0 unknown
- 1 plantation
- 2 seedling origin
- 3 natural regeneration
- 4 coppice shoot
- 5 nat. reg. and planting
- 6 nat. reg. & seedling origin
- 7 seedling origin & planting
- 8 replanting
- 9 nat. reg., seed and planting
- A nat. reg. and coppice shoot

14 site information
climatic data only, when information on local climate available

15 occurrence: code
- 0 within stand
- 1 outer forest edge
- 2 inner forest edge
- 3 edge of way
- 4 small wood
- 5 thicket

16 reason for conservation
- AL age
- AO phenotypic peculiarity
- AS adaptation to the site
- AU autochthony
- BW representative stand in growing area
- RA rarity
- RW rarity in growing area

17 kind of threat
- BA road-works
- BF fungus
- BI insects
- BS mammal/birds
- DU lack of light
- EN final cutting
- ER erosion
- FF frost
- SB pollutant in soil
- SD snowbreak
- SL air pollution
- SO sunburn
- ST stagnant moisture
- ÜA overmaturity
- VH impoverishment
- WG changing of water table
- WT desiccation
- WW windthrow
- XX note under "comment"

18 grade of injury
- 0 no damage
- 1 little damage
- 2 moderate damage
- 3 heavily damaged
- 4 dead

19 grade of risk
on the site, not for the species
- 0 unknown
- 1 not endangered
- 2 moderately endangered
- 3 heavily endangered

20 priority
- 1 very urgent
- 2 urgent
- 3 necessary
- 4 desirable

21 possibility for seed harvest
- 1 good
- 2 not so good
- 3 bad

22 *in situ* measures
- 01 "clean forestry"
- 02 support of natural regeneration
- 03 artificial regeneration *in situ* with reproductive material out of the origin stand
- 04 favouring
- 05 pest control
- 06 shelter against bark peeling
- 07 site restoration
- 08 note under "remark"

23 *ex situ* measures
- 21 checking species identity
- 22 generative propagation
- 23 vegetative propagation
- 24 storage of plant tissue
- 25 transfer of reproductive material into conservation orchard
- 26 note under "remark"

Research

Global warming and gene conservation of Noble Hardwoods

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Abstract
Two main types of factors of importance for species survival under global warming were identified: dispersal ability and speed of evolution. One of these has to be larger than the speed of environmental change to enable the species to cope with global warming. The speed of evolution depends on existing additive variance in important traits and this in turn depends on mutation rates and mating pattern. For the northern countries, in which global warming is expected to be largest, the growth rhythm will be decisive for the continued existence of a species. A large phenotypic plasticity will be an efficient means in the short-term perspective to prevent death, whereas it may be an obstacle to high speed of evolution in the long-term perspective. Little is known about the genetic architecture of the Noble Hardwoods species. Therefore, the consequences of global warming for them will be, at best, educated guesses. This means that much research on the genetic structure of these species is needed. It is of particular interest to obtain more knowledge on mating pattern and the consequences of fragmentation.

Introduction
During the last decade several meetings have been held and several books have been published on the genetic consequences of global warming. Both breeding and conservation aspects have been discussed. Is there a need for another treatment of the same topic, especially since the predictions about future climates seem to be so uncertain? Even if the exact predictions are imprecise it seems that we are experiencing a greenhouse effect (Kattenberg *et al.* 1996). The environment in which species exist is a result of the ambient abiotic conditions as well as the biotic components of that ecosystem. As components of an ecosystem, trees and other living organisms are continuously exposed to global warming. Therefore, the influence of global change on genetic processes will probably be quantitative rather than qualitative. In this context, a discussion of factors of importance for the continued existence of tree species and species associated with them may be worthwhile. Before this is done it should be mentioned that Boyle (1994), in a summary of a meeting on consequences of global warming on forest trees, stressed that it is urgent to find methods to survey global change, perhaps by identification of good indicator species.

Factors of importance under a global change
The factors listed below are regarded as important in global warming:
- dispersal ability
- existing additive variance for important traits
- mutation rates in these traits
- speed of evolution
- genetic correlations among the important traits
- mating pattern: population size, breeding system, fragmentation
- phenotypic plasticity.

They will be briefly introduced before a more detailed discussion is carried out.

It is self-evident that a species must be able to spread its propagules when environmental conditions change. Without such an ability the next generation will suffer from severe competition from immigrants with a higher adaptedness in the area invaded.

Additive variance is a prerequisite for natural selection and a limited additive variance will constitute a great constraint to future evolution. Of fundamental importance is the additive variance for traits of great significance in global warming. Since mutations in loci regulating such traits will increase the additive variance, the mutation rates at these loci play a major role in the possibilities for continued survival of the species. The pattern of genetic correlations among the important traits also plays a great role for the response to selection. The amount of additive variance and the correlations among adaptive traits will influence the speed of response to selection.

The mating pattern is defined as the zygotes formed from the crosses realized in a population. It is decisive for the amount of additive variance. At low effective population (N_e) sizes, genetic drift and inbreeding reduce the additive variance. The breeding system, i.e. whether a species is autogamous or allogamous, will also influence the mating pattern in a population. The pollen vectors – wind, insects, birds and bats – will also influence the mating pattern. Fragmentation may reduce the N_e and thus indirectly cause loss of additive variance.

The amplitude of a trait of a genetic entry studied in at least two environments is called phenotypic plasticity. It offers an individual a means to survive even under adverse environmental conditions.

Before these factors are discussed in some detail, traits of importance under global warming are presented below.

Traits of importance under global warming

The traits that may be of particular interest under global warming will be discussed with a starting point in Figure 1. It is anticipated that weather extremes will be more common as a consequence of global warming. Therefore, water availability may be limiting for growth during certain periods. Genotypes that grow well under conditions with drought spells will probably have an advantage under global warming. Similarly, genotypes that can grow well under extremes of temperature during the growing season will probably be favoured by future natural selection. To cope with these extremes in temperature and water availability, the trees existing in stands need to have large phenotypic plasticity. For the long-term survival of the species under such conditions there is a need for a large genetic component of the adaptability besides the phenotypic component.

Especially at high latitudes and high altitudes, the length of dormancy and date of bud burst are important for avoidance of late spring frost and early autumn frost exposure. Therefore, individuals that have a growth rhythm such that these frost exposures are avoided have probably been favoured by natural selection. The harsher the climate, the shorter the growing season will be. This explains why a clinal variation in growth cessation has been noted for *Acer platanoides* (Håbjørg 1978; Westergaard 1997) as well as for other broadleaved tree species (Håbjørg 1978). Night length is the main triggering factor for growth cessation. Northern populations respond to shorter nights than southern sources. Such a response also leads to shorter trees as summarized by Jonsson and Eriksson (1989) for American species of the genera *Acer* and *Fraxinus*. The change in photoperiod is most pronounced at high latitudes and the cline in response to photoperiod increases exponentially with latitude toward the north. In trees from the Mediterranean area the photoperiodic response is probably negligible.

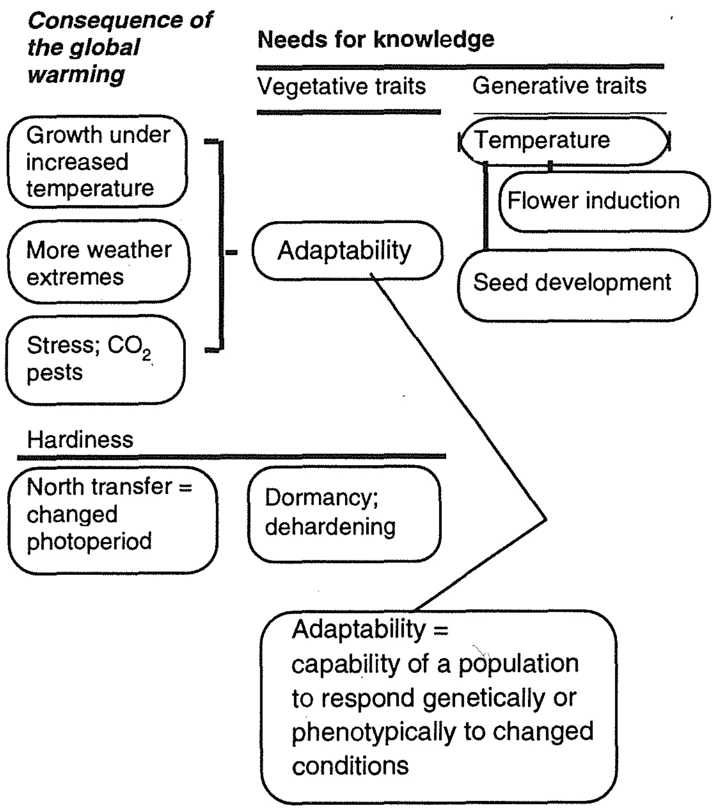


Fig. 1. Schematic illustration of the consequences of global warming on vegetative and generative traits.

Trees from the boreal and the temperate zones are characterized by a bud rest. To break the bud rest a certain amount of chilling is required. Temperatures below zero do not seem to be necessary for release of this bud rest (Perry 1971). Once the bud dormancy is broken a certain temperature sum is required for bud burst (e.g. Cannell and Smith 1983; Kramer 1995). For *Picea abies* it is shown that northern populations require a lower amount of heat for bud burst than southern (Krutzsch 1975). Clinal variation in bud burst was reported for *Fraxinus excelsior* by Kleinschmit *et al.* (1996b) in eastern and central Europe from Romania to Switzerland. Menzel (1997) estimated the change of date of bud burst and flower appearance based on data from so-called phenological gardens distributed over many countries in Europe. Bud burst and appearance of flowers in *Prunus avium* was estimated to occur approximately 5 days earlier per degree of temperature increase. The corresponding estimates for *Sorbus aucuparia* and *Tilia cordata* were 3 and 2-3 days, respectively. In a similar type of study based on fewer phenological gardens, Kramer (1995) reported that temperature increase would not affect the leaf fall in *T. cordata* but cause an earlier bud burst with approximately 3 days per degree temperature increase. Therefore, it is likely that the bud burst will take place earlier after global warming since the temperature sum required to induce bud burst will be reached earlier. With a prediction of more temperature extremes, this early bud burst might lead to exposure to low and damaging temperatures. Thus, however strange it might seem, the risk for spring frost damage may increase after a temperature increase.

It was documented 60 years ago that female flowering in *Picea abies* was induced by high temperatures during the summer of flower bud initiation (Tirén 1935). In a review paper on flowering and seed set in trees, Owens (1991) stated that "high summer temperatures generally increased flowering". Most observations were on conifers. In *Fagus sylvatica* a high temperature favoured flowering (Holmsgaard and Olsen 1960). In apple trees the highest temperature (25°C day and night) reduced flower bud induction (Jonkers 1984). Tromp (1984) noted that flower induction at day/night temperatures of 22/22 and 22/16°C was lower than at 16/16 and 16/22°C. Therefore, no general flowering stimulation by high temperatures seems to exist and a temperature increase may be positive or negative depending on the species.

It is likely that flowering will take place earlier in the season after global warming. With a prediction of more temperature extremes, this early flowering might lead to exposure to low and damaging temperatures. In consequence, severe frost damage may occur owing to early flowering followed by a frost spell.

Dispersal capability

Many ecologists question whether any tree species will migrate fast enough to survive the global warming predicted from the increase of greenhouse gases (e.g. Davis 1988; Peters 1990). The predictions have mostly focused on the present climatic condition at the southern border of a species and where these climatic conditions will occur after global warming. Based on this, the future southern border of the species is predicted (e.g. Dahl 1990). This is simplistic from two points of view. First, most tree species have some phenotypic plasticity which means that they will probably survive in the stands for a long time unless their growth rhythm is totally unsuitable for the changed conditions. No mass death of tree species is expected due to the changes predicted for global warming. Second, the evolutionary potential of a species is frequently forgotten in predictions of its future distribution area.

The dispersal ability probably varies from trees with heavy seeds, nuts or acorns to those with light seeds that have wind as a vector. The former category frequently has animals as vectors and their distribution is thus heavily dependent on the migratory patterns of these animals. On average it is assumed that species with wind as the vector for seed dispersal are more likely to migrate successfully. If this holds true for the Noble Hardwoods I would assume that elms migrate faster than chestnut and walnut.

If a species has to rely solely on its dispersal ability, this must keep pace with the speed of the environmental change. It is possible that among Noble Hardwoods some of the rare *Rosaceae* species have so limited additive variance owing to limited population size or asexual propagation that they have to rely on their dispersal ability.

Additive variance

The response to selection is frequently designated as ΔG, which is (additive variance × selection differential)/phenotypic variance. This ratio illustrates the importance of additive variance since without additive variance there will be no response to selection. Most quantitative traits that have been studied genetically show additive genetic variance, which means that populations and species have the capability to respond to changed environmental conditions (e.g. Lynch and Lande 1993).

The prerequisites for population differentiation in species with random mating in its subpopulations were dicussed (Eriksson 1998). I pointed out that one prerequisite is the existence of different *Selective Environmental Neighbourhoods* (SEN = an area in which there are no changes in ranking with respect to fitness, a concept introduced by Brandon (1990) and moreover, that SENs have a high degree of stability over generations. For species distributed over several climatic zones there are probably several SENs and in consequence, populations will be genetically differentiated, which in turn means that additive variance will exist within the species with respect to adaptive traits. For most of the widely distributed Noble Hardwoods occurring in large panmictic populations there is probably ample additive variance for growth rhythm traits to cope with the global warming.

For species with low N_e, random genetic drift might have caused a considerable loss of alleles accompanied with a differentiation that is not always adaptive. If N_e is increased naturally or artificially, the existing additive variance could be exploited. For the Noble Hardwoods with one or a few individuals per stand, artificial populations must be created to generate a new generation that can be exposed to natural or artificial selection to improve the adaptedness (cf. Kleinschmit 1994).

It has long been known that after ten generations of artificial selection there is no overlap of the distributions of the original and the selected population after directional selection for oil content in corn (cf. Allard 1960, p. 185). Since mainly alleles at intermediate frequencies respond to the selection, these alleles would be fixed after 10-20 generations. In spite of this, response to selection has continued up to 100 generations. Lynch and Lande (1993) have treated this theoretically and they gave the following conclusions:

> "As selection jointly advances the frequency of favourable alleles at multiple loci, very large changes in the mean phenotype can be accomplished with the genetic variance residing in the base population alone."

and

> "...compelling evidence that polygenic mutation makes significant additional contribution to selection response (Lynch 1988; Mackay 1989; Keightley and Hill 1990; Weber and Diggins 1990; Caballero *et al.* 1991)."

Thus, the mystery of the long-term continuous response to selection has one possible explanation. The pooled mutation frequency in quantitative traits has been estimated at 10^{-3}-10^{-2} (Lande and Barrowclough 1987). This pooled frequency is 100-1000 times higher than in loci with oligogenes.

Even if presence of additive variance is a prerequisite for continued evolution, it must also be remembered that it constitutes a load to the existing population. This is illustrated in Figure 2 for fitness. If the environment is stable, a species lacking genetic variation in fitness may reach a higher degree of fitness than a species with a variation in fitness. If these two species grow in the same environment, the species with highest mean fitness would obviously be more competitive than the species with a variable fitness. However, the absence of variation is a dead end in a changing environment. When the environmental conditions are expected to change drastically, particular concern for vegetatively or asexually propagated species with limited additive variance is justified as regards priorities in gene conservation. This may be relevant for some species in the genus *Sorbus*.

Hoffman and Blows (1993) stressed that marginal populations are those that will first be exposed and most severely affected by global warming. They also stressed the importance of understanding why a species does not grow beyond its present margin (Fig. 3). One possible explanation for not reaching beyond the present margin would be that there is a need for changes in many traits simultaneously (Namkoong 1994). Individuals with such a unique genetic constitution must be extremely rare and in consequence an expansion has not taken place. Negative genetic correlations between traits of importance still further erode the possibilities to obtain appropriate genotypes for colonization beyond the present range.

It is generally believed that the closer to the margin of the distribution, the fewer the individuals that participate in creating the next generation. In other words N_e is small. In consequence, the population might have been exposed to inbreeding and genetic drift, both leading to reduction of the additive variance. The rate of loss owing to genetic drift is $1/2N_e$ per generation, which means a considerable loss of additive variance with N_e less than 10 individuals. If the weather conditions vary much over years the environmental variance will be large in relation to the additive variance. There is limited empirical support of the hypothesis that marginal populations are less variable than central populations.

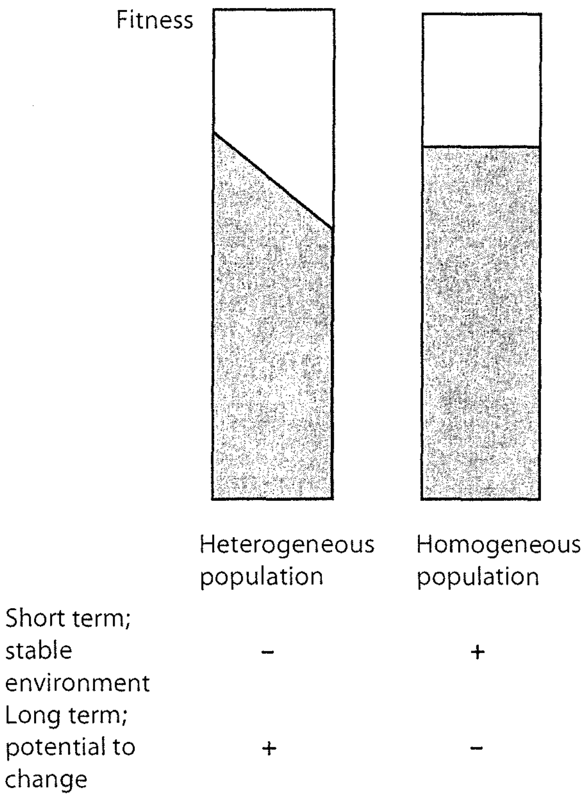


Fig. 2. Schematic illustration of the merits of heterogeneity or homogeneity of fitness in a population in the short-term and long-term perspectives.

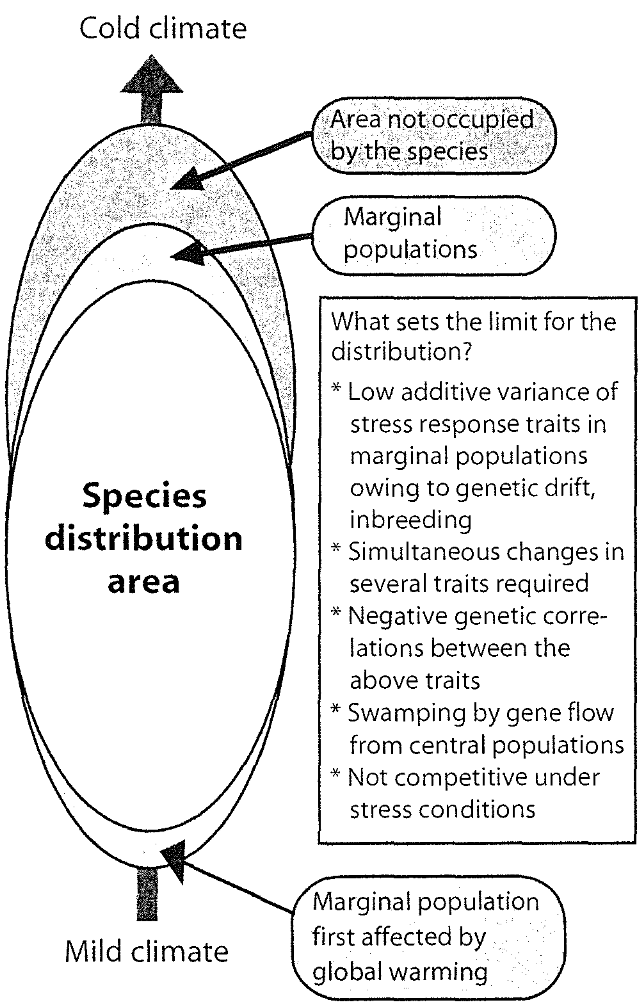


Fig. 3. Schematic illustration of the effects of global climate change on marginal populations as well as listing of factors limiting the distribution range of a species.

Especially for wind-pollinated species there might be a considerable geneflow of less hardy genotypes to the harsh marginal areas. This will give rise to a skewed distribution compared with what would be obtained if all pollination took place within the marginal population. The skewness is attributed to a surplus of the "southern" tail of the distribution and thus constrains adaptive evolution.

If there is a large cost to develop genotypes that can survive under stressful conditions, this may lead to less competitive genotypes as a side effect. If this is the case, even a contraction of the species' range may be the result. Thus the species might not be competitive under the stress conditions.

Genetic correlations

If two traits of importance are positively correlated with each other there is no problem to obtain response to selection in both traits. However, if the traits are negatively correlated with each other (Fig. 4) progress in one will lead to regression in the other.

Hoffmann and Blows (1993) stressed that few studies have been carried out to estimate genetic correlations under stressful conditions. They also argued that genetic correlations between fitness traits estimated under optimal conditions may be misleading since the correlation pattern might be different under the two conditions. From a few publications they concluded that genetic correlations between life history traits "tend to become more positive under conditions of environmental stress because genes that allow an organism to survive in a new environment are likely to affect a range of fitness components."

A different prediction was given by Namkoong (1994) who stressed that for survival under global warming a population may need to respond to two different environmental stimuli, such as temperature and water availability, in contrast to the unidirectional change that was required before. As a consequence of this, the selection must be changed to disruptive from earlier being either stabilizing or directional. Since our knowledge about genetic correlations between important traits is at best limited, the predictions will be very uncertain.

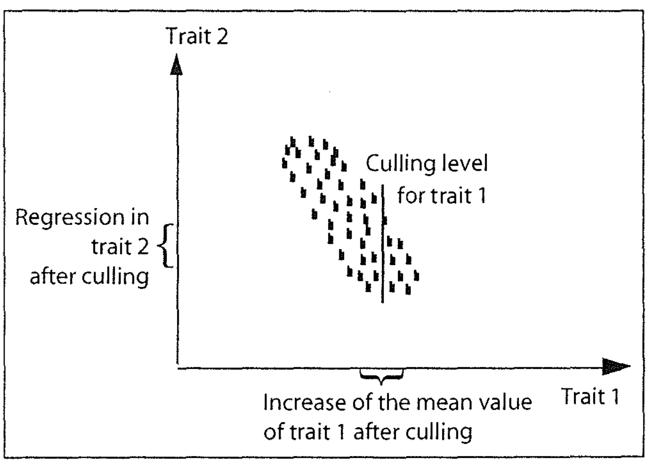


Fig. 4. Illustration of the effect on a trait negatively correlated with another trait that is favoured in selection.

Speed of evolution

Obviously for long-term survival under changed conditions the speed of evolution must be as fast as the change of the environmental conditions. Lynch and Lande (1993) stated that for populations with N_e less than 500 the rate of environmental change must not be larger than one unit of the standard deviation, rather much smaller, to enable the population to respond genetically to the change.

In *Picea abies* Norwegian colleagues have studied for approximately 15 years a phenomenon that was coined physiological after-effects. This means that environmental conditions in some way give an imprint in the seed, such that the same genetic entry harvested under harsh and mild conditions give rise to offspring with totally different hardiness. One example from a recent paper by Skrøppa and Kohmann (1997) will illustrate this phenomenon (Fig. 5). The data presented originate from a study in a nursery, Sticklestad, approximately 35 kilometers from the two northern stands, one Norwegian and one originating from Harz, Germany. From this figure it is evident that the offspring from the Harz stand, cultivated in Norway for some 50 years, has a bud set development close to the autochthonous Norway population from the same latitude. The offspring from the autochtonous Harz stand behaved quite differently from expected. The Norwegian scientists have systematically studied this phenomenon and ruled out different kinds of selection. What remains as explanation is a turning on of different genes depending on the ambient conditions. This certainly causes a high speed of change but it seems less reliable as a means to cope with global warming.

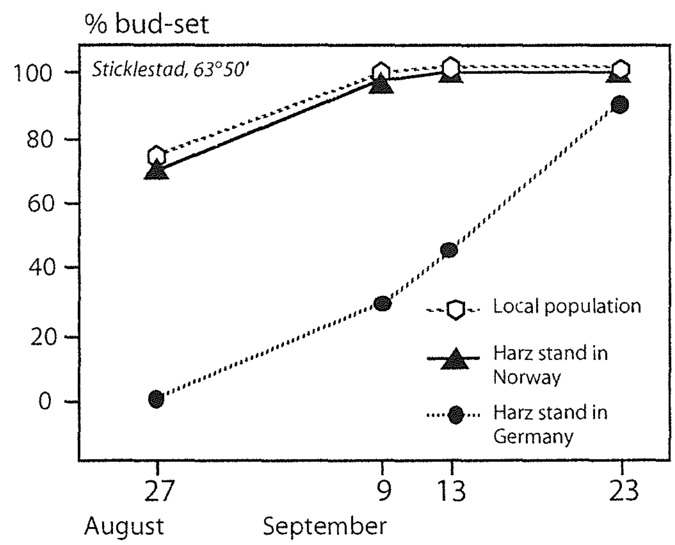


Fig. 5. Percentage bud-set Norway spruce seedlings from the local population as well as in Harz seedlings from a planted stand in Norway and Harz, respectively. Original data from Skrøppa and Kohmann (1997).

Mating pattern

Geneflow, inbreeding and genetic drift are the forces that influence the mating pattern (Fig. 6). The mating pattern gives rise to the raw material that is exposed to natural selection. The latter will be stabilizing or directional in most cases and in consequence the genetic within-population variance will be reduced. It is well known that inbreeding and genetic drift both lead to reduced additive variance whereas mutations increase the additive variance. With the figure, I have tried to illustrate that the mating pattern is critical for the amount of additive variance that a population has. If geneflow is limited, simultaneously with a high degree of genetic drift and inbreeding, the genetic raw material created will not contain much additive variance and natural selection will have limited possibilities to operate. Geneflow might be drastically changed under global warming for species that are dependent on animals as pollination vectors if the distribution of the latter is drastically changed. Understanding of the mating pattern is highly desirable to enable predictions of the possibilities of a population to survive under drastically changed conditions.

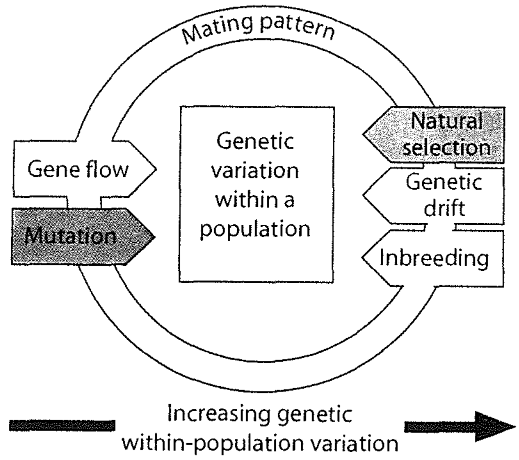


Fig. 6. Schematic illustration of the evolutionary entities influencing within-population genetic variation. The entities with the same shading are components of the mating pattern (= the zygotes formed in a population).

Recombination gives rise to new genotype frequencies without any change of gene frequencies. Therefore, recombination cannot be regarded as a component of the mating pattern, but it may have an indirect influence on the genetic constitution of the filial population.

Fragmentation

Holsinger (1993) addressed the consequences of fragmentation related to global warming and much of what is presented below is influenced by his paper. Figure 7 illustrates that a species with a patchy distribution will hardly suffer from fragmentation since it is already composed of small isolated populations. In contrast, a species with continuous distribution may suffer severely from fragmentation. The degree to which this will be true depends on how the geneflow among the island populations is changed compared with the situation with a species continuum. It will also depend on the local population extinctions and recolonizations.

All reductions in population number, as is the case with fragmentation, will lead to loss of rare alleles. However, Holsinger (1993) stressed that losses of rare alleles as a consequence of fragmentation are of no importance for these reasons:

- most rare alleles are detrimental and are the result of recurrent mutations
- a rare allele does not contribute to additive variance and its existence in a population is due to chance events and not to selection
- even if a rare allele would be useful in a distant future it would be lost before needed
- adaptive responses in the future might be obtained from other alleles with the same effect.

In a simulation study with 16 heterozygous loci and with the assumption that the gene action was completely additive, Holsinger reported that almost 13 000 different homozygous genotypes produced the optimum phenotype. The points presented above support the view that a focus on rare alleles in gene conservation is not genetically justified.

In Figure 8 a hypothetical situation is illustrated in which two central populations become extinct after global warming. The strength of the geneflow among the populations is indicated by the breadth of the arrows. The figure illustrates that the strength of the geneflow decreases with the distance between the populations. There is no direct geneflow between the two most distantly located populations before the global warming.

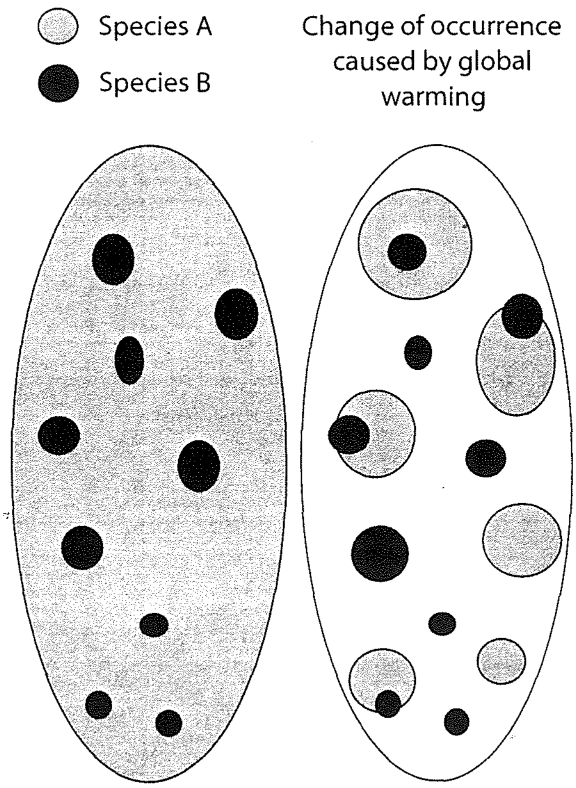


Fig. 7. Schematic illustration of the consequences of global warming on a species with continuous distribution as compared with a species with scattered distribution. Only in the continuously distributed species may there be a large change of the geneflow owing to global warming.

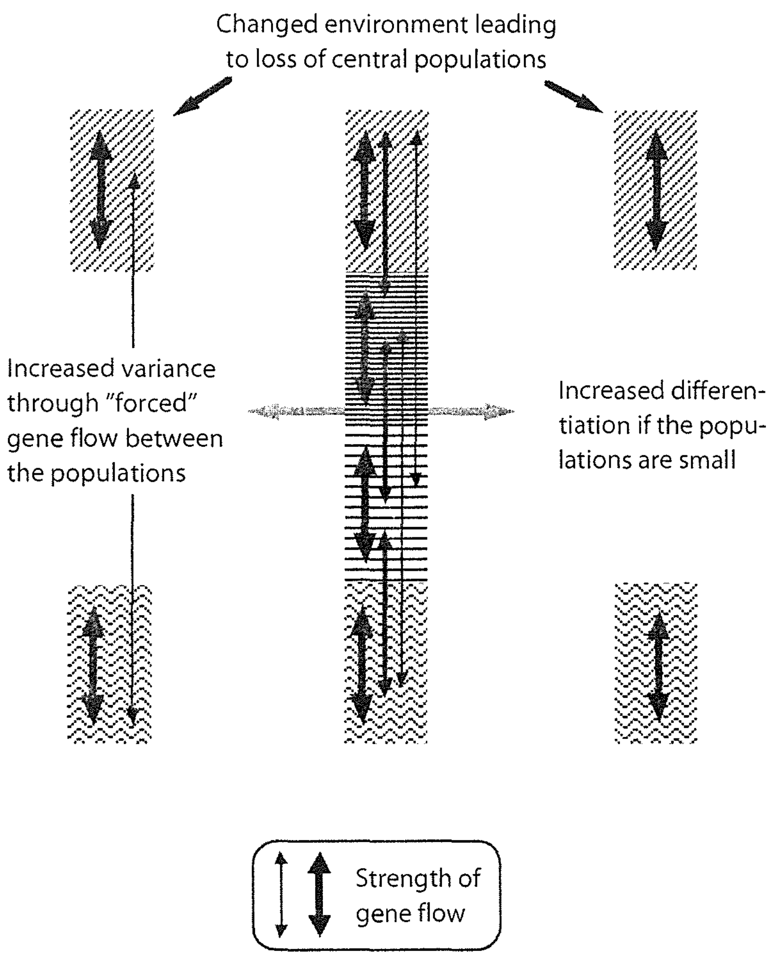


Fig. 8. Two contrasting consequences of loss of two central populations on the additive variance in the fragmented species (see also text).

The extinction of the two central populations may lead to a complete isolation of the two populations. If this is accompanied by a low N_e there may be genetic drift and random loss of alleles leading to a more pronounced differentiation of the two populations. There is a high likelihood that extinction of central populations will lead to an increased differentiation between surviving populations. Global warming can thus have two simultaneous effects of genetic significance, preventing geneflow among subpopulations and reduced N_e in them.

The extinction of the two central populations may alternatively lead to an increased additive variance in the two populations if there is a direct geneflow between the two surviving populations. This can be attributed to the absence of the two central populations that previously absorbed all geneflow between the two extreme populations. Alternatively the number of flowering trees might be so low that sexual partners have to be searched in another population. Young *et al.* (1996) reviewed population genetic consequences of fragmentation and they concluded that fragmentation in some cases had provoked an increase of geneflow among remnant populations.

Fragmentation might be positive for adaptation under situations when swamping by pollen from less hardy subpopulations is interrupted after fragmentation (cf. above, section on Additive variance).

More knowledge on mating patterns in Noble Hardwoods generally and after fragmentation is urgently needed. Research in this field ought to be given priority.

Phenotypic plasticity

During recent decades phenotypic plasticity has been treated in many papers and it is generally believed that not only a trait but also its phenotypic plasticity is genetically controlled (e.g. Bradshaw 1965; Eriksson 1997). It is highly likely that the phenotypic plasticity depends on the ecological characteristics of a species. Thus, it is believed that annuals that can respond genetically to year-to-year variations of the environmental conditions will have a lower degree of phenotypic plasticity than species with long intervals between the populations, like most forest trees. Moreover, wind-pollinated species with a continuous distribution over large areas and with highly varying SENs over short geographic distances will probably have the highest levels of phenotypic plasticity (Box 1). Hardly any of the Noble Hardwoods have this combination of characteristics but their long generation intervals have probably promoted some level of phenotypic plasticity.

It has previously been stated that a large phenotypic plasticity is useful for survival in the short-term perspective. On one hand, phenotypic plasticity may be favoured by natural selection. On the other hand, it may slow down a direct selection to a specific environment since phenotypic plasticity may be regarded as a disguise of the genotype.

Discussion

It must be stressed that there are large needs for genetic research to enable precise predictions of the possibilities of survival and evolution of Noble Hardwoods under global change. Therefore, the discussion will mainly be general.

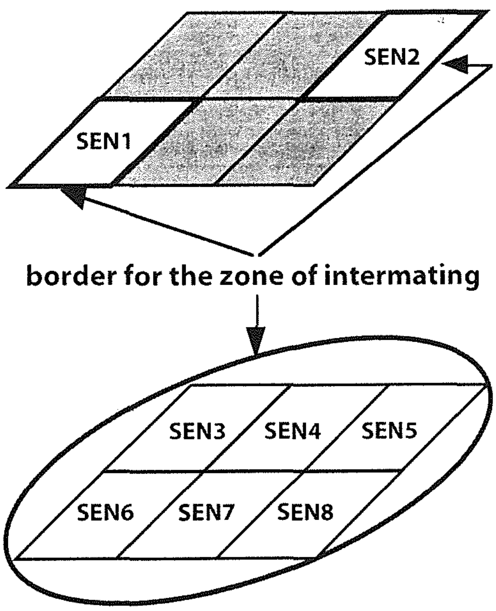
Trees growing in stands for a century or more will experience a gradual and probably fast change of the climatic conditions during their lifetimes if the scenarios of the effect of greenhouse gases are fairly correct. These trees may be able to cope with this situation, assuming that they have large enough phenotypic plasticity. However, for the long-term survival of the species it must be assumed that the phenotypic plasticity will not be sufficient.

From the presentation in previous sections it is evident that there are two long-term means to cope with environmental change, **dispersal ability** and **speed of evolution**. The speed of environmental change must not exceed what can be achieved by selection to cope with the changed environmental situation. Thus the ratio of genetic response (=ΔG)/speed of

Box 1

The potential for development of among- and within-population variation and phenotypic plasticity based on the concept of selective environmental neighbourhoods.

The concept of selective environmental neighbourhoods (SENs) was introduced by Brandon (1990). Within a SEN there is no genotype x environment interaction with respect to fitness.



With two populations growing isolated from each other with respect to gene flow, the between-population additive variance may be large either owing to adaptation or to genetic drift in small populations.

With a large gene flow among populations growing in different SENs the within-population additive variance may be large.

Since a tree in any of SENs 3–8 may contribute to the filial populations in all other SENs within the same zone of intermating a large phenotypic plasticity will be favoured by natural selection. Thus, the situation depicted will be advantageous for development of large phenotypic plasticity in a long-generation species.

Large among-population additive variance will be obtained if the disruptive selection among the different SENs is strong enough to counteract the gene flow.

environmental change must be ≥1. If the speed of the migration of a species is equal to or larger than the speed of environmental change, the species will also survive. For simplicity it is assumed that the dispersal occurs to a new environment which has the old environmental conditions. Since species migrate individually and not as ecosystems this assumption is an oversimplification (Huntley 1992).

In Figure 9 the two means to cope with long-term survival under changing environmental conditions are illustrated. It is indicated that one of the two ratios always have to exceed 1 to guarantee continued survival. The probability of survival increases with increasing ratios for stochastic reasons.

The ΔG/speed of environmental change ratio is neutral with respect to time unit. However, it is evident that a species with an average turnover time of 25 years would need a much larger additive variance than an annual species that can respond to environmental change 25 times during this period. Asexual species without any additive variance have to rely solely on their dispersal ability.

It should be remembered that ecologists fear that no species will be able to disperse their propagules fast enough to cope with the speed of the environmental change owing to greenhouse gases (e.g. Davis 1988, Peters 1990).

If neither dispersal ability nor selection response is satisfactory for the species survival, only human intervention remains. The measure to increase the population size for many of the rare Noble Hardwoods in Germany as described by Kleinschmit *et al.* (1996b) is probably the path that must be followed.

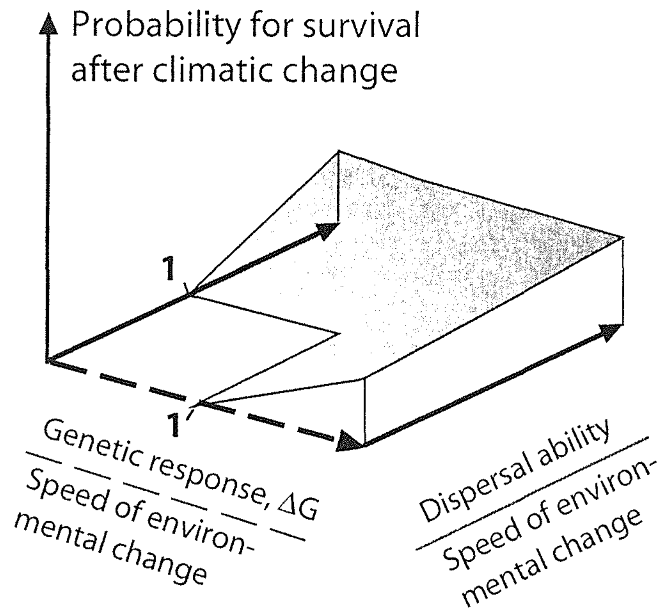


Fig. 9. The graph illustrates that either the speed of response or the dispersal ability has to be larger than the speed of environmental change to enable a species to cope with environment change.

Namkoong has argued on several occasions for planting of populations beyond the present range of distribution to obtain adaptation to the changed conditions in the future (e.g. Namkoong 1994). This is certainly a good measure to take, but can probably only be used for a very limited number of commercially important species. Few of the Noble Hardwoods will probably meet this standard. However, in connection with the establishment of new provenance trials, Namkoong's recommendation may be pursued.

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Programme

Friday 12 June
Arrival, transfer to Sagadi, registration, dinner

Saturday 13 June

07.30-08.00	Breakfast
08.30-09.00	Introduction
09.00-10.30	European long-term gene conservation strategies • Presentation of new strategy documents: *Fraxinus* spp., *Tilia* spp., *Castanea sativa* and *Juglans regia* • Discussion • Development of concise, practically oriented gene conservation guidelines
10.30-11.00	Coffee break
11.00-13.00	European long-term gene conservation strategies (continued) • Silvicultural management strategies for *in situ* conservation
13.00-14.00	Lunch
14.00-15.45	Progress made in the national strategies on Noble Hardwoods • Brief round-the-table updates from the represented countries
15.45-16.15	Coffee break
16.15-18.15	Progress made in the national strategies on Noble Hardwoods Introductory country reports
20.00	Dinner

Sunday 14 June

07.30-08.00	Breakfast
08.00-18.00	Excursion • "Bus session": Information from the other EUFORGEN Networks; international developments on forest genetic resources; public awareness activities of the Network
19.00	Dinner

Monday 15 June

07.30-08.00	Breakfast
08.00-10.30	Gene conservation of Noble Hardwoods in view of the global changes of the environment
10.30-11.00	Coffee break
11.00-13.00	Inventories of Noble Hardwoods genetic resources • Basic requirements • Links with FAO Forest Resources Assessment • Databases
13.00-14.00	Lunch
14.00-15.45	Bibliography
15.45-16.15	Coffee break
16.15-18.00	Information from complementary research projects related to Noble Hardwoods genetic resources • Links between the Network and the projects • Coordination and promotion of research
19.00-20.00	Wrap-up session and conclusions
20.30	Farewell dinner

Tuesday 16 June
Departure of participants

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