EUROPEAN FOREST GENETIC RESOURCES PROGRAMME (EUFORGEN)

Picea abies Network

EUFORGEN

Report of the first meeting
16-18 March 1995
Tatra National Park, Starà Lesnà, Slovakia

J. Turok, V. Koski, L. Paule and E. Frison,
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The International Plant Genetic Resources Institute (IPGRI) is an autonomous international scientific organization operating under the aegis of the Consultative Group on International Agricultural Research (CGIAR). IPGRI's mandate is to advance the conservation and use of plant genetic resources for the benefit of present and future generations. IPGRI works in partnership with other organizations, undertaking research, training and the provision of scientific and technical advice and information, and has a particularly strong programme link with the Food and Agriculture Organization of the United Nations. Financial support for the agreed research agenda of IPGRI is provided by the Governments of Australia, Austria, Belgium, Canada, China, Denmark, France, Germany, India, Italy, Japan, the Republic of Korea, the Netherlands, Norway, Spain, Sweden, Switzerland, the UK and the USA, and by the Asian Development Bank, IDRC, UNDP and the World Bank.

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.

Citation:
Turok, J., V. Koski, L. Paule and E. Frison, compilers. 1995. *Picea abies* Network. Report of the first meeting, 16-18 March 1995, Tatra National Park, Stará Lesná, Slovakia. International Plant Genetic Resources Institute, Rome, Italy.

ISBN 92-9043-256-X

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The first EUFORGEN network meeting on *Picea abies*

Introduction to the Network

The first meeting of the Norway spruce network of the European Forest Genetic Resources Programme (EUFORGEN) was held in Stará Lesná, Slovakia, from 16 to 18 March 1995. The meeting was attended by participants from nine countries (Appendix I). Dr Christel Palmberg and Dr Oudara Souvannavong (FAO) sent their apologies for not being able to attend the meeting, and Dr Birģelis, Latvia, Mr Hussendörfer, Switzerland, and Dr Vančura, Czech Republic also sent their apologies. A representative from Denmark also was not able to attend.

The meeting was opened by Prof. L. Paule who welcomed the participants to Slovakia and in particular to the Tatra National Park which contains a large area of native stands of Norway spruce.

Dr Frison welcomed the participants on behalf of IPGRI and expressed the wish that this first meeting of the Norway spruce network will be the beginning of a close and active collaboration between European countries in the conservation of Norway spruce genetic resources. He introduced Mr J. Turok, the EUFORGEN coordinator who was recently appointed by IPGRI.

Dr Frison stressed that the success of the Network would depend greatly on the enthusiasm and spirit of the participants and that the role of IPGRI is that of a facilitator in the network.

Mr Turok expressed his desire to develop a close collaboration with the network members and he looked forward to a fruitful discussion during this meeting. He informed the participants that the report of the meeting, including the country presentations, would be published by IPGRI and asked for volunteers to assist with the compilation of the report. Dr V. Koski, Dr L. Paule and Dr E. Frison agreed to help Mr J. Turok with this task.

Mr Turok then introduced the draft agenda, which was discussed and amended. A discussion leader was identified for each agenda item. The approved agenda is given in Appendix II.

Dr V. Koski gave a brief presentation of the history of the Norway spruce network and a paper prepared by him in January 1994 was distributed to the participants.

Presentation of the current situation by countries

The organizers had requested the participants to prepare a country presentation where seven topics should be discussed.

The overviews provided in the country reports show that Norway spruce forests are important in all countries. The natural distribution area of Norway spruce covers most European countries. In some countries, Norway spruce was planted outside its natural distribution range. The abundance and population structure of spruce forests vary considerably among countries. Large continuous populations in the Nordic countries and the scattered small populations in Central Europe require different conservation approaches.

The aims and the present state of gene conservation were not expressed very clearly in all reports (which actually influenced the contents and outcome of the workshop).

Information on various types of gene conservation populations shows that a lot of work has been done. Because of a lack of standardized terminology, a comparison of *in situ* and *ex situ* gene reserves in various countries is difficult to complete from the reports.

The topic of threats to genetic resources is only vaguely touched on in several reports, and is missing in some others. However, the threat is very real in many Central European high-altitude populations exposed to air pollutants. Many other factors cumulatively increase the adverse effects of pollution.

Research activities and needs are well introduced, and are obviously considered essential components of gene conservation.

The public awareness of forest genetic resources (and concern about their future) is not mentioned in several reports. This is, however, a matter that is to be taken seriously. Public opinion is a necessary driving force. On the other hand, wrong signals to the public may cause much trouble.

Finally, the information needs are not dealt with in all reports. This may reflect a low demand, or indicate that the information needs have not been assessed.

In conclusion, although the importance of gene conservation has been recognized, and considerable activity has been done so far, a considerable effort will be required to properly address the needs of Norway spruce genetic resources conservation in Europe. In this context, it is felt that a harmonization of conservation methodologies is desirable.

Definition of the objectives of the Norway spruce Network

Following a discussion on the objectives of the Norway spruce Network, the meeting agreed on a main goal of the network activities:

> **To promote the maintenance of a broad genetic variation in Norway spruce in order to ensure the necessary evolutionary adaptability to a changing environment over many generations.**

It was recognized that the situations vary greatly among different countries and that each country needs to develop its own conservation strategy. A number of different objectives for Norway spruce genetic resources conservation which could contribute to the overall goal were identified:

— to conserve representative populations of all ecogeographical regions
— to conserve marginal populations
— to conserve endangered populations
— to save still unknown genetic variation
— to conserve characterized genetic diversity for enhanced breeding
— to ensure sufficient genetic variation in the reproductive material
— to conserve reference populations for future research.

Individual countries will put more emphasis on some of these objectives according to their particular situation. The objective of the gene conservation activity should be stated first and an appropriate method should be selected accordingly.

It was agreed that Technical Guidelines for Norway spruce genetic resources conservation will be developed by the Network. These guidelines will provide a useful input in the development of national strategies for Norway spruce conservation.

Descriptors and database for Norway spruce

The development of an international database for Norway spruce genetic resources was discussed. The objective is to develop a tool to identify gaps in the coverage of Norway spruce genetic resources conservation in Europe.

Dr Skrøppa presented his experience with the maintenance and use of a database with experimental data from IUFRO provenance experiments. As major benefits of the existence of a database in the conservation of genetic resources, he stressed the joint analyses of data as well as the identification of gaps in a system of conservation activities.

It was felt that it is not useful to duplicate at the European level the national registers of basic materials, many of which cannot be considered as being part of a conservation strategy. The lack of funding is also considered to be the major constraint to the successful development of a database.

Dr Nanson described an example of an internationally maintained database in Douglas-fir and its use in the conservation of genetic resources. The discussion then focused on the type of information most urgently needed for the conservation network in Norway spruce. The difficulties of including various types of material in one uniform database were mentioned by several participants.

All countries were encouraged to set up national databases and take the responsibility to further maintain them. The Network will produce a minimum list of descriptors which will enable the description of all populations irrespective of national programmes in a simple and uniform way and will facilitate the exchange of data.

The meeting decided to consider populations with relevance to conservation purposes as basic units of the database. To meet the different targets of different countries it was recommended that, as a first step, populations *in situ* actively included in national conservation programmes be basic entries in the European database.

The terminology in describing passport data will be standardized. Genetic information or characterization data for each entry will be in the passport data. The meeting recommended the use of suitable commercial software and development by the Network of common formats for data exchange.

Current criteria for selection of populations for genetic conservation

The participants of the meeting presented the criteria for selection of populations used in their respective countries. The Network listed the following criteria for the selection of populations for genetic conservation:

For *in situ* conservation

— autochthonous (indigenous) populations,
— well-adapted introduced populations,
— representativeness of selected populations for all ecological zones (Norway), or natural forest communities and altitudinal zones (Austria), or seed zones (Finland, Slovakia),
— good yield, phenotypic quality and vitality of populations,
— good conditions for natural regeneration,
— minimum size of selected populations varies in individual countries from 10 or 30 ha to 2000 ha. The size of 100-200 ha was usually given. The dynamic aspect of gene conservation in large complexes (more than 500 ha) should be considered,
— good vitality in the case of endangered stands in air-polluted areas (Poland, Czech Republic, Slovakia) or marginal stands.

For *ex situ* conservation

— endangered populations of *in situ* conservation are to be conserved in *ex situ* conditions,
— good yield, phenotypic quality and vitality of populations,
— breeding populations containing sufficient genetic diversity.

In the case of *ex situ* conservation there is no unanimity on the minimum size of long-term breeding populations. Two hundred genotypes per unit or 500 genotypes per breeding zone are frequently used. It is also recommended that multiple populations be maintained in different sites.

Identification of common research needs

The discussion of this topic has reflected the research needs of individual countries and it was agreed that the necessary and urgent research tasks could be summarized as follows:

— to carry out the genetic inventory using compatible morphological and adaptive traits and/or genetic markers (e.g. isozymes, DNA markers) as the basis for selection of populations (core or endangered and marginal ones) from the entire distribution range,

— investigation of the relationship between the genetic diversity measures and morphological and adaptive traits,

— investigation of the influence of the silvicultural practices on the changes of genetic structures of populations,

— investigation of mechanisms generating the observed variability in phenotypic adaptive traits,

— development of long-term storage techniques for reproductive material, cryopreservation of tissue cultures and investigation of the biological and genetic consequences of these conservation methods,

— further studies of ecophysiology and ecological genetics, including provenance research,

— studies of reproductive biology and dynamics of Norway spruce populations.

Identification of contact persons in all countries

The concrete actions of gene conservation of Norway spruce and other forest trees are undertaken by each country according to its own systems and facilities. EUFORGEN is a coordination mechanism through which advice can be given to participating countries, but the implementation of conservation activities is the responsibility of each participating country. In order to facilitate the establishment of a gene conservation network, it is necessary that in each country one person acts as a *primus motor*. This person shall be the link or contact point to EUFORGEN. The contact persons can be backed by EUFORGEN in their efforts to enhance gene conservation in respective countries.

It was agreed that the EUFORGEN coordinator should identify a contact person in each country of the distribution area of *Picea abies*. This contact person should be familiar with gene conservation issues, and in addition the ability to communicate with ministries and forestry organizations is necessary. A fair knowledge of English is desirable in order to facilitate communications.

Agreement on Network tasks and development of a workplan

Six major tasks to be carried out during the next year were agreed upon by the Network members and a workplan identifying responsible persons and deadlines was agreed upon.

1. Publication of the report of the first meeting of the Norway spruce Network

IPGRI will publish the report of the meeting, including the country reports presented by the participants and other attachments.

TASKS:

- Participants should send their contributions in hard copy and on diskette to J. Turok by 10 April 1995
- J. Turok will finalize the report by 15 June 1995
- IPGRI will publish and distribute the report by 15 July 1995.

2. Clarification of the terminology used in the Network

It was felt that the differences in terminology used in different countries could lead to confusion and it would be desirable to agree upon a common terminology which will be used by the Network members. It was suggested that OECD terminology should be used where appropriate and that a compilation should be made by J. Turok of terms used by IPGRI and FAO.

TASKS:

- J. Turok will compile and circulate a draft list of terms to be used in the Network by 30 April 1995
- Members should send back comments by 15 May 1995
- The list will be included in the report of the meeting.

3. Compilation of a list of descriptors for Norway spruce

The utilization of common descriptors was perceived as essential by the Network. Dr Skrøppa agreed to coordinate the production of the descriptors which will be published as part of the technical guidelines (see below).

TASKS:

- J. Turok will send IPGRI descriptors to T. Skrøppa by 20 April 1995
- A. Nanson will send descriptors used in his database to T. Skrøppa by 20 April 1995
- All other members will send the descriptors used in their countries to T. Skrøppa by 20 April 1995
- A first draft will be compiled by T. Skrøppa and distributed to members by 31 May 1995
- Comments should be sent back to T. Skrøppa by 15 June 1995
- Final draft will be sent to IPGRI by T. Skrøppa by 20 July 1995.

4. Compilation of a database for Norway spruce

It was recommended that, as a first step, each country should develop a database with passport data of populations designated for conservation (both *in situ* and *ex situ*) using the minimum descriptors developed by the Network.

It was agreed that it would be useful to compile a European database and the participants agreed to investigate the possibilities of developing such a database. One possibility could be the inclusion of this task in the programme of a postgraduate student.

TASK:

- J. Turok will identify a host institute for the European Norway spruce database by 31 December 1995.

5. Technical guidelines for Norway spruce genetic resources conservation

It was agreed to develop a technical manual for forest officers and decision-makers to provide practical guidelines for the conservation of Norway spruce genetic resources.

The main responsibility for compilation of the manual was accepted by Veikko Koski. Jozef Turok, Ladislav Paule and Tore Skrøppa will be co-authors.

The responsibilities for different parts of the document were divided as follows:

Introduction	J. Turok
In situ conservation	V. Koski
Ex situ populations	T. Skrøppa
Ex situ gene banks	L. Paule

TASKS:

- Network members should send voluntary contributions (suggestions) to authors by 15 April 1995
- Co-authors should send their contributions to V. Koski by 15 May 1995
- V. Koski will circulate the first draft of the manual by 1 June 1995
- Comments and amendments should be sent by members to V. Koski by 15 June 1995
- Final draft should be sent by V. Koski to J. Turok by 30 June 1995
- Editing, layout, printing and distribution by IPGRI by 15 October 1995.

6. Identification of Norway spruce contact persons in Europe

It was agreed that a list of contact persons for matters relating to Norway spruce genetic resources conservation should be compiled by IPGRI for all European countries.

TASK:

- J. Turok should compile a list of contact persons, as complete as possible, for inclusion in the report of the meeting, by 15 June 1995.

Discussion on the International Technical Conference on Plant Genetic Resources

The history of the conference and the process leading to it were presented by Dr Frison. Preparation of the conference is carried out by a secretariat at FAO through a project entitled International Conference and Programme on Plant Genetic Resources (ICPPGR). The revised versions of the ICPPGR Briefing Notes No. 1 and 2 were distributed to the participants. The importance of the Global Plan of Action, which will be endorsed at a Ministerial level at the Conference in Leipzig in June 1996, was stressed.

IPGRI is closely collaborating with FAO in the preparation of the Conference and an agreement defining the role of IPGRI has been signed between FAO and IPGRI. The preparation of country reports was the first step in the process and several countries have already sent draft copies of their report to IPGRI. According to this agreement, IPGRI is responsible for the contacts with individual countries to facilitate the production of the country reports.

A regional meeting will be organized in Europe in October 1995 in Nitra, Slovakia at which time a synthesis of the country reports will be discussed. This meeting will also address common problems and discuss approaches to overcome them, and will identify priorities at a regional level. Regional collaboration will also be discussed at this meeting.

Contribution of EUFORGEN to the ICPPGR process

It was recommended that EUFORGEN should play a role in the development of the Global Plan of Action and that EUFORGEN should be given sufficient visibility in the ICPPGR process and in the Global Plan of Action. It was recommended that the meeting of the steering committee of EUFORGEN, which is planned for the end of 1995, should be taken as an opportunity to organize a workshop addressing European forest genetic resources issues and that this should be done as an input to ICPPGR.

Boreal Forest Genetic Resources Workshop

Dr T. Skrøppa presented the objectives of the workshop on Boreal Forest Genetic Resources which will be held in Toronto, Canada from 19 to 22 June 1995. A copy of the tentative agenda and additional information was distributed to the participants.

This meeting, which is organized by the Canadian Forest Service, is a supporting activity and an integral component of the ICPPGR.

Several European countries have already confirmed their participation (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Norway, Russia and Sweden).

Dr Skrøppa conveyed the wish of the organizers to also have participants from Alpine countries such as Austria and Switzerland as well as from Poland.

It was agreed that a presentation describing EUFORGEN and more particularly the Norway spruce Network should be prepared by J. Turok and be presented at the meeting.

Final session: Approval of the report

The meeting unanimously elected Dr V. Koski as chairman of the Norway spruce Network.

The report was discussed and amendments were incorporated. The report was then endorsed by the participants.

It was agreed to hold the 2nd EUFORGEN Norway spruce Network meeting in 1996 and the participants asked IPGRI to organize that meeting in consultation with the chairman. Dr Koski thanked the local organizers and IPGRI for the nice organization of the meeting and praised the participants for the hard work which made the meeting successful.

E. Frison thanked the local organizers and the participants for their contribution to this successful meeting.

Country reports

Conservation of Norway spruce gene resources in Finland

Veikko Koski
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Norway spruce (*Picea abies* L. Karst.) is a relatively new tree species in most parts of the country. After the latest glaciation spruce returned later than birch and pine. Probably spruce occurred sporadically earlier, but no more than 5500 years ago it began to spread from the east. It took some 3000 years to reach the western and northern parts of Finland. It is also worthwhile to mention that a large proportion of the present land area has risen from the sea rather recently. Later on, some 100 to 200 years ago, human impact on forests, especially pine and spruce forests, used to be exploitive. Shifting agriculture with prescribed burning, deliberately ignited forest fires, tar burning, grazing of cattle, and merciless cuttings resulted in treeless areas, which primarily turned to broadleaved forests. Owing to early legislation, education and silviculture, forests recovered and are now a dominating component of the Finnish landscape.

The total area of forest land of Finland is 20 million hectares, which is 66% of the total land area. Norway spruce is the second in abundance, after Scots pine (Table 1). In terms of growing stock the proportions of tree species in 1983-1993 were as follows (Yearbook of Forest Statistics 1994):

Pinus sylvestris	45.6%
Picea abies	36.8%
Betula spp.	14.5%
Other broadleaved	3.1%

The earlier land use, mentioned above, had favoured broadleaved species. More recently spruce has reoccupied fertile sites, and even penetrated to rather poor 'pine sites'.

For the time being nothing seems to threaten Norway spruce and its genetic resources. However, gene conservation is a matter for the unforeseeable future. Our tree populations are close to the northern margin — the tree line of many species goes across Finland. Thus, in respect to climatic adaptability the populations must represent extreme variants of the species in question. On the other hand, a wide genetic variation has been revealed within populations. The goal of gene conservation is to ascertain that this kind of natural resource is neither accidentally nor deliberately lost. The global change of environment is a potential threat to genetic resources. Cultivated forests with foreign seed sources and genetically improved material will gradually alter gene frequencies, if there are no counteractions. The need for gene conservation was recognized by forest geneticists as early as the 1970s. Consequently, the number of trees subject to breeding has been large since the beginning. The establishment of gene reserve populations did not get started until the Strasbourg Ministerial Conference and UNCED had an impetus.

As the first step, establishment of a network of *in situ* gene reserve forests was started in 1992. By March 1995 we have registered six spruce forest areas, the total area being 886 ha (Fig. 1). The distribution and coverage of the gene reserves is not satisfactory yet. The target is to find and establish some 10 more gene reserve forests, especially in the southwestern part of the country. There are also gene reserve forests of *Pinus sylvestris*, *Betula pendula* + *B. pubescens*, and even of *Tilia cordata*. The total number over all species is 29, and their area 5188 ha (March 1995). Besides gene reserve forests, genetic diversity has been stored in clonal archives. There are altogether close to 1600 clones, both plus trees and special forms in the clonal archives.

Table 1. Proportions of species according to their dominance in forests (Yearbook of Forest Statistics 1994)

Region	Forest area (x 1000 ha)	Proportion (%)						
		Tree-less	Pine	Spruce	Other conif.	White birch	Downy birch	Other broad leaved
Whole country	20 058	1.8	64.6	25.5	0.1	1.3	6.0	0.6
South Finland	11 499	1.6	56.8	33.2	0.1	2.2	5.1	1.1
North Finland	8 559	2.1	75.0	15.2	0.1	0.2	7.2	0.2

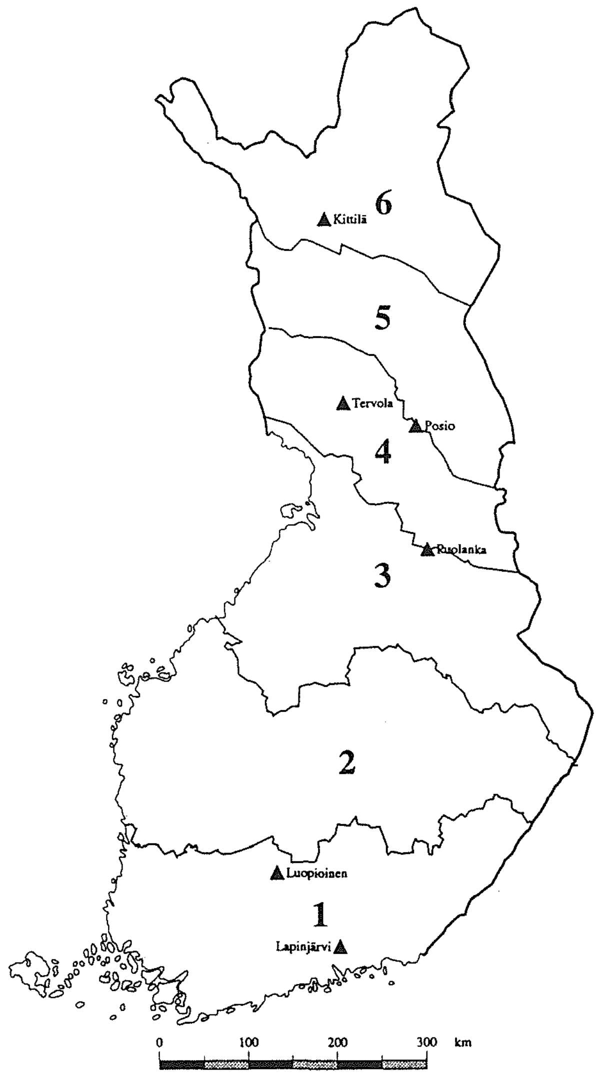

Fig. 1. Gene reserve forests of Norway spruce (nos. 1-6 refer to breeding zones, see Table 2)

Table 2. Gene reserve forests of Norway spruce in Finland, registered by 1 January 1995

Code no.	Locality	Latitude, N	Longitude, E	Area (ha)
3	Lapinjärvi	60° 39′	26° 08′	250
4	Luopioinen	61° 23′	24° 48′	80
9	Tervola	66° 09′	26° 01′	190
10	Kittilä	68° 01′	25° 25′	150
18	Puolanka	64° 39′	28° 03′	112
25	Posio	65° 54′	27° 48′	120

A national long-term tree breeding program of 1989 suggests establishment of long-term breeding populations for all main species by breeding zones. For *P. abies* six breeding zones have been delineated in Finland. The basic material of these breeding zones would be phenotypically selected plus trees. The designing of the factual populations is still underway.

Finland is in the fortunate position that the genetic resources of the main forest trees, *P. sylvestris*, *P. abies* and *B. pendula* + *B. pubescens*, are not subject to direct threat. The challenge of gene conservation is how to justify necessary actions now in order to maintain the wealth even in the far future. Biodiversity and gene conservation are favourite issues, as long as your own money is requested. After a few years people may have new topics in their minds and selling the idea of gene conservation may be much harder than it is today.

The main stream of gene conservation is by means of gene reserve forests. Based on the conditions of efficient pollination and the need of parcels of various age classes the minimum area of one unit ought to be 100 ha, i.e. 1 km^2. Finding this large area of naturally originated forest in public ownership is not always easy. In the southern part of Finland forests are mainly privately owned and consist of rather small holdings. Plantings with transferred, and even unknown, origins interfere with the natural population structure. The frequency of nonindigenous provenances and genetically improved stock will gradually increase in the future.

Rather than giving up the purity requirement and the target area of 100 ha, we could start with smaller 'kernels' and then later on enlarge the population with plantings. Seed must, of course, originate from the nucleus. Extra costs of artificial enlargement may cause difficulties, and it requires sincere effort to carry through this kind of action. The advantage of gene reserve forests is that they are managed and merchantable timber may be harvested, as well as seed.

For the time being we do not see urgent research needs in our spruce gene reserves. I consider the project a practical operation, where we must not waste any more time. Selection and documentation of the missing samples is the main goal. Characterization of populations by means of genetic markers would be desirable, but is out of the question because of economic restrictions. On the other hand, gene reserves provide excellent reference and study material for genetic studies.

Public concern on nature protection and biodiversity has been efficiently promoted by the mass media. An emotional attitude readily leads to an all-or-nothing approach to conservation. The need for gene conservation is certainly well accepted and understood. Some contradiction occurs as regards the methods of conservation. Old forests and strict nature reserves appeal to laymen, whereas forest geneticists prefer actively managed genebanks.

We have to keep on saying that conservation of forest genetic resources is the duty of the present generation. We still have large areas of native (spruce) forests in our country. As the first step a covering network of *in situ* gene reserve forests should be established. A guidebook for the handling of gene reserve forests is anticipated.

The establishment of *ex situ* long-term breeding populations is still on the planning desk. Breeding zones have been delineated, and there are sufficient numbers of phenotypically selected plus trees in each zone. Every breeding zone will have a breeding population of its own. As the composition and the physical location of the breeding populations determine the mode of action into the far future, the planning has been thorough and time consuming. The choice between closed or open systems, large entities or substructures, basic population versus nuclei, are under discussion. Information on possible experiences on Small Multiple Population Breeding Systems or other advanced models of breeding/conservation would be useful.

To my mind, gene conservation proper and effectively functioning breeding populations do not necessarily cover each other. After a few generations of selection a broad variation in breeding populations may become a 'genetic load' instead of a 'hidden treasure'. My final statement is: Let us start with simple and inexpensive measures, such as gene reserve forests, now. If we wait for a perfect universal method, it may be developed too late.

Conservation of Norway spruce gene resources in Latvia

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Introduction

The forest is one of Latvia's major assets, its most important and valuable natural resource, covering 2.82 million hectares (i.e. 44% of the total land area). This illustrates the great importance of the forest for the economy, landscape, environment, flora and fauna of Latvia. For many, the forest also has significance for leisure activities, recreation and hunting.

During the last 70 years, the forest cover area has had a stable growth trend: from 25% in 1923 to 44% in 1994. Despite that, there are significant regional variations; for example a higher forest coverage is in the central part, in the northeast as well as in the western part, where forests cover 50-60% of land area.

The various forest-growing conditions in Latvia are subdivided into five edaphic types: dry mineral (58.0%), wet mineral (10.4%), wet peat (12.0%), drained mineral (9.6%) and drained peat soils (10.0%). The distribution of tree species over the edaphic rows is not homogeneous.

Occurrence and origin of Norway spruce

The ecological position of Norway spruce in Latvia's flora has been stable since the postglacial era. As evidenced by pollen analyses and the data for forest resources today, the species covers about 530 000 ha or 20.6% of the total forested area. In accordance with the forestry development programme for 1992-2000 and 2030, the optimal share of Norway spruce is estimated to be about 24%. It means that the present occurrence of spruce in Latvia is close to an ecological optimum, particularly on dry mineral soils with fair productivity potential (*oxalidosa* site type), on wet mineral soils (*myrtiloso-politrichosa* site type), on drained mineral soil (*myrtilosa mel*) and on drained peat soil (*myrtilosa turf.mel* site type).

The share of Norway spruce in the structure of natural forests appears to reflect the selection pressure of the environment on the species. Latvia's forest resources data show the Norway spruce to predominate (33-37% of the total forest area) in the upland areas of Kurzeme (west) and Vidzeme (east-central part of Latvia). When comparing these figures with the data of K. Bambergs' paleobotanical studies, it can be shown that the pollen curves for spruce over the whole postglacial era, except for occasional fall-offs, show similar patterns. So, it appears that these areas are favourable for Norway spruce owing to the amount of precipitation and the temperature.

Geographical differences within a species may be attributed to both its migration route during the postglacial era and the natural selection controlled by the environment in the course of evolution. The immigration of spruce into the Baltic area during the postglacial era is believed to have followed two alternatives: either from the central Russian plains in the east or from the north, from the Baltics. In the latter case the related pattern is likely to become complicated owing to factors such as climatic conditions and distinct origin.

Conservation aims and current state of conservation activities

The conservation of forest genetic resources was initially started in 1986 by tree breeders at the Latvian Forestry Research Institute in Silava. The main aim was to conserve sufficient genetic variation for present purposes and future challenges. Among other species, two rather large (considering Latvia's forest conditions) overmature Norway spruce populations in the east and west part on 493 ha and 197 ha, respectively, were established as genetic reserves (see Table 1).

Table 1. The main characteristics of Norway spruce gene reserves

Population	Mean age	Mean diameter (cm)	Mean height (m)	Standing volume (m^3)	Straight stems (%)
Rezekne	102	40	33	561	45
Tukums	105	36	31	470	50

The data were analyzed in 1990. Among others, the species age structure was evaluated, results from previous studies summarized and, taking into account the geographical distribution and differences, the first attempt at forest gene conservation as a separate research project was initiated.

The main objective of gene conservation in Latvia is to maintain genetic variability among breeding material as well as to preserve the genetic potential of species for adaptation to future environmental conditions.

As it was stated in the gene conservation project, the most important and pressing task is a purposeful conservation of the spruce stands of natural origin. Silvicultural treatment of stands began at the end of the last century. In the 1970s, large areas were reforested with Norway spruce reproductive material of unknown origin. However, natural origin populations for the related research and conservation of the forest tree genepool are still common among older stands (more than 50 years). The following steps are to be taken:

— establishment of genetic reserves for *in situ* conservation of Norway spruce as a priority in Kurzeme and Vidzeme upland regions, known as the areas of optimum growing conditions for spruce; a large extent of spruce forests was destroyed by storm of 1990 and subsequent insect damage,
— special attention is to be paid to the spruce from the Latgale upland area (in the southeastern part of Latvia); the stock from these high-yield stands is noted for its high adaptability and productivity (the most significant features in future forests),
— *in situ* conservation of populations on wet mineral and drained peat soils,
— *in situ* regeneration, by using methods stimulating natural regeneration or by artificial methods in the overmature or endangered stands of the existing gene reserves,
— in cases of *ex situ* conservation, the material of nonidentifiable or foreign origin must be avoided in the surroundings of plantations,
— collection of material for seed bank with different aims (until now the existing Norway spruce seed bank contains 15 seed sources each representing 50 logged or still growing trees).

At present, the gene conservation project is underway. In accordance with the mentioned guidelines, significant work has been carried out during the last two years in establishing new conservation areas (see Table 2) of Norway spruce genetic resources.

Table 2. Norway spruce populations to be registered as gene reserves

Population	Area (ha)*	Mean age	Mean diameter (cm)	Mean height (m)	Standing volume (m^3)
Malta	10.5	125	36	32	475
Saldus	11.7	115	46	31	474
Žiguri	8.3	132	49	35	540
Dzerbene	13.6	110	28	26	350
Skujene A	5.9	50	24	21	272
Skujene B	6.1	105	34	28	410
Jaunpiebalga	18.8	65	27	26	350
Nitaure	5.6	80	28	25	294
Silene	5.4	55	24	22	390
Naujene	10.8	90	28	26	380
Ludza	3.3	75	32	26	320

* Without surroundings. Small conservation areas were accepted in most important regions.

The previous tree-breeding activities with Norway spruce were:
- — 292 phenotypically selected individuals (plus trees) represented in 170 ha of seed orchards,
- — *ex situ* conservation of 73 provenances in provenance field trials,
- — *ex situ* conservation of about 100 plus tree progenies in seedling progeny tests.

Summary of research activities and results obtained

The phenotypic composition of stands of natural origin was investigated at the Laboratory of Forest Tree Breeding during the 1960s and 1970s. The forms *acuminata-europaea* and *europaea* were identified. Types of branching largely depend on the site conditions, with *pectinata* branching being typical for higher productivity stands. The analysis of the related field data showed that this type of branching increased relatively in a west-east direction, but reached a higher proportion in the upland areas of Kurzeme and Vidzeme. They appear to be the most favoured regions for Norway spruce growth. Genetic differences were evaluated in progeny tests or by isozyme analyses.

Suitable markers for the assessment of geographical and genetic differentiation of Norway spruce were: time of spring flushing and growth termination, ability to develop lamma shoots, juvenile growth as well as shape of branching. The geographical differences were studied following the changes in climatic factors for different regions, with the total sum of active temperatures and the amount of precipitation as principal indicators.

In provenance trials in the country and abroad, Latvia's spruce is usually ranked among the provenances that are late flushing and fairly fast-growing, when tested against geographically diverse backgrounds.

The local provenances are distinguished by a higher degree of survival and better stem quality. When comparing progenies set into favourable site conditions, the provenances coming from the south of Latvia fall, with a few exceptions, under the group of fast-growing ones, while those coming from the north of Latvia are distinguished by lower survival and smaller stem dimensions. If the spruce coming from the southwest of Latvia is cultivated on frost areas and unfavourable soil conditions, the provenances of this region lose their advantages. So, the Remte seed orchard progeny (southwest of Latvia), which in provenance trials under favourable site conditions outperformed Dorna Cindreni (152 and 128 m^3/ha at the age of 17 years, respectively), nearly died away on peat soils with late frost after repeated frosts. The Ranki provenance (Ogre region) survived and showed normal performance, while progenies coming from the southeast (Daugavpils, Rezekne, Jekabpils) showed a similar reaction to adverse environments. Fast-growing spruce showing a good adaptability to varying conditions has thus been found in the southeast of Latvia. The clonal breeding, underway since the late 1970s, is based on the material of this region. The related seed reforestation is recommended for all Latvia.

A pilot study on genetic structure, level of diversity and degree of differentiation at isoenzyme gene loci in five stands of Norway spruce was carried out. Eighteen enzyme systems were electrophoretically analyzed and 78 allele variants at 26 loci observed. Three rare alleles (at the gene loci controlling Aat, Lap and Dia), which had not been observed in earlier studies, were found in one of the studied populations (Ranki, central part of Latvia). It was shown that:

- the genepool in analyzed stands is practically identical, genetic distance does not exceed 0.008, the differentiation is less than 1%,
- the studied stands from different regions of Latvia have a high level of variability and fairly uniform genepool observed at isoenzyme loci.

On the contrary, differences of Latvia's Norway spruce populations in traits such as flushing time, juvenile growth rate or adaptability are significant and linked with geographical origin or ecological conditions.

To ensure a responsible approach and to raise the public awareness of plant genetic resources conservation in Latvia, discussion of the necessity of a National Plant Gene Conservation programme was started, which would include state authorities, research and NGO representatives. It should also be noted that there is an urgent need for an internationally accepted forest gene resources database, e.g. as a contribution to EUFORGEN.

Norway spruce (*Picea abies*) genetic resources and their conservation in Lithuania

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Summary

Lithuanian forests cover an area of 1.86 million hectares. The total wooded area of the country is 30.1%. Coniferous forests comprise 61.6%, and spruce stands 24.2%. Native spruce stands make up more than two-thirds of their total area. Middle-aged and older stands are divided into three selection groups. The best (1st selection groups) spruce stands cover 41 000 ha. Genetic resources of spruce stands are conserved *in situ* and *ex situ*. Permanent inventory and assessment of genetic objects are carried out. Studies on phenotypic and genotypic structures of populations are conducted; adaptation, stability and selection effect of provenances and families, as well as changeability of traits, peculiarities of reproductive biology and hybridization are determined. Standards for conservation and utilization of genetic resources are being prepared.

Introduction

The Lithuanian forests are situated throughout the territory and cover an area of 1.86 million hectares. The total wooded area of Lithuania is 30.1%, in which coniferous forests comprise 61.6%, and spruce stands 24.2% (Table 1). During the last two decades, intensive reforestation has had a tendency to increase the area of spruce stands. Mature spruce groves are the most productive (285 m^3/ha) of all stands growing in Lithuania while they suffer the most from negative natural and anthropogenic factors such as storms, droughts, insect pests, fungus disease, frosts, animal damage and, finally, industrial pollution.

In Lithuania, spruce stands are situated mostly in the western, northern and central parts of the Republic. Scots pine forests take up a large area but there are no clear big spruce forests. The forests of Rietavas-Taurage and Birzai are somewhat larger. The characteristics of spruce groves are presented in Table 2. The spruce groves of *Piceetum myrtillosum* and *Piceetum oxalidosum* forest types prevail in Lithuania. Mostly, mixed spruce stands with pine, birch and aspen are noted. Mixed spruce stands with birch and aspen produce about 650 m^3/ha of timber at the cutting age. They distinguish themselves in better stability and resistance to storms.

The area of spruce stands in Lithuania has been decreasing continually (Fig. 1). True, it began to increase during the last two decades because of young stands. At present, young stands until 10 years of age make up 15.4% of the total area of spruce stands. It is known how many disasters the spruce groves suffer during their ontogenesis. Continually recurring storms (in 1967, 1982 and 1993) destroyed most spruce stands. Usually a big invasion of spruce bark beetles, which destroy what is left after windfalls in spruce groves, follows the storms. The latter process was particularly severe after the storm in 1992. One of the main measures at present being used in Lithuania for cleaning defaced and damaged spruce stands is to cut the damaged stands and remove the stem together with spruce bark beetles. It is impossible to determine the losses which we will suffer.

Another significant factor destroying the spruce stands is industrial air pollutants. According to the data of our specialists who are carrying out ecological monitoring activities (Ozolincius 1994), defoliation of spruce groves continually increases. For instance, in 1989 the spruce stands damage class was 0.7 while in 1994 it was 1.1. General spruce stand defoliation level at present comes to 21.7%.

Table 1. Resources of Lithuanian woods

Species	1962		1993						
					Distribution by age classes (%)				Volume of premature stands (m³/ha)
	1000 ha	%	1000 ha	%	Young	Middle-aged	Pre-mature	Mature	
Pinus sylvestris	642.4	41.2	695.3	37.4	37.0	42.7	11.7	3.6	278
Picea abies	308.6	19.9	450.2	24.2	39.0	26.3	26.2	8.5	285
Other coniferous	2.7	0.2	0.8	0.04	—	—	—	—	—
Quercus robur	23.6	1.5	32.4	1.7	17.3	58.0	8.7	16.0	246
Fraxinus excelsior	16.1	1.0	47.3	2.7	48.9	44.4	4.9	1.8	244
Betula verrucosa and *B. pubescens*	276.6	17.7	363.4	19.5	7.2	65.9	15.5	11.4	235
Populus tremula	93.8	6.0	50.4	2.7	6.9	12.7	25.0	55.4	261
Alnus glutinosa	97.8	6.3	104.0	5.6	14.4	56.4	15.7	13.4	270
Other deciduous	97.5	6.2	114.5	6.2	—	—	—	—	—
Total	1559.1	100	1860.3	100	27.8	44.7	17.9	9.6	244

Table 2. Productivity of various Norway spruce stands at 100 years of age and 0.7 of stocking level

Type of forest	Mean height (m)	Mean diameter (cm)	Mean volume (m^3/ha)
Piceetum myrtillosum	24.1	27.5	313
Piceetum myrtilloso-oxalidosum	25.7	29.0	333
Piceetum oxalidosum	24.4	28.8	317

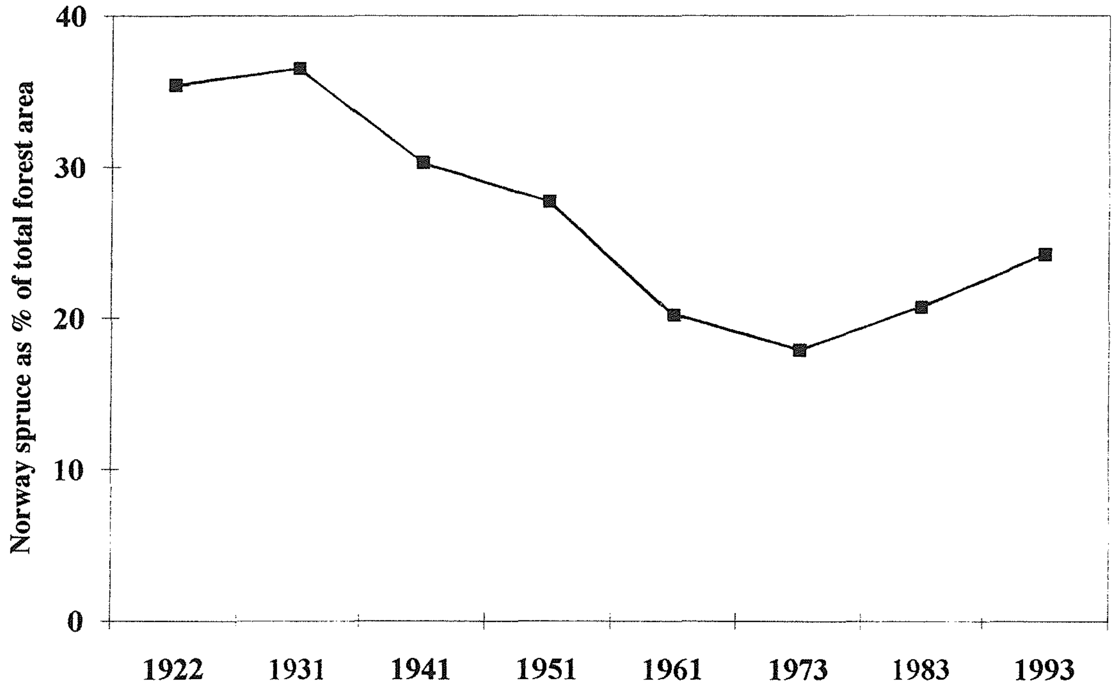

Fig. 1. Dynamics of Norway spruce stand areas in Lithuania by years

At present the spruce stands of natural origin in Lithuania make up more than two-thirds of total spruce forest area. Annual spruce cutting woodlots consist of 2000 ha on average and the stands of natural origin are cut. Therefore, the situation of the natural spruce grove genofund will change owing to the artificial reforestation. The necessity arose to conserve the valuable natural genofund of spruce as well as of other tree species.

Main Norway spruce populations and their status

Six natural forest regions are selected in Lithuania in which different populations of separate tree species, among them Norway spruce, have formed. The main object of forest tree selection is natural populations, because populations are a primary link of genetic information. Valuable genotypes which are adapted to the local conditions are best and genotype conglomeration forms in natural stands, while the crossing of separate individuals acts as natural selection under certain environmental conditions.

Elucidation of population bounds is a long and intricate process but it is possible to choose and evaluate the populations most distant from each other and separate due to the climatic differences and origins of specific structural traits.

Diversity of genofund decreases because the area of stands of artificial origin increases, reforestation does not always use the seed of the best trees and sometimes there are separate genotypes of low value. All potential elements of a genofund participate in reproduction of new generations in naturally formed autochthonic stands.

At present there are no big spruce forests in Lithuania. They are situated in the western, central and northern parts of the Republics and divided by larger or smaller deciduous stands. Larger spruce groves remain in four parts of the country and make up the following spruce accumulations: southwestern Zemaitija, northeastern Zemaitija, forest of Birzai and central southern part. However, these spruce stands are cut by woodlots and damaged by windfalls. There are some spruce stands in other parts of Lithuania as well but they do not form big forests. Mostly, they are mixed with big forests of other tree species. Therefore, it is necessary to conserve the genofund or remaining spruce groves and to utilize them rationally in reforestation (Gabrilavičius and Pliura 1993).

At present, the following best Norway spruce populations are selected in Lithuania: Survilai (1st forest natural region); Rokiskis (2nd forest natural region); Ignalina (3rd forest natural region); Mociskis (4th forest natural region); Sakiai, Kazlu Ruda, Punia (5th forest natural region); Trakai (6th forest natural region). Investigated populations differ significantly in most structural traits. Height differences of separate populations make up 21.4%, and ones of crown width comprise 35.8%.

It is important to ascertain the limits of population transfer, using them to establish new spruce stands. The influence of environmental conditions on trait variability must be studied, and the progenies transferred into new ecological conditions; other studies include determining the influence of genetic characteristics (Gabrilavičius 1992).

Ecological adaptability of populations is the genetic result of different reactions of each population to site fertility, humidity and micro- and macroclimatic conditions so it is possible to get additional selection effect by selecting specifically adapted populations.

Studies have evaluated reliable growth and adaptability differences between some Lithuanian Norway spruce populations (Danusevičius 1993; Gabrilavičius 1992). Adequate populations (their progenies) are being recommended for reforestation in every forest natural region.

In the winter of 1993 the storm turned a significant part of the spruce stands upside down. A dry summer followed and also in 1994 was an unforeseen drought. For this reason, the spruces became significantly weaker and the pest *Ips typographus* has spread. At present, there are 60 000-70 000 ha of spruce stands being damaged by the abovementioned pest; this area makes up 32-38% of middle-aged and older stands. It is planned to clear-cut an area of 35 000-40 000 ha of the damaged spruce stands, which represents more than a 2-year cutting rate.

Methods to conserve genetic resources

Primary evaluation of forest genetic resources is carried out during forest inventory, when middle-aged and older stands are divided into three selection groups: Group I—stands of Ia and I bonitet, high productivity and quality, healthy, normal thickness; Group II—stands of II-III bonitet, average productivity and quality; Group III—stands of IV and lower bonitets, low productivity and quality. At the present moment, Lithuanian middle-aged, premature and mature spruce stands are of good selection value (Tables 3 and 4). Stands of the Group I cover 41 000 ha, or 22% of the area of middle-aged and older spruce stands (Kenstavičius and Brukas 1993). They make up the most valuable genofund of Lithuanian spruce stands, and therefore more attention is paid to their conservation and regeneration. In Lithuania two methods of genetic resources conservation are applied:

In situ

— genetic reserves, when highly valuable stands are singled out and conserved up to natural maturity, allowing the removal of dying or damaged trees, to fight against pests and to protect the main species from overtopping by others; natural regeneration is used,
— plus (elite) individual trees, when individual trees are supervised and kept until their death, while progenies are transferred into archives or plantations,
— seed orchards, when the stand is left until maturity, and the seed crop is gathered from standing trees. Regeneration is natural.

Ex situ

— clone archives, when 15 ramets from each clone are grown in special sites,
— seed clone orchards,
— test plantations from plus (elite) tree seeds or genetic reserves and seed sites.

Table 3. Distribution of Norway spruce stands according to the selection (genetic) groups in Lithuania

Age classes	Total area (ha)	Distribution according to the selection (genetic) groups (%)		
		I	II	III
Middle-aged	75.2	24	64	12
Premature	17.9	14	58	28
Mature	93.1	22	63	15
Total	186.2	—	—	—
Mean	—	22	63	15

Table 4. The amount of first selection group stands of Norway spruce by forest natural regions in Lithuania

No.	Forest natural region	Area	
		ha	%
I.	Lowland of Zemaitija	3013	14.9
II.	West Aukstaitija	4800	23.7
III.	East Aukstaitija	965	4.8
IV.	Littoral lowland	1891	9.3
V.	Suvalkija and Kaunas region	7810	38.6
VI.	Dzukija	1764	8.7
	Total	20243	100.0

Data presented in Table 5 are from work carried out in the field of genetic resources conservation. In agreement with the Law of Lithuanian Forests, genetic reservations in the future will acquire the status of genetic reserves, because in the first case man's interference is prohibited. Genetic reserves comprise 0.5% of the total area of middle-aged and older spruce stands (Baliuckas *et al.* 1994).

This year additional selection is still foreseen, while damaged ones will be reassessed. Additional seed reserves also will be singled out. At present, standards for selection, management and utilization of the abovementioned conservation objects of genetic resources are being specified and therefore an international experience here would be of great help.

Some plus trees are dead or damaged, and therefore in the near future their additional selection and evaluation will be carried out. Clones of most of dead plus trees are concentrated in archives, so that their genotypes are not lost.

Table 5. The conserved Norway spruce genetic resources in Lithuania

No.	Way of preservation	Number of objects	Area (ha)
In situ			
1.	Strict genetic reserves	1	429.0
2.	Genetic preserves	51	542.0
3.	Seed stands	21	149.6
4.	Plus trees	589	—
Ex situ			
5.	Clonal archives	5	15.5
6.	Clonal seed orchards	27	339.1
7.	Progeny plantations	18	45.2
	Progeny tests	13	22.0
	Provenance tests	5	23.2

Studies on genetic resources and the need for their improvement

At present, studies on genetic resource are conducted by the Lithuanian Forestry Research Institute. Owing to long-term isolation from West European countries and inadequate financing, investigations were carried out on a small scale and slowly. The works that have been and are being carried out can be divided into two groups: fundamental and applied (Table 6).

More detailed studies were performed concerning phenotypic and genotypic structure of populations, selection efficiency of provenances and families *in situ* and *ex situ*, including adaptability and stability indices; investigations of genotype by environmental interaction and geographical changeability, as well as peculiarities of reproductive biology in seed orchards and interspecific as well as intraspecific hybridization.

In the field of applied sciences, recommendations and standards for stand selective evaluation, for selection of plus trees, genetic and seed reserves, as well as for establishing seed orchards and clonal archives, and for increasing seed crop productivity, have been prepared.

It is foreseen to continue the inventory of forest genetic resources, studies and compiling of catalogues, work on tree assessment and genotype identification, as well as to work out criteria for the selection of plants under conservation.

The quality and extent of these works depends considerably upon international collaboration which is carried out by the International Plant Genetic Resources Institute, and upon our united efforts in the EUROFORGEN programme, as well as on financial support.

Table 6. Research investigations in genetic resources estimation, preservation and utilization

No.	Basic research	No.	Applied research
1.	Analysis of the phenotypical and genotypical structure of populations and provenances.	1.	Criteria for selection of the plus trees, stands and selection groups.
2.	Methods for selection of the plus trees and stands.	2.	Selection of genotypes for the higher generation seed orchards; methods and technologies for establishment of the seed orchards.
3.	Efficiency of selection of families and provenances, grown *in situ* and *ex situ*.		
4.	Limits of provenance transfer.	3.	Selection of the genetic reserves and seed reserves.
5.	Methods of the early prediction and evolution of genotypes.	4.	Establishment of the clonal archives.
6.	Bioecological peculiarities of flowering and bearing in seed orchards.	5.	Means to increase the forest seed production.
7.	Creation of new hybrids.		

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Gene conservation of spruce (*Picea abies*) in Poland

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Introduction

The network connected with gene conservation of forest tree species started in 1991 when the Programme of gene conservation and tree breeding for 1991-2010 was formally confirmed by Officials. This Programme was mainly prepared for conservation of genepools of the species in economical forests (State Forests). In this Programme the strategic aims of gene conservation were estimated. Conservation of the forest gene resources is necessary to sustain:

- continuity of fundamental ecological processes,
- maintenance of forests and utilization of ecological systems,
- restitution of forests destroyed by anthropogenic factors,
- preservation of biological and genetic variety for future generations,
- increased natural resistance of the future forests.

To the main factors causing threats to genetic variety of native populations belong:

- decrease of participation of same species in next generations by their substitution by foreign provenances or species,
- pollen contamination of other provenances or species,
- biotic factors causing forest decline (insects, fungi, game),
- abiotic factors (greenhouse effects, air pollution).

Methods

Depending on the threat to the forests it is planned to use different methods of gene conservation. For these reasons the forests (areas) are classified in three groups:

Areas without threat

(mainly *in situ* preservation)

- choose the stands and trees for gene conservation,
- initiate natural regeneration in these stands,
- provide additional protection of very old stands and trees,
- provide secondary protection where necessary on *ex situ* plots,
- progeny plantations,
- seed orchards,
- clonal archives,
- seeds in genebank.

Areas of medium threat

(*in situ* and *ex situ* preservation)

In situ

- initiation of natural regeneration in chosen stands,
- choose threatened populations and trees for preservation *ex situ*.

Ex situ

- progeny plantations,
- seed orchards,
- seedling seed orchards,
- clone collections,
- long-term storage of seeds, pollen and parts of plants.

Areas of total decline of forests

(*ex situ* preservation)

- — vegetative propagation of populations and single trees by cuttings and tissue cultures,
- — progeny plantations,
- — seed orchards from vegetatively propagated materials,
- — long-term storage of plant materials.

Results

Spruce exists in Poland in three subranges (or regions Giertych), separated by areas where spruce does not occur naturally. It is probably connected with glacial epoch and spruce refugial regions from which spruce migrated mainly in northerly and westerly directions. Spruce growing in northeast Poland (northeast subrange) is connected with the northern and eastern ranges of this species in Lithuania, Latvia and Byelorusia. Hercynian West Carpathian subrange is the part of natural range connected with spruce growing in Germany, Czech Republic and part of Slovakia. Spruce growing in the southeast part of Poland belongs to the southeast Carpathian subrange.

On the basis of this macrodivision were delimited the areas where existing natural populations of spruce should be included in a long-term gene conservation programme. Between these populations there are also well-known and valuable Polish provenances such as: Bystrzyca, Lądek, Istebna, Wisła, Nowy Targ, Tarnawa, Zwierzyniec, Białowieża, Augustowo, Knyszyn and Borki.

Apart from these populations, other spruce stands located in central and northwest Poland were included in the programme of long-term gene conservation of spruce. In total, 52 populations (stands) of spruce were chosen for gene conservation in Poland (Table 1). All of these stands will be managed as normal stands and at the proper time the natural regeneration for establishing *in situ* progeny plantations will be started.

Parallel *ex situ* progeny plantations were established artificially from seeds collected in these stands. The size of the work connected with *ex situ* gene conservation of spruce in Poland is shown in Table 2. Until 1993, 623.7 ha *in situ* and *ex situ* progeny plantations had been established.

Also, clones of spruce (about 500) existing in seed orchards are treated as an additional source of genes for conservation.

Short-term activities in gene conservation of spruce are connected with the threat of populations growing in Sudety region.

For this reason, field work was done, which let us choose natural or probably natural stands in 11 Forest Districts (about 670 ha) for *ex situ* gene conservation. In these stands 2 years ago was begun the first clone collection and 49 samples of seeds (1.5 kg each) were put in a genebank for long-term storage (Table 3).

Additionally, a special short-term programme for gene conservation of spruce for the oldest natural stands and trees growing in our protected areas is managed by Dr A. Korczyk in northeast Poland, mainly for Białowieża National Park.

In the first phase of this work one natural stand of different ages (40-240 years) and 73 trees older than 200 years, growing in different soil conditions, were chosen for conservation of our premanagement natural population of spruce. These trees were used for establishing *ex situ* clone collections (4.16 ha) in two different places.

Table 1. The populations (stands) of spruce included in long-term gene conservation programmes

	Regional Forest District	Forest district	Forest subdistrict	Forestry	Number of plot	Area (ha)
1	Białystok	Białowieža	Zwierzyniec	Budy	278Bb	10
2				Teremiski	311Bgh	8
3		Borki	Borki	Zielonki	191c, 202b	17
4			Przerwanki	Diabla Góra	105c, 142bg, 159a	20
5		Czerwony Dwór	Czerwony Dwór	Dunajki	80gh, 81dk, 148c	32
6		Gołdap	Gołdap	Budwiecie	34d, 35bc	21
7				Ostrówek	42f, 97g, 98ad, 153ch	29
8			Žytkiejmy	Maków	175b, 230a, 231a	57
9		Pomorze	Pomorze	Wiłkokuk	591g, 615cd	22
10		Suwałki	Suwałki	Papiernia	11a, 12b	40
11				Płociczno	66a	24
12				Pijawne	80a, 81c	33
13		Wigierski PN	Wigry	Krzywe	126bc	25
14				Krzywe	144g, 146dl, 147ab, 155f	44
15	Katowice	Ujsoły	Rycerka	Kiczora	65f, 68b	30
16				Sól	99c, 100f, 101c, 103d, 108a, 110bc, 111d	107
17				Praszywka	116g, 125b, 128b	54
18				Plaskurówka	140b	36
19				Rycerka	155bc, 157abc, 158a, 159a, 160a	150
20				Bendoszka	211c, 212g, 223c	77
21	Katowice	Ujsoły	Ujsoły	Gawłowskie	9f, 10f	19
22				Złatna	100c	15
23				Dobka	24ik	12
24		Ustroñ	Ustroñ	Žabnica	28f, 29abc	21
25		Wêgierska Górka	Wêgierska Górka	Boracza	49a, 50f, 52c, 62b	77
26				Prusów	98f, 99d, 100d	17
27				Kamesznica	194d	12
28				Baranica	249h, 250f, 252c	49

	Regional Forest District	Forest district	Forest subdistrict	Forestry	Number of plot	Area (ha)
29		Wisła	Istebna	Gańczorka	71bc, 72cdfg	36
30			Wisła	Zapowiedź	108f, 109bcdg, 115gi, 120fg, 121a, 122b,	129
31				Bukowiec	123cdg	58
32				Czarne	136b, 138cd, 140b, 146b, 149d	37
33				Malinka	54gi, 55ad	67
					89cd, 90d, 91gh, 91k, 92fghi, 93no	
34	Kraków	Nowy Targ	Orawa	Police	14bc, 15a, 17gf	38
35				Smietanowa	25b, 26c, 33a, 34a	106
36				Stańcowa	40c, 44c	8
37	Krosno	Stuposiany	Tarnawa	Sianki	322b, 337b	75
38	Lublin	Biłgoraj	Tereszpol	Hedwiżyn	25g	6
39	Olsztyn	Olsztynek	Grunwald	Dylewo	108b, 118ab	7
40	Warszawa	Płońsk	Płońsk	Załuski	438bd, 439f	22
41	Radom	Suchedniów	Bliżyn	Œwinia Góra	133f	4
42	Szczecin	Dobrzany	Dobrzany	Kielno	548f, 549fk	12
43		Nowogard	Czermnica	Olszyca	69d	10
44		Resko	Resko - Wschód	Dąbie	346j, 347b	11
45	Wrocław	Bystrzyca	Pokrzywno	Lasówka	189f	10
46		Klodzka	Jugów	Przygórze	44dg, 45ab	20
47		Jugów	Bolków	Sêdzisław	275c, 276ij	12
48		Kamienna Góra	Lubawka	Chełmsko	240g, 241ad	20
49			Strachocin	Wojtówka	50d	14
50		Lądek Zdrój	Stronie Śląskie	Kamienica	279di, 280d	18
51				Kletno	314fl	13
52			Duszniki	Zdrój	175cd, 181d, 295h, 297c, 309d	29
		Zdroje				

Table 2. Areas of *in situ* and *ex situ* progeny plantation established up to 1993

Regional Forest District		Area (ha)
1	Białystok	16.1
2	Gdańsk	82.0
3	Katowice	226.0
4	Kraków	8.5
5	Krosno	80.9
6	Lublin	80.9
7	Łódź	80.9
8	Olsztyn	69.0
9	Piła	34.4
10	Poznań	34.4
11	Radom	34.4
12	Szczecin	34.4
13	Szczecinek	9.7
14	Toruń	9.7
15	Warszawa	9.7
16	Wrocław	97.1
17	Zielona Góra	623.7

Research

At the same time as networks connected with gene conservation were started, the Gene Bank Laboratory was created in the Department of Genetics and Physiology of Woody Plants of the Forest Research Institute. This laboratory carries out the studies which are necessary for practical realization of gene conservation, including:

- — genetic diversity of natural populations of spruce in Poland,
- — influence of the anthropogenic factors on genetic structure of populations,
- — methods of long-term storage of seeds and pollen,
- — consequences of long-term storage of seeds on genetic structure of seed samples,
- — methods of propagation by:
  - — cuttings,
  - — organogenesis,
  - — embryogenesis,
- — somaclonal variation of seedlings from somatic embryos,
- — cryopreservation of embryos, callus and 'artificial seeds',
- — monitoring changes in stored seed, pollen and embryo samples.

Table 3. Spruce stands where cones were collected for long-term storage in genebank

Forest District		Altitude (m)	Number of plot	Age (yrs)
701	Świeradów	490-570	224 g	90
		550-630	263 a	90
		550-680	277 c	85-90
		880-930	411 f	80
	Szklarska	600	240 i, 134 l	110
	Porêba	670-700	116 c	134
	Kamienna Góra	600-800	278 ac	—
	Wałbrzych	500-550	117 j	140
		520-550	126 a, 127 a	130
		520-600	117 c	140
		520-600	117 i	140
		520-600	126 f	100
		550-620	127 b	105
		620-640	291 f	95-100
		600-800	216 k, 217 b	83
		600-800	337 ab	—
		600-800	281 d	140
702	Jugów	550-810	41 f	110
		590-790	34 c	95
		730-870	9 c	120
		740-940	212	95
		790-940	224 f	115
	Zdroje	480-500	34 c	110
		630-700	23 h	115
		500	152 a	145
		510-650	52 a	100
		690-720	129 g	135
		760-960	295 h, 297 c	115
703	Miêdzylesie	520-630	146 f	158
		680	199 b	128
		680	132 i	117
		750	192 c	120
		690-780	166 c	112
		780-830	138 c	112
		840-910	163 c	122
		990-1060	154 bf	133
		1120	17 c	132
		940	23 l	112
		1250	220 d	150
	Lądek Zdrój	400-600	280 d	145
		450	50 d	140
		700-800	240 b	110
		800	151 a	100
		820	197 i	105
		900	312 g	140
		800-950	314 lf	160

Current status of genetic conservation of Norway spruce (*Picea abies*) in Austria

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Abstract
In Austria, Norway spruce is a naturally occurring forest tree species that is of outstanding ecological and economic importance. In total, 1 870 000 ha or 56.1% of the production forest area is covered by spruce. Genetic resources of this species are not at stake in general. However, owing to uncontrolled forestry in former times the natural geographical pattern of genetic variation has been strongly modified. This complicates the study of natural genetic differentiation and the identification of gene resources. Anthropogenic activities have often blurred effects of local selection regimes and postglacial immigration.

The preservation of the adaptive potential of Norway spruce is done within the frame of a federal conservation programme that was launched in the 1980s. This predominantly pragmatic programme focuses on the declaration of gene reserves, i.e. *in situ* stands that represent ecologically important forest communities. In total, 3073 ha of large-scaled Norway spruce gene reserves (42 stands) and an additional 1069 ha of small-scale conservation units (82 stands) have been declared as genetic resources. As a backup, 318 kg of Austrian Norway spruce seeds are currently stored in the federal seed bank.

In the long term, identification of valuable spruce genetic resources should be based on a synoptic assessment of ecological (predominantly forest communities) and genetic parameters (results derived from field trials and genetic inventories).

Introduction
In view of an uncertain climatic future, the preservation of genetic adaptability of tree populations is crucial for the long-term stability of forest ecosystems (Committee on Managing Global Genetic Resources 1991). Global conservation efforts have to lay emphasis on those forest tree species that are close to extinction.

In Austria, no forest tree species is threatened to such an extent. It is not the whole species that is being driven to extinction, but diminishing local races or ecotypes are the main concerns. This also holds true for Norway spruce (*Picea abies*).

Austria is a mountainous country influenced by different climatic regions and manifold geological conditions. Thus, because of the various environmental factors, different ecotypes can be expected within a forest tree species. However, besides these natural environmental conditions, postglacial immigration and, beginning in the early Middle Ages, indiscriminate extensive cuttings for ore and salt mines, have long-lasting effects (population fragmentation, seed transfer, species shift) on the genetic composition of today's forest tree populations. These peculiarities have to be borne in mind if the existence of certain forest tree populations is at stake and means of conservation is discussed.

Austria's total wooded area amounts to 3.88 million hectares, i.e., 46.2% of the land area is covered by forests. Therefore, Austria is rich in forest resources compared with other European countries. However, governmental implementation of conservation activities is intricate. Only 30% of the forest is publically owned and a high proportion (69%) of private owners operates nonindustrial forest enterprises or owns small woodlots (< 200 hectares) (Anonymous 1993).

Distribution of Norway spruce in Austria

Natural range

A meticulous depiction of the native range of Norway spruce was published by Tschermak in 1949. Here the range is only briefly described. In Austria, Norway spruce is widely distributed. The Alps, mountains of the Bohemian massif [Mühlviertel (Upper Austria) and Waldviertel (Lower Austria)], and higher elevations of the alpine foreland (Hausruck, Kobernauerwald) are naturally covered by Norway spruce. The Danube basin separates the Austrian range into the alpine and the range on the Bohemian massif with a sparsely covered link in the Strudengau between the cities of Grein and Ybbs. The eastern natural limits are indicated by a connection line starting from the cities of St. Pölten over Wiener Neustadt to Graz and then south along the eastern slope of the Koralpe. Some natural stands are also found in the mountainous region called Bucklige Welt.

Pure spruce stands are found in the *Piceetum subalpinum*. In this forest community the range varies in the Central Alps between 1400 and 2100 m and between 1100 and 1400 m in the Bohemian massif. In the northern alpine transitional zone, an elevational range of this forest community is typical at 1400-1900 m, and in the southern alpine transitional zone at 1500-2100 m. In the *Piceetum montanum*, Norway spruce is also the prime tree species. Elevational zones vary strongly from ecoregion to ecoregion (Central Alps 650-1700 m, northern transitional zone 500-1700 m, southern transitional zone 500-1800 m, Northern Limestone Alps 700-1600 m, Southern Limestone Alps 1000-1700 m).

Together with common beech and silver fir, *P. abies* is found in the *(Abieti)-Fagetum* with varying proportion between 600 and 1700 m along the northern and southern edge of the Alps and between 600 and 1300 m in the Bohemian massif. A detailed description of the natural forest communities is found in Kilian *et al.* (1994). Figure 1 shows the actual and the natural distribution of Norway spruce in Austria.

Artificial range

By the end of the Middle Ages high timber demand for ore and salt mining caused extensive clear cuts in the Limestone and Central Alps. Uncontrolled natural regeneration often turned out to be extremely difficult. If regeneration did not fail, larch and spruce were favoured and caused a reduction of the natural distribution area of broadleaved species.

The first, more extensive artificial sowing of Norway spruce was reported at the end of the 18th C in Upper Austria. Later, significant regenerations by planting were carried out in forestry. During the 19th C, extensive pure spruce forests were artificially established, especially in mountainous regions, e.g. south of the city of Steyr. Later, these spruce stands were devastated by heavy storms and bark beetles.

After World War I, Austrian forests were intensively utilized (Tschermak 1934). Restocking of these areas and smoothing out damage due to World War II, in total an afforestation area of 384 000 ha, favoured the artificial distribution of spruce. Today it is extremely difficult to differentiate between autochthonous and nonindigenous spruce stands. Even within the native range of this conifer, cutting and uncontrolled restocking have covered over the natural geographic differentiation. This especially holds true for lower and middle elevational ranges. In Austria, approximately 29% of the natural forest communities are pure coniferous forests. However, the actual proportion amounts to 69% of which pure spruce stands have a great share (45% of all coniferous stands) (Kilian 1985).

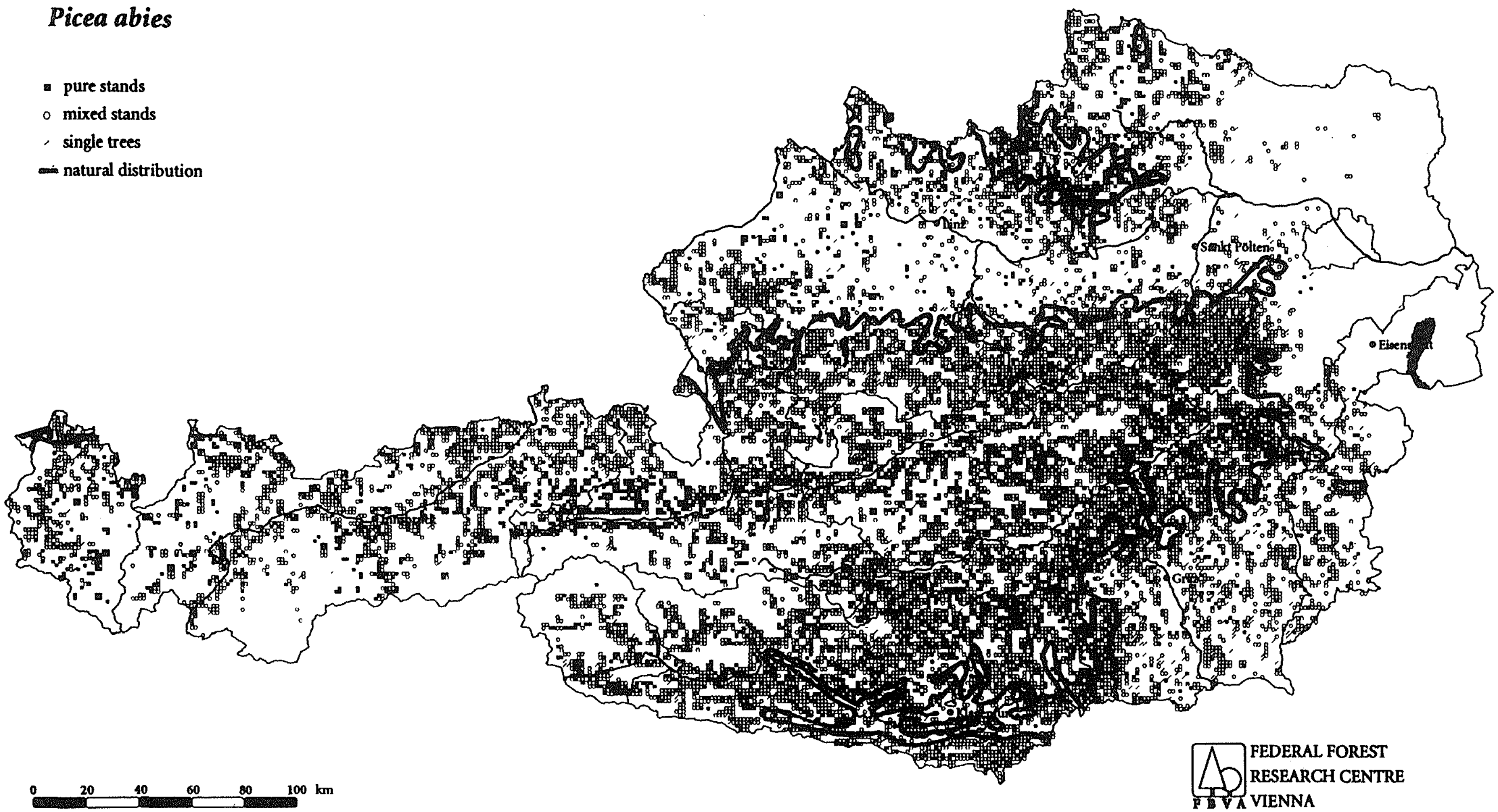

Fig. 1. Natural distribution area of Norway spruce (based on data by Mayer 1975) and the current range indicated by the Austrian Forest Inventory

Geographical genetic variation

As the Austrian spruce forests are found from lower to subalpine regions, appropriate adaptedness of spruce populations is highly desirable for practical use. By the end of the 19th C some Norway spruce field trials had been launched. One of the more comprehensive common garden experiments comprised 80 Austrian Norway spruce populations originating from different elevations and forest communities (Cieslar 1907).

Today elevational adaptedness in forest tree species is taken as a self-evident truth, but at the turn of the century, Cieslar's conclusions were striking in forest science. Later, early tests to identify spruce populations by different growth rhythms in phytotrons were developed (Holzer 1975). Like other spruce provenances originating from the alpine range, Austrian populations are not characterized by outstanding field performance in field trials established outside the natural range (e.g. Krutzsch 1974). This is in accordance with biochemical investigations in Norway spruce (Lagercrantz and Ryman 1990). Consistently, alpine populations are genetically highly adapted compared with other native populations and result in poor performance if planted outside the alpine range.

Austrian provenances originating from lower elevations of the Bohemian massif (Waldviertel, Mühlviertel) have a yield performance which is typical of provenances of the Hercynic-Carparthian region (Guenzl 1979).

Conservation

Severe forest decline in Austria made conservation efforts inevitable. In 1986, a programme for the preservation of forest genetic resources was launched at the Federal Forestry Research Centre, Vienna (Nather 1990; Litschauer 1994). Owing to Austrian peculiarities (see above), the ultimate goal was the conservation of genetic resources and in doing so restricting forestry as little as possible. For principal forest tree species, such as Norway spruce or silver fir, emphasis was laid on *in situ* conservation.

In situ *conservation of Norway spruce*

In Austria, forests aiming at the preservation of gene resources of Norway spruce are classified as (1) gene reserves and (2) small-scale conservation units. At least 5% of the wooded area is intended for *in situ* conservation. Relic populations and stands close to the timber line are over-represented in the conservation programme. As these stands are declared as conservation stands on a voluntary basis, a harmonious relationship between the Federal Research Centre and the owners is mandatory. There are no official means to declare and protect gene resources without the approval of the owner. Logging in these stands is the rule rather than the exception. However, there might be certain management restrictions. For instance, it can be agreed on that exclusively natural regeneration is permitted, cutting of undesired forest tree species will be necessary, and among other restrictions, a supplemental planting with forest reproductive material originating from the *in situ* population is mandatory if artificial regeneration is a must. The fulfilment of these agreements and the status quo of the *in situ* stands is periodically revised every 5-10 years. From an owner's perspective it is not obvious at first glance that a declaration might be advantageous for his forest enterprise. However, in declaring a resource there will inevitably be close links to silvicultural experts who contribute their expertise and a declaration may open the way to applying for federal funds.

Gene reserves

Austrian gene reserves are forests that comprise an area of at least 30 ha. As pollen contamination from outside sources is unwanted, the core area should be framed by a 300-500 m wide buffering zone. The identification and declaration of Norway spruce gene reserves have been completed in the province of Carinthia. In the provinces of

Lower Austria, Salzburg, and Tyrolia declaration has commenced (Table 1). Up to now (as of early 1995), more than 3000 ha of Norway spruce gene reserves have been declared.

Small-scale conservation units

Exceptionally, single stands (< 30 ha) were selected to preserve special populations. Approximately 1100 ha of small-scale conservation units are identified (Table 1).

Table 1. Size and number of gene reserves and small-scale conservation units of Norway spruce in Austria

Province	Forest community	Gene reserves (>30 ha)		Small-scale conservation units	
		Area (ha)	No.	Area (ha)	No.
Carinthia	*Piceetum subalpinum*	263.8	6	157.2	8
	Piceetum montanum	—	—	18.2	1
	Abietetum	189.4	5	246.1	21
	Abieti-Fagetum	762.7	11	363.5	33
	Total	1215.9	22	785.0	63
	(average size)	(55.3)		(12.5)	
Lower Austria	*Piceetum subalpinum*	130.0	1	—	—
	Abieti-Fagetum	59.1	1	75.0	5
	Total	184.1	2	75.0	5
	(average size)	(92.0)		(15.0)	
Salzburg	*Piceetum subalpinum*	345.2	6	30.3	3
	Piceetum montanum	32.8	1	64.5	3
	Abietetum	—	—	8.0	1
	Abieti-Fagetum	35.0	1	—	—
	Total	413.0	8	102.8	8
	(average size)	(51.6)		(14.7)	
Tyrolia	*Piceetum subalpinum*	46.0	1	47.0	2
	Piceetum montanum	72.0	2	6.5	1
	Abietetum	101.4	1	—	—
	Abieti-Fagetum	1041.5	3	53.4	3
	Total	1269.9	10	105.9	6
	(average size)	(126.1)		(17.7)	
Total (average size)		3073.4 (73.2)	42	1068.7 (13.0)	82

Ex situ *conservation in Norway spruce*

Seed bank

In Austria, *ex situ* measures to preserve gene resources of Norway spruce have mainly been restricted to the storage of seeds originating from different ecoregions. Seed storage is a static conservation means and does not allow a change in the genetic composition of the resource in the course of environmental changes. This means does not significantly contribute to the ultimate goal to preserve the genetic adaptability in Norway spruce. Therefore, seed storage has to be assessed as a back-up measure. However, if this measure is a supplemental part of the conservation programme, for instance to bridge periods of lacking or insufficient seed crops, it is an important means. As the conservation of high elevated spruce stands (*Piceetum subalpinum*) requires special attention, those seed sources are especially maintained (Table 2).

Table 2. Seed quantity of Austrian Norway spruce populations

Ecoregion	Elevation (m)	Seed (kg)	Subtotal
Central Alps	< 900	11.0	
	> 900-1400	54.0	
	> 1400	66.0	131.0
Northern Alpine Transitional Zone	400-900	15.9	
	900-1300	30.5	
	> 1300	5.0	51.0
Southern Alpine Transitional Zone	400-900	18.0	
	> 900-1300	19.0	
	> 1300	5.0	54.0
Northwestern Limestone Alps	400-900	16.0	
	> 900-1300	15.0	31.0
Alpine Foreland	300-600	3.0	3.0
Bohemian Massif	300-600	6.0	
	> 600-900	21.0	
	> 900	8.0	35.0
Total		318.0	

Conservation orchards

Up to now, no seedling or clonal conservation orchards have been established. However, two clonal Norway spruce orchards are in preparation. One orchard will represent populations of the ecoregion 'Northern Limestone Alps' (elevational range: 1350-1750 m); 107 clones have been propagated. Norway spruce of the subalpine region of Central Alps (elevational range: 1680-2050 m) will be represented by a second conservation orchards, for which 99 clones are selected. Besides the preservation of high-elevation Norway spruce populations, the seeds originating from these orchards are intended for additional seed supply for high-elevation afforestation (avalanche and torrent control). However, it must be considered that progenies of high-altitude parents do not completely retain the annual growth rhythm of their parents when parental trees have been grown at a low-altitude site (Johnsen 1989; Skröppa 1994).

Production forests and selected stands as potential sources

An important but indirect means to preserve the adaptability of Norway spruce is the fact that meanwhile many spruce forests are regenerated naturally. For a long time restocking was predominantly performed after small clear-cuts by artificial planting. Today, approximately 53% of the final cut area is naturally regenerated. Since natural regeneration offers many genetic advantages over artificial reforestation (Geburek and Thurner 1993; Müller 1993) naturally regenerated forests are a prime choice for genetic resources. Even without identification and declaration, many naturally regenerated forests are potentially valuable gene resources.

According to the Austrian Forestry Act of 1975, spruce seeds have to be harvested in selected stands. In 1995, an area of 33 038 ha of spruce stands has been selected and declared as seed stands. It is clearly mentioned that these stands have been selected under criteria to improve forestry yield. Therefore, it is self-evident that the selection criteria to identify gene resources are not necessarily identical with those applicable to genetic conservation.

Relevant research activities and future conservation strategies

To get a better insight into the geographical genetic variation of Norway spruce, biochemical investigations have been started. Up to now, 22 presumably autochthonous populations (100 trees per individual population) have been sampled and genetically analyzed in part. Preliminary results of the federal genetic inventory indicate that the Austrian Norway spruce populations exhibit moderate genetic variation (for instance, mean of observed heterozygosity Ho = 0.15) with very low among-population differentiation (FST = 0.01) (for more details see Geburek 1994). This genetic inventory lays emphasis on native populations; however, nonautochthonous spruce stands also will be studied in the coming years.

In the long term, declaration of gene resources should be based on ecological criteria, biochemical variation (isozymes, molecular markers), and the results of stress experiments. Then a meaningful identification of populations of high adaptability could be performed, as already performed by the USDA-Forest Service (Miller and Westfall 1992).

Public awareness of the necessity of forest genetic resources

It is extremely difficult to assess the public awareness of the necessity of forest genetic resources. In Austria, no opinion polls have been held on this issue. If the recent number of reports in public media (newspaper, TV, radio) is considered to indicate the public awareness of genetic diversity in forests, Austria is probably above the European average. This might be connected with the fact that in an alpine country the protection of forests has always been important because of erosion, torrents, avalanches, etc. Most of the forest owners are aware of the urgent need to conserve gene resources and contribute on a voluntary basis to the federal conservation programme. Also indirectly, the public awareness of the importance of genetic diversity can be concluded from the following:

In the draft bill of the Austrian Forest Reproductive Material Act, besides the standard EU-categories (selected and tested reproductive material), the hallmark 'high genetic diversity' is introduced.

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Conservation of genetic resources of Norway spruce (*Picea abies*) in Switzerland

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Introduction

In 1988, a Swiss joint working group initiated a programme which suggested the *in situ* conservation of genetic variation of significant forest tree species (Anonymous 1988). Within this programme, the study of genetic structures was considered to provide necessary criteria for the declaration of genetic resources. The knowledge of the geographical differentiation of genetic structures among populations within the natural range was considered to help in the determination of the minimum number and the spatial distribution of the future gene reserves.

Since a forest genetic working group had been established at the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) in 1991, a monitoring programme on genetic structures of tree populations could be performed. The main focus of the first period was the characterization and quantification of levels of genetic variation within and between high elevated Norway spruce population stands in Switzerland. The present paper will briefly survey material and methods and include some preliminary results.

Material and methods

Selection of stands and trees

Within the natural range of Norway spruce, 20 indigenous populations were chosen from high-elevation stands located in the Swiss Alps and the Jura region. For geographical distribution of the majority of stands see Müller-Starck (1994). For each stand, 100 adult trees were selected on an area of 10 ha.

Genotyping and genetic parameters

Using bud tissue, the genotype of each of 2000 trees was determined by isoenzyme gene markers at 18 polymorphic gene loci (see Müller-Starck 1995).

For each population and each gene locus, allelic and genotypic structures were compiled. To compare the genetic structures, genetic parameters were calculated using the GSED programme: heterozygosity, genetic multiplicity, diversity, differentiation and genetic distance (for general concept of measuring genetic variation see Müller-Starck and Gregorius 1986; Hattemer *et al.* 1993; Müller-Starck 1993; Gillet 1994).

Results and discussion

A detailed description of all results of the investigation will be given separately (Müller-Starck *et al.*, in preparation).

In Table 1 the given values per population were calculated as hypothetical gametic multilocus diversities. This measure is equal to the number of genetically different gametic types which can be produced by each population at the level of the studied number of gene loci. This parameter has been accepted as an essential measure to characterize the ability of forest tree populations to adapt to changing enviromental conditions (see Gregorius *et al.* 1986). It is used to select populations for the conservation of genetic resources because the ability to adapt to changing enviromental conditions is expected to increase with the level of this parameter. This level depends on the diversity of alleles at each of the gene loci. Assuming equal allelic multiplicity, large diversities show that the alleles are more equally distributed than in the case of low values. A high level of hypothetical gametic multilocus diversity will reduce the risk of losses of genetic variation under different enviromental impacts.

Table 1. Hypothetical gametic multilocus diversities of 20 Norway spruce populations

No.	Stand designation	Diversity*	No.	Stand designation	Diversity*
1	Le Brassus	1592.6	11	Overwald	691.3
2	Chaux du Milieu	394.4	12	Faido	406.5
3	Orsières	943.6	13	Bödmeren	454.0
4	Gstaad	735.4	14	Scatlè	1000.4
5	Adelboden	385.9	15	San Bernadino	470.4
6	Saxeten	329.1	16	Bondo	967.5
7	Grindelwald	647.1	17	Rona	597.9
8	Aletschwald	659.0	18	Conters	346.2
9	Simplon	427.1	19	Poschiavo	571.8
10	Engstlenalp	494.1	20	Ardez	568.1

* Hypothetical gametic multilocus diversity.

Table 1 indicates that population 1 (Le Brassus) can be considered as one of the most suitable populations for the *in situ* conservation of genetic resources. Compared with the mean of the hypothetical gametic multilocus diversities of all other populations, its level is more than double the value. This is one example for the declaration of a population as a gene reserve area of Norway spruce.

Generally, the following trend is indicated: in contrast to silver fir (*Abies alba* Mill.), Norway spruce reveals smaller interpopulational but larger intrapopulational genetic variation (Hussendörfer and Müller-Starck 1994; Hussendörfer 1995). For the present, a larger number of gene reserve areas appears necessary for silver fir than for Norway spruce.

Conclusion

The analysis of the genetic structures and the quantification of the level of genetic variation revealed significant deviations among populations of Norway spruce. Genetic parameters provide essential criteria for the selection of populations to be suitable for the declaration of gene reserve areas. The hypothetical gametic multilocus diversity is regarded as an important parameter for evaluation. Other genetic parameters (e.g. occurrence of geographically unique alleles) will be taken into account in order to facilitate the declaration and conservation of genetic resources.

Acknowledgements

The technical assistance of Elaine Escher is greatly appreciated. The study was supported financially by the Federal Office of Environment, Forests and Landscape (FOEFL), Bern, Switzerland.

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Situation of the conservation of Norway spruce in Belgium

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Summary
Norway spruce stands in Belgium cover around 200 000 ha, about one-third of the total forest area of Belgium. Production averages 12 m^3 ha^{-1} yr^{-1}, making it the most valuable and profitable forest tree species in Belgium. The conservation of Norway spruce as a species is in no way endangered but some concern can appear at the level of populations. As a matter of fact, some outstanding ones have already disappeared. An important but indirect genetic conservation has taken place in breeding programmes. More than 20 provenance experiments (20 ha, 600 provenances), 29 seed stands (230 ha), 1224 plus trees or clones, 2 seed orchards (10.2 ha, 189 clones), 20 progeny and clone tests (25 ha, 300 genetic elements), 4 clone parks (878 clones) and 1 scientific seed collection (295 scientific seedlots, 21.4 kg) are maintained *in situ* or *ex situ*. However, no consistent and comprehensive active long-term management of forest genetic resources has yet been implemented. To develop such long-term management of forest genetic resources, it will be necessary to construct and manage databases and fill them with updated genetic resources, to implement trace keeping in forest management of the provenance or variety used in new plantations, and to develop a management programme using accepted principles and apply them at the level of practical implementation.

Introduction
The purpose of this paper is to present a short account of the present situation of the conservation of Norway spruce (*Picea abies*) in Belgium.

It has to be recalled that Norway spruce is not indigenous in Belgium and that it was introduced around the middle of the last century from central Europe (Austria, Germany and possibly Poland). The precise origin of every stand is, however, almost never known.

Norway spruce is planted almost exclusively in Wallonia, the southern and most forested region of Belgium (80% of total forest area), mainly in the Belgian Ardennes. This last subregion is a 'Region of Provenance' in the sense of OECD/EEC regulations. It is characterized by an elevation ranging generally from 300 to 700 m (mean around 450 m), a rather harsh climate (mean temp. ~7°C; annual rainfall from 1000 to 1400 mm) and acid soils (pH ~4.5).

The total area of Norway spruce stands amounts to around 200 000 ha, about one-third of the total forest area of Belgium (~620 000 ha).

The mean annual increment amounts in average to 12 m^3 ha^{-1} yr^{-1} with extremes lying from under 9 m^3 ha^{-1} yr^{-1} on the high boggy plateaux up to around 20 m^3 ha^{-1} yr^{-1} on the best sites.

From the economic point of view, Norway spruce is the most profitable forest tree species because it is easy to plant in the open and to manage in evenly aged stands. Moreover, all products find easily a profitable output (small roundwoods—poles, excellent paper; medium woods—poles; large woods—valuable timber for sawmills and possibly veneer).

It is criticized by 'Ecologists' mainly because it is not indigenous and it forms dark homogeneous stands that may degrade the soil. This last point has never been proved in spite of many studies; the 'darkness' and homogeneity of the stands are being solved by heavier thinnings than in the past.

Present situation of conservation

So far, no pure conservation has been practised. Genetic conservation has only been done in the frame of the present breeding programme for which it is a sort of by-product.

Therefore, the classical scheme of presentation used in forest tree breeding will be followed hereafter.

Provenance experiments

Provenance experiments are indirectly a means to conserve many provenances outside of their range.

In a number of cases, the original stands from which seed was collected have disappeared or their trace has been lost. When these provenances are outstanding, a way to try to restore the original population is to collect material from provenance experiments. For example, this has been done for the Polish provenance Zwierzyniec Lub., the original stand of which having been cut down, cuttings and grafts were sent from Belgium to Polish colleagues.

For Norway spruce in Belgium, there are more than 20 provenance experiments covering more than 20 ha (Table 1) and comparing more than 600 provenances from the whole European range (a certain amount of these provenances is common to different experiments). The first experiment was planted in 1931.

Among them are the three International Provenance Experiments in Norway spruce (Promoters: First: Schmidt, 1938; Second: Langlet-Krutzsch, 1964; Third: Tyszkiewicz-Kociecki, 1972). Some of them have been assessed in detail in Belgium (n°1: Delevoy 1949; Gathy 1960; Nanson 1964c, 1965a; Verstraete 1993).

The transformation of some of these old provenance tests into Provenance Seedling Seed Orchards (Nanson 1972) through severe selective thinnings, leaving only the best trees of the best adapted provenances, is contemplated. This could be envisaged for replicates of experiment n°2 that have a one-tree plot structure.

Table 1. Present situation of the genetic conservation of Norway spruce in Belgium*

Kind of population or individual	Number	Number of genetic elements[†]	Area (ha)
1. Provenance experiments	20	600	20.0
2. Seed stands	29	29	230.0
3. Plus trees and clones		1224	
Mature		198	
Juvenile		148	
Infantile		878	
4. Seed orchards	2	189	10.2
5. Progeny and clone tests	20	300	25.0
6. Clone parks	4	878	0.3
7. Seed bank	1	295	214.0[‡]
Total	76	3515	504.0

* Minimum numbers.

[†] A genetic element is the genetic unit considered, e.g. a provenance, a progeny, a clone, a clonal mixture, etc. Some elements can be common to different items.

[‡] N.B.- 21.4 kg x 10 ha/kg = 214 ha.

Seed stands

According to definitions (e.g, OECD/EEC regulations), a 'seed stand' is a stand that is phenotypically superior for most forest characteristics and that has been officially selected and included in an official Register of Basic Materials. In Belgium, Galoux and Reginster (1953) first began this selection around 1950; Gathy continued up to around 1960 and Nanson after that.

At present in Belgium, 29 seed stands of Norway spruce covering a total area of 230 ha are officially registered. So far, these seed stands are not really protected against normal felling (around 60-90 years in usual practice).

This should be envisaged in the future. Difficulties are, however, present due to the kind of ownership (private seed stands are almost outside any measure) and to the limited longevity of Norway spruce in Belgium (practically not more than 100-120 years).

Active *ex situ* conservation in 'conservation plantations' is then a good opportunity but needs some supplemental financial means and human resources as well as a long-term follow-up organization.

Individual selection and conservation

Plus trees

So far, 198 plus trees ('mature clones': phenotypically selected at forest stage after sexual maturity: more than 30 years), 148 'juvenile clones' (selected in early forest stage: between 5 and 30 years) and 878 'infantile clones' (selected in nursery), so a total of 1224 clones, have been selected.

Mature and juvenile clones are conserved *in situ* but not over the normal forest exploitation term (60-90 years). The best of them are conserved *ex situ* in seed orchards (see below).

Infantile clones are conserved in four propagation clone parks, either of ortets, or of ramets, or both. These propagation clone parks have, however, a limited lifespan (10-15 years) and should be then re-propagated.

Seed orchards

Two grafted clonal seed orchards of respectively 1.50 ha (in Halle) and 8.7 ha (in Fenffe) are settled; they now contain respectively 54 and 135 clones, so 189 clones in total. The last one is an 'evolving seed orchard' that, besides its functions of seed production and a source of 'clonal mixtures'[1], is also a conservatory of one of the best clones (Nanson 1986; Nanson *et al.* 1992).

The lifespan of such seed orchards is expected to be between 50 and 100 years. The conservation of these seed orchards and thus of component clones is dependent on their performances and their economic justification.

Progeny and clone tests

So far, at least 20 comparative experiments are planted; they are composed mainly of genetic materials from the Ardenne Region of Provenance. They contain at least 300 genetic elements (progenies, clones, standards) and cover at least 25 ha in total. This represents a considerable source of genetic diversity of high value.

The lifespan of these tests is again some 60-90 years. Their further conservation depends on the general breeding strategy but has not yet been truly envisaged from the pure conservation standpoint.

A precise updated inventory of this resource would be a first step.

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[1] 'Clonal mixtures' is a new wording used in the new OECD Scheme for Certification of reproductive materials. It is equivalent to the term 'Multiclonal Varieties' previously used.

Clone parks

Classical clone parks: Classical clone parks are pure collections of clones represented by 2 or 3 ramets of every clone planted at rather large spacing (4 x 4 m at least).

In Belgium, there are no such parks because they are too expensive to create and maintain. They are replaced partly by evolving seed orchards which merge the functions of clone park and seed production on the same site. Note that these evolving seed orchards are conserving only the best clones. The number of these clones is a compromise between the importance of the genetic gains requested and the need of genetic diversity within the synthetic variety produced by the evolving seed orchard.

Propagation clone parks: Propagation clone parks are made of ortets or ramets of infantile clones, with the main purpose of producing cuttings en masse for the vegetative propagation of clonal mixtures. At present, two propagation clone parks of ortets and two propagation clone parks of ramets are planted and hedged to produce cuttings: 878 infantile clones are thus conserved. With a present spacing of 1 x 1 m (a bit too low), they cover about 0.30 ha.

The lifespan of such propagation clone parks is expected not to exceed some 15 years. Therefore, a conservation policy and actions will be soon necessary. However, this needs time, money and labour.

Seed banks

In our Research Station, 295 scientific seed lots (provenances, progenies) with a total weight of 21.4 kg are stored in refrigerators (at +2 or –17°C). In our conditions, 1 kg of seed of Norway spruce can create around 10 to 15 ha of plantation at the standard spacing of 2 x 2 m. Therefore, this seed amount represents at least 214 ha of plantations.

Pollen banks

No pollen has yet been stored.

In vitro *conservation*

Because of the present failure of the *in vitro* propagation of Norway spruce, no such conservation is envisaged.

Usual forest plantations

Usual forest plantations can be a source of genetic diversity within the species because every plantation can be from a different provenance (population). In Wallonia, the Forest Service is using in principle 'Recommendable Provenances' from Belgium and from some other countries (Nanson 1978). This should bring a genetic gain in total production of around 20% compared with a random use of provenances.

So far, however, the identity of the provenance has not been frequently registered in the Forest Management Plan. It is hoped that this measure will be generalized by the Wallonian Forest Service and it should be the rule within a few years (see **Trace keeping in forest management**, below).

After inputting this information to an adequate database, these data can be the basis for long-term management of Wallonian genetic resources, making the balance between genetic gains and genetic diversity.

Natural regeneration

In the Belgian Ardennes, many Norway spruce stands can be regenerated by natural seeding. However, foresters are finding it simpler to use plantations.

Natural regeneration can be worthwhile when the mother trees have a good phenotype and a genetic base sufficiently large to prevent further inbreeding. For more detailed aspects of natural regeneration from the genetic standpoint, see Nanson *et al.* (1991).

Natural regeneration can be very useful to conserve exceptional seed stands, for example. However, conservation plantations with the reproductive material collected in these seed stands are another more flexible opportunity.

Threats and awareness of genetic conservation

In Belgium, Norway spruce as a forest species is not threatened[2] thanks to its profitability. However, the trace and identity of many very good seed stands (e.g., OECD/EEC blue labels or equivalent) have been lost because of the lack of active conservation measures. In fact, much seed has been collected on these 'elite seed stands' and later commercialized and this has led to numerous plantations. But we do not know where these plantations are situated. From the conservation point of view it is as if they were lost!

In this way, some very good populations have been lost after the severe windfalls of January 1990!

The public and even foresters are not aware of this situation.

Forest Geneticists are a bit concerned but, up to now, their means were so restricted that they were directed almost exclusively toward Forest Tree Breeding in the short term.

Let us hope that the evolution of ideas on gene conservation will bring them some additional means in order to preserve the future!

Prospects for further conservation

This matter needs further consideration, deep reflection, extended exchange of ideas and a deeper literature survey (e.g., Arbez *et al.* 1987; Kleinschmit *et al.* 1989; Martin 1986; Namkoong *et al.* 1980; Nanson 1993, 1994; Palmberg 1987; Steinmetz 1991).

However, it seems that the following tentative guidelines could be open to discussion.

Construction and management of databases

One of the first steps to consider is surely to do a survey and an updating of present known genetic resources and to include them in an adequate database.

In this respect it should be noted that the embryo of such a database does exist. Through the FOREST EEC Research Project, Belgium, France and Germany agreed on a European common database structure for seed stands and conservation plantations with the example of Douglas-fir (Riboux 1993; Servais 1993; Servais and Riboux 1993). This database, with a decentralized structure and needing only personal computers, was tested and partly fulfilled: it is thus operational and maintained at our Station de Recherches Forestières in Gembloux. It can be extended easily to Norway spruce.

Projects are to extend this database to other objects such as plus trees, seed orchards, clone parks, family mixtures, clonal mixtures, seed and pollen collections, etc. and to other species.

Trace keeping in forest management

As mentioned earlier, the provenance (or variety) of every usual plantation in public forests will be identified and reported in the Forest Management Plan.

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[2] However, the so-called 'acid rains', recent furious storms possibly in relation to a global warming and leading to larger windfalls and a certain rejection of Norway spruce by 'Ecologists', could represent a certain threat and contribute to a diminution of the total area of this species.

Three levels of reliability are to be distinguished in ascending order:

1. identification through the standard EEC certificate of provenance for commercial plantations made with plants provided by private nurseries,
2. identification through a State certificate of provenance for plantations made with plants provided by State nurseries,
3. identification through the direct control of the Forest Research Station.

Long-term management of forest genetic resources

Once reported in the Forest Management Plan, with their own level of reliability, these data can be transferred to the conservation database, at least for the most outstanding or typical provenances. There they could join data coming from breeding programmes (plus trees, seed orchards, etc.). This will be the raw material for the development of long-range management of forest genetic resources.

This last should optimize the balance between genetic diversity against genetic gains in long-term plantation programmes. For example, a sufficient amount of diverse outstanding provenances and varieties for productivity, quality, resistance-adaptation, could be favoured without excluding special provenances or varieties to maintain a sufficient genetic diversity between stands.

Of course, this management should ensure the long-term preservation of the chosen materials through adequate special actions programmed over a century at least. For example, present seed stands and seed orchards should be conserved through several conservation plantations (1 to 4 ha each) perfectly registered, controlled (thinnings, etc.) and renewed in due time.

In Wallonia, the Forest Tree Seed Centre named 'Comptoir Wallon des Matériels Forestiers de Reproduction' will be soon established in the centre of the region, in Marche. Besides its main mission of providing Walloon nurseries with the best genetic materials, it can also play a major role by collecting adequately such basic materials and distributing them to state nurseries for conservation.

All these actions should be set up with definition of priorities in a general Long-term Management of Forest Genetic Resources programme under the control of the Forest Service and prepared by forest tree breeders with the collaboration of relevant tree seed centres.

Conclusion

In Belgium, Norway spruce is one of the most valuable and profitable forest tree species. The conservation of Norway spruce as a species is in no way endangered but some concern can appear at the level of populations. As a matter of fact, some outstanding ones have already disappeared.

A very important but indirect genetic conservation has taken place in breeding programmes. Many provenance experiments, seed stands, plus trees, seed orchards, progeny and clone tests, clone parks, scientific seed collections are maintained *in situ* or *ex situ*. But because of lack of means that, of necessity, are allocated by priority to genetic improvement, no consistent and comprehensive active long-term management of forest genetic resources has been implemented yet.

In order to develop such long-term management, it seems that construction and management of databases and filling them with updated genetic resources represents a prerequisite. Trace keeping in forest management of the provenance or variety used in plantations is a second one. Then should follow the development of a programme for long-term management of forest genetic resources, using accepted principles and at the level of practical implementation. At this stage, long-term management of forest genetic resources and long-term strategy of forest tree breeding should probably merge into a unified philosophy.

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Conservation of Norway spruce genetic resources in Slovakia

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Introduction

The forest land in Slovakia is about 1.94 million hectares, out of which 90% belongs to the Carpathians. In the Polish Carpathians, the forests cover about 480 000 ha, in the Ukrainian Carpathians about 1 500 000 ha and approximately 5 500 000 ha belong to the Carpathians mountain range in Romania. This means that the Carpathian forests cover about 9 million hectares in total.

The present distribution of trees in European forests has been influenced by several factors:

— the natural migration of tree species in the post-glacial period (different refugia and geographical conditions – mountain ranges – influence migration),
— long-lasting human activity before the period of modern forestry,
— a short period of modern forestry (in Europe about 100–200 years),
— the influence of human activities and human-caused processes during the period of industrialization.

Occurrence, origin and distribution of Norway spruce in Slovakia

The forest stand area of Slovakia covers in total 1 904 339 ha (Table 1). The proportion of Norway spruce is 27.5% and that of conifers is 43.1%. The most common broadleaved species in Slovakian forests (European beech) covers in total 29.8%. The present proportion of Norway spruce is higher than the original one. It is estimated (Hančinský 1972) that originally Norway spruce covered about 10% and during the last century it replaced the silver fir (e.g. 15% in 1920 and 5% at present).

Natural distribution of the Norway spruce forests in Slovakia is in altitudes between 600 m and the upper tree limit, which is usually in the altitudes of 1400-1500 m. The upper tree limit is usually created by the mixed Norway spruce and larch stands (e.g. the southern slopes of the High Tatras or Norway spruce with the admixture of rowan or stone pine). In all mountain ranges the Norway spruce creates the upper tree limit except in the Eastern Beskydes where in the Carpathian disjunction the Norway spruce is missing and the beech reaches the highest altitudes.

Indigenous occurrence of the Norway spruce populations is in all mountain ranges of central and northern Slovakia. It is missing in the Little Carpathians and Štiavnické vrchy and in eastern Slovakia. In eastern Slovakia the Norway spruce's natural range is disrupted by the Carpathian disjunction, i.e. from Košice toward the Ukrainian border and further into Carpatho–Ukraine a 200-km zone is without spruce. From the northern side of the Carpathians, the limit of natural occurrence of Norway spruce reaches Tarnawa, i.e. more or less the border of Slovakia.

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

- Oak forest vegetation zone
- Oak-beech forest vegetation zone
- Beech-oak forest vegetation zone
- Beech forest vegetation zone

- Beech-fir forest vegetation zone
- Beech-fir-spruce forest vegetation zone
- Spruce forest vegetation zone
- Mountain pine forest vegetation zone.

The principal characteristics of forest vegetation levels are as follows (Table 2):

- increasing intensity of solar radiation
- decreasing temperature (for each 100 m, 0.54°C)
- increasing number of frost days
- increasing difference between air and soil temperatures
- decreasing vegetation period
- increasing precipitation total (but only up to a certain altitude over the upper vegetation limit)
- increasing proportion of snow precipitation
- increasing number of foggy days
- increasing evaporation
- rapidly decreasing air humidity with temperature decrease.

Table 1. Norway spruce area in Slovakia

	Norway spruce	Conifers	Total
Actual area (ha)	523 692 (27.5%)	820 770 (43.1%)	1 904 339
Growing stock (1000 m^3)	126 391 (34.5%)	183 068 (50.0%)	365 946
Area by age classes (ha)			
1	53 446		
2	45 981		
3	34 724		
4	33 711		
5	53 120		
6	53 832		
7	53 802		
8	64 956		
9	50 077		
10	27 871		
11	17 820		
12	10 874		
13	7 858		
14	5 761		
15+	9 839		
Annual allowable cut (1000 m^3)			
Final cutting	1 118	1 742	3 724
Thinnings	366	459	1 087
Total	1 484	2 201	4 811
Share of Norway spruce composition (%)			
Natural	7.7	23.6	
1950	27.3	42.8	
Actual	27.5	43.1	
Optimum	23.6		

Table 2. Principal characteristics of forest vegetation zones

Vegetation zone	Altitude (m a.s.l.)	Mean annual temp. (°C)	Annual precip. (mm)	Vegetation period (days)
Oak	< 350	> 8.0	< 600	> 165
Oak-beech	350-400	7.5-8.0	600-650	160-165
Beech-oak	400-550	6.5-7.5	650-700	150-160
Beech	550-600	6.0-6.5	700-800	140-150
Fir-beech	600-700	5.5-6.0	800-900	130-140
Spruce-beech	700-900	4.5-5.5	900-1050	115-130
Beech-spruce	900-1050	4.0-4.5	1050-1200	100-115
Spruce	1050-1350	2.5-4.0	1200-1500	60-100
Mountain pine	> 1350	< 2.5	> 1500	< 60

The ecological characteristics of the forest vegetation zones are given in the paper of Vančura (this volume). The natural range of Norway spruce covers the following forest vegetation zones: beech–fir, beech–fir–spruce and spruce forest vegetation zone. In the first two forest vegetation zones, the occurrence of mixed forests is prevalent (broadleaves with spruce admixture or spruce with silver fir admixture), while in the last forest vegetation zone the pure spruce forests prevail.

In Table 3 is shown the proportion of the individual stand formation of spruce forests and mixed forests with spruce: spruce-silver fir–beech and silver fir-beech according to individual forest vegetation belts. From this table it is clear that the proportion of the spruce forests within the beech–fir, beech–fir–spruce and spruce forest vegetation belts could be considered as more or less natural. The occurrence of Norway spruce in the 1st to 4th vegetation belts is not natural and partially also that within the beech–fir and beech–fir–spruce forest vegetation belts could be considered as the replacements of silver fir in the mixed stands.

Table 3. Proportion (%) of individual forest formations (types) in forest vegetation belts

Forest vegetation belt	Spruce	Spruce-fir-beech	Beech-fir
1	0.2	0	0
2	0.8	0.6	0.3
3	2.9	7.7	2.4
4	10.6	26.4	12.4
5	33.5	24.4	29
6	55.9	11.2	23.6
7	89.5	1.9	6.8
8	1.5	0	0.1
Total (ha)	308 562	250 609	210 628

Conservation aims and current state of conservation activities

In the forest practices of Slovakia there are several methods of genepool conservation *in situ* and *ex situ*.

In situ

1. National parks and large–scale protected areas
2. Gene reserves (bases)
3. Approved stands for seed procurement (A and B category).

Ex situ

1. Reproduction plantations *ex situ*
2. Genebanks (seed)
3. Clonal archives
4. Seed orchards
5. Experimental trials.

The first regulation aimed at the seed procurement only from approved stands originated in the territory of Slovakia in 1938 and in the Czech Republic in 1939. In the sense of this law, the seed of conifers (Norway spruce, silver fir, Scots pine and European larch) could be procured only in approved forest stands of A and B category and seed transfer was allowed only within silvicultural zones. The silvicultural zones were defined according to their geographical distribution and the length of the vegetation period:

— subalpine regions with the vegetation period shorter than 100 days,
— mountains with cooler climate with the vegetation period 100-129 days,
— mountains with mild climate and vegetation period 130-165 days,
— lowlands and hills with plain climate and vegetation period longer than 165 days.

Subsequently, this regulation was renewed in 1965 and since 1985 and 1988 there are new regulations valid for the Slovak and Czech Republics. It has to be noted that these two different regulations for both republics of former Czechoslovakia were necessary due to different ecological conditions and history of the forest stands.

Following these regulations there are two different categories of approved stands, A and B, and a new term was introduced for the territory of Slovakia—'seed zone'. The seed zone is defined as the zone with similar conditions within which seed transfer is allowed. Exceptionally, seed transfer is allowed between individual zones (as stated in the regulation).

For Norway spruce there are seven seed zones in Slovakia (Fig. 1), five of which are within the natural range and two are outside the natural range. Vertical transfer of seed is allowed for altitudes up to 1200 ± 200 m and over 1200 ± 100 m in the Tatra seed zone and in other zones over 1200 ± 150 m from the altitude of forest stands.

It has to be noted that there are two seed zones into which it is prohibited to import seed: the Tatra seed zone (Tatra National Park) and the Beskydy-Orava seed zone which is adjacent to the Polish Beskydes (Istebna and Rycerka) and also to the Moravian Beskydes.

At present there are in total 6075.25 ha of approved Norway spruce stands of the A category and 16 328.81 ha of stands of the B category, selected 345 phenotypically superior plus trees (in total 3171) and established 4.50 ha of clonal seed orchards and 2 ha of seedling seed orchard (Stará Lesná) (in total 202.82 ha of seed orchards of all species). The highest proportion of the Norway spruce approved stands is in Northern Slovakia (2958 ha of A category and 7907 ha of B category) and in Central Slovakia (1668 ha or 2887, respectively), while in the Tatra National Park alone there are 722 ha of the approved stands of the A category and 1554 ha of stands of the B category.

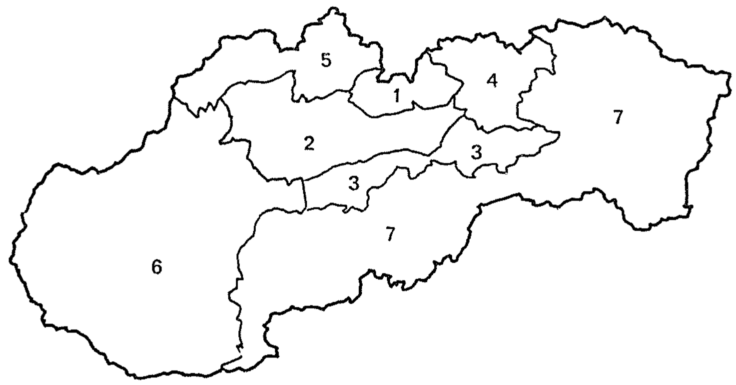

Fig. 1. Natural Norway spruce zones of the Slovak Republic

The gene reserves (bases) are, in the forestry practice of Slovakia, a new item aimed at genepool conservation *in situ*. The gene bases are in general units of the gene conservation practices established in the regions of the most valuable genepool and the size is usually several hundreds of hectares (200-2000 ha). In comparison, the size of approved stands is equal to the size of a stand as a forest management unit, which is usually a maximum of 10-15 ha. The gene bases usually include the forest stands of different age classes with the aim to maintain the dynamic aspect of genepool conservation. From the forest management point of view, the gene bases are forest stands with a special management regime, in which natural regeneration is the principal method of regeneration allowed (the artificial regeneration with plants originating from the local seed sources is allowed). At present 44 gene bases are established in Slovakia (in total 12 673 ha) of which 3154.46 ha are declared to conserve the genepool of Norway spruce. From those seed orchards should be mentioned those which are aimed at the gene conservation of Beskydy spruce (region adjacent to Polish Beskydes), those in the High Tatras and in the Low Tatras.

Seed stands are special units established mainly for genepool conservation *in situ* or *ex situ* for the purposes of conservation and future procurement of seed. In general the seed stands are progenies (from natural regeneration or artificial regeneration as open-pollinated progenies) of the approved stands of A category.

In total 127 seed stands are established in Slovakia (not identical with seed stand according to the OECD/EEC regulations) with the area of 635.5 ha and of this number 37 seed stands of 196.5 ha are established for Norway spruce. Forty percent of Norway spruce seed stands are established *ex situ* and 60% *in situ*. From those established *in situ* 40% again originate from natural regeneration and the remaining 60% originate from artificial regeneration.

In Slovakia there are in total seven provenance trials (12 to 49 provenances) established from the material of the IUFRO 1964/68 Norway spruce Inventory Provenance Experiment (Holubčík 1980) and four provenance trials being part of the IUFRO 1972 provenance experiment with Polish Norway spruce provenances. There exist only single-progeny tests with 42 open-pollinated progenies of a single stand from the Tatra National Park (considered also as a seedling seed orchard).

In the seed bank established in Liptovský Hrádok there are in total 75 seedlots with Norway spruce (363.5 kg). They are stored with the aim to cover the seed needs in the period of lower crops as well as for scientific and genepool conservation purposes. In Slovakia all seed used in forestry practice has to originate from approved stands only. Each seedlot has a 10-digit code which should be maintained also in the nurseries and planting stock. In the Semenoles, Liptovský Hrádok, there are at present 332 units (8996.65 kg) of Norway spruce seed from approved stands. At present, there are no pollen and tissue banks established in Slovakia.

There are in Slovakia in total 292 state nature reserves and 74 protected sites with the total area of 79 415 ha. The proportion of Norway spruce in the state nature reserves is 37.74% and in protected sites 20.64%; almost 48% of all state nature reserves are found in the spruce-fir-beech and spruce forest vegetation zone (Vološčuk 1993). In contrast to many neighbouring countries there are in Slovakia several remnants of spruce or mixed virgin forests with spruce occurrence. The best known of them are Pod Chlebom (222.77 ha) and Rozsutec (650 ha) in the Little Fatra, Čierny Kameň (34.40 ha) in the Great Fatra, Babia Hora (530.33 ha) and Pilsko (580 ha) in the West Beskydes and Kotlov Žľab (46.94 ha), and Podbanské (1800 ha) in the High Tatras (Korpeľ 1995).

Threats to Norway spruce genetic resources

Several factors affect negatively the genetic resources of Norway spruce in Slovakia: air pollution, game grazing, abiotic damages (e.g. drought) and subsequent biotic damages (e.g. bark beetle), and improper forest management practices not supporting natural regeneration.

High-elevation Norway spruce populations are usually damaged by air pollution. Most affected are the populations in the Beskydes and the High Tatras on the western to northern slopes facing Ostrava and Katowice industrial regions from which the long–distance transported pollutants are the main damage factor. Also other air pollution sources are negatively influencing the health state of Norway spruce populations in the Spiš region and the Low Tatras. Along with the decreased vitality and damage of the assimilatory organs the air pollution affects the regeneration processes and decreases flowering intensity and seed production.

Browsing by excess populations of larger ungulates (red deer) is the main factor negatively influencing natural regeneration and the healthy state of middle-aged Norway spruce stands. The worst situation is when the combination of several damage factors (air pollution, insects, deer) occurs.

The negative impact of forest management practices (higher proportion of the artificial regeneration, improper seed transfer, simplification of forest management practices (e.g. replacement of mixed stands by one–species spruce stands, etc.) is also known from the territory of Slovakia and owing to these activities the high proportion of very valuable indigenous Norway spruce stands disappeared.

Relevant research activities and needs; further development of conservation strategies

At present there is not very much information about the genetic diversity of economically important tree species in the Carpathians. However, there are tree species in which the genetic structures and genetic diversities have been systematically investigated, also in the Carpathians, during the last decade. Among these species are the Norway spruce, silver fir (*Abies alba*) and European beech (*Fagus sylvatica*). Rather scarce information is available on the genetic structure and diversity of other economically valuable tree species (e.g. oaks, European larch, Scots pine, etc.).

In the abovementioned tree species, research has been predominantly on the geographic variation of allelic frequencies in natural populations, with an aim to understanding the differences between individual regions and/or populations and to understand the migration of individual tree species from the different post-glacial refugia or selection processes. Three examples of intensive investigation of genetic diversity and differentiation in which our team has participated can be given.

The first investigation of the genetic structure of Norway spruce populations from Slovakia was done by Paule *et al.* (1990). They investigated the genetic structure of adjacent populations and found insufficient genetic differences between adjacent populations but in some cases also between the more distant populations.

The investigation of the geographic variation of Norway spruce in Eastern Europe, including the Carpathians, was done by Bergmann and Gömöry (in preparation) and another investigation of the differences between the Norway spruce virgin forest and naturally and artificially regenerated Norway spruce forest stands was done by Gömöry (1992). Results of this investigation give insight into the structure of the natural Norway spruce forests of Slovakia and show that naturally regenerated forest stands do not significantly deviate from the natural forest of virgin character. Significant deviations could be expected only in the case of artificially regenerated forest stands in which significant narrowing of the genetic diversity could also occur (Gömöry 1992).

The practical gene conservation in Slovakia is carried out in the Forest Research Institute, Zvolen, Research Station Liptovský Hrádok, where the central register of approved stands, seed stands and gene bases is localized. Experts from this research station (Hoffmann, Piovarči and earlier also Chudík) are responsible for approval of forest stands for seed procurement and also of the approval of genebases (reserves). The coworkers of the Faculty of Forestry of the Technical University in Zvolen (Paule, Gömöry) are involved mainly in basic population genetic research.

Public awareness of the importance of forest genetic resources

The public awareness of the importance of forest genetic resources has been reflected in the updating of laws on the approval of forest stands (1985) and gene reserves (1991) as well as in the preparation of the Law on Plant Varieties which is prepared for approval in the Parliament. This is the first time in the legislation of this country that the Law on Plant Varieties (common with agricultural crops) will be a part of the legislation. It will be compatible with EC and OECD rules.

The next updating of law regulations is under discussion and has considered recent ownership changes in Slovakia.

Reconstruction of the forest seed bank in Liptovský Hrádok is planned for the near future. It will be aimed not only at the technical reconstruction and replacement but also the new regulation on the content (the selection of samples and their quantities) of the Seed Bank will be updated.

The topics of gene conservation are permanently a part of the research programme of the Forestry Research Institute in Zvolen and their research stations in Liptovský Hrádok and Banská Štiavnica. In Liptovský Hrádok there is also a central database on gene resources (approved stands, genebases, seed stands and seed orchards). A part of this research station is Seed Control, an organ of the Ministry of Agriculture which aims to control the forest seed procurement and business in Slovakia.

The most urgent needs in Norway spruce conservation

There are several urgent needs for the conservation of the Norway spruce genepool in Slovakia. **Among them, there is the danger of air pollution in several regions with very valuable Norway spruce populations (e.g. Spiš and Beskydy), the grazing by ungulates (e.g. red deer) and the simplification of forest management activities (e.g. replacement of mixed forest by Norway spruce monocultures).**

Last but not least there is danger from forest owners themselves. Within the reprivatization process of the Slovak forests the highest proportion of small private forest owners is in the region of the best Norway spruce populations of the Beskydy ecotype of Norway spruce, i.e. Orava and Kysuce.

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Genetic resources of *Picea abies* in the Ukraine

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Introduction

Ukraine is considered to be a republic with scarce woodland, the total forest area being only 14.3% of its territory. The Carpathian mountains is the most wooded region of the republic (37.5%). It occupies 7.4% of the Ukraine territory with about 21% of the forests concentrated there. The total area of the Ukraine woodland is 6 151 000 ha. Owing to favourable forest-growing conditions, the forest productivity in the Ukraine is much higher than in many other countries of eastern Europe: the average wood stock on 1 ha is 194 m^3, and in the Ukrainian Carpathians, 373 m^3; an average increment per 1 ha is, correspondingly, 3.9 and 5.1 m^3. However, as investigations have shown, these indices cannot be considered sufficient for the Ukraine (Chernyavskij and Shvadchak 1994). At the same time, the problem of increasing forest productivity should be considered together with solving the problem of genepool conservation of forest tree species.

These problems are of particular importance for spruce forests of the Ukrainian Carpathians, where excessive forest exploitation during the last one and a half centuries and the application of seed material of unknown origin during forest growing have led to decreases of many spruce stands and to considerable economic losses. A preference for spruce monocultures in the Carpathians led to an increase of 200 000 ha in areas of spruce stands during the last two centuries (Golubets 1978). The situation was aggravated by the fact that in artificially created spruce stands, forms and races of different west European origin began to grow together (Bardecki 1909). It was in these stands that catastrophic wind damage and epidemics of diseases and insects periodically took place.

Spruce forests in the Ukrainian Carpathians and in Polissya presently occupy an area of about 570 500 ha (9.3% of the lands covered with forests). In modern forest cover of the Ukrainian Carpathians, forests formed by common spruce occupy about 533 000 ha, or a third part of the forested area of this region. Taking into consideration all the forests where spruce occurs, the total area will amount to 1 million ha. The area of flat spruce forests is about 37 000 ha.

Natural range and ecological conditions

The area of natural distribution of Norway spruce in the Ukraine consists of two parts: unbroken spruce forests in the Eastern Carpathians and small island places of this species growing on the plains of the northern part of the Ukrainian Polissya.

Owing to a long exploitation period of the Ukrainian Carpathians spruce forests and considerable spruce cultivation, the current limits of distribution of this species have been considerably changed. On vast areas, beech, beech-spruce, beech-fir-spruce groups of uneven age and composite structure have reformed into pure spruce cultures. That is why two categories of spruce forests—natural and artificial—are singled out in the forest cover of the Ukrainian Carpathians (Fig. 1).

Natural spruce forests of the Ukrainian Carpathians are adapted to the climatic zone with the sum of active temperatures from 1000° up to 1600°, the general vegetation period duration not more than 136 days and total annual precipitation up to 1500 mm.

Natural spruce forests (*Piceeta abietae*) occupy the highest elevation zones of the forest cover of the Gorgan, Chernogory, Chyvchyn, Marmarosh and Grynyav mountains. In the spruce forest zone two ecologically and cenotically different levels are singled out: the upper level with pure spruce forests (higher than 1200 m) and the lower level with mixed spruce forests that include fir and beech.

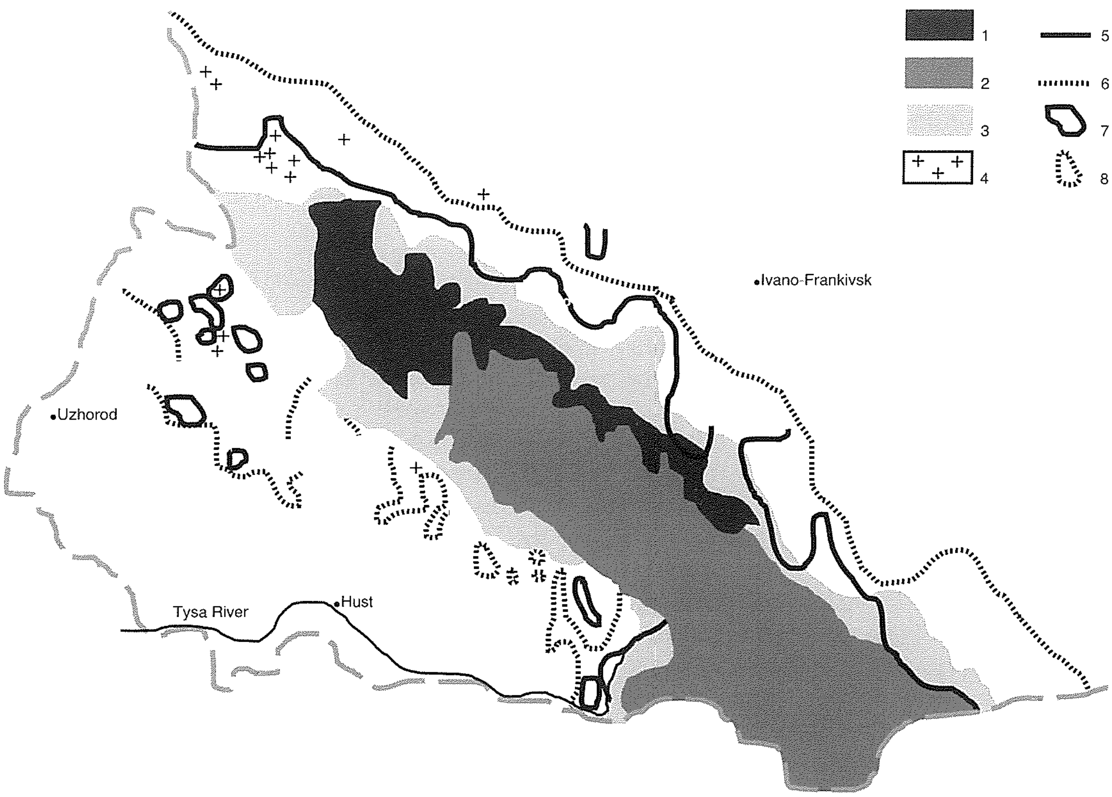

Fig. 1. Area of Norway spruce in the Ukrainian Carpathians. I - natural occurrence regions: 1 - large-scale, 2 - partial, 3 - isolated, 4 - island; II - artificial (anthropogenic) occurrence regions: 5 - border of modern large scale; 6 - border of modern isolated; 7 - island spruce as a dominant of artificially created cenoses; 8 - island spruce as an artificially introduced component in the forest stands of other species.

The average value of the lower border of an unbroken spruce forests is 1030 m (minimum 700 m), and the upper value is 1470 m (Golubets 1988). Composite natural spruce forests prevail in the northeast and occur in the southwest microaspects of the Ukrainian Carpathians at elevations of 900-1200 m. It is there that a lot of research of the Carpathian forests determines optimum conditions for spruce growing (Vincent 1936; Gensiruk 1957; Tyshkiewich 1962), and conditionally the same-age spruce stands under the same conditions give over 1000-1100 m^3/ha at the age of 100 years (Tsuryk 1981).

Spruce formation in the Ukrainian Carpathians is divided into six subformations: *Piceeta* (130 000 ha), *Cembreto-Piceeta* (2000-3000 ha), *Fageto-Piceeta* (35 000 ha), *Abieto-Fageto-Piceeta* (100 000 ha) and *Fageto-Abieto-Piceeta* (50 000 ha) according to Golubets (1988).

About 40% of the total spruce forest area in the Ukrainian Carpathians is occupied by artificially established spruce forests. Their simplified structure, one layer, lower age of natural maturity (than in natural spruce forests), low endurance to windbreakage, diseases and harmful insects are characteristic features of these forests.

Reconstruction of spruce monocultures, regeneration of mixed forests, increase of spruce forest endurance and improvement of their useful and protective functions remain actual problems of the Carpathian forestry.

Genetic resources of the Norway spruce

Classification of genetic resources

Reserve territories organization; selection of forest genetic reserves (representing the best populations of species), plus stands (stands with the highest productivity and qualitative characteristics) and plus trees (trees with high economical characteristics); creation of clone and archive-parent plantations (in order to preserve and space plus trees by means of vegetation); creation of forest seed plots (to provide seeds); creation of clone and family plantations (in order to obtain seeds with higher genetic-selection characteristics); creation of test cultures of plus trees; population cultures, and initial sort tests are the main methods of forest genetic conservation.

Nature reserves

There is a developed network of natural reserve fund in the Ukraine including State reserves, natural national parks, protected localities, etc. The network of especially protected territories including mainly spruce forests at present consists of 74 objects with an area of 39 550 ha or 6.9% of the total area of spruce forests of the Ukraine.

Natural flat spruce forests are protected in Shatsk National Park (the total area is 67 000 ha) and in 14 protected localities in Polissya. The area of the latter is about 700 ha. In most cases they are mixed forests of an island type which overcame a significant anthropological influence.

The biggest stands of native spruce forests in the Ukrainian Carpathians have been preserved in Grynyav, Chyvchyn and Marmarosh crystal mountain mass. Practically, all of them are now in different reserves and protected localities. About 28 230 ha of natural spruce forests have been included in Carpathian National Park (21 350 ha) and Carpathian State Reserve (6880 ha), 1610 ha of them being represented by the groups of a virgin type. In 20 protected localities representing different forest-growing conditions of the northeast and southwest microaspects of the Ukrainian Carpathians, 5126 ha and 4194 ha of natural spruce forests, respectively, are protected. The total area of spruce forests of a virgin type, according to our estimates, is about 5740 ha.

Approved stands for seed procurement

The main method of improvement in forest growing of the past lies in a wider implementation in forestry practice of up-to-date achievements of seed procurement and selection.

Seed application in the Ukraine is regulated by 'Instructions on Forest Seed Growing' (Molotkov *et al.* 1993). Seed procurement should be done in plus stands and specially accredited to seed departments. Seed collection in artificial stands or in unapproved forest seed regions or subregions is forbidden.

There is the following division into districts in the Ukraine concerning common spruce:

Carpathian forest seed district
- a) high mountain subdistrict (higher than 1250 m a.s.l.),
- b) low mountain subdistrict (1250-950 m; 950-500 m a.s.l.),

South-Polissya forest seed district
- a) Rivno-Zhytomyr subdistrict,
- b) Kiev-Chernigov subdistrict,

Ukrainian forest-steppe.

Spruce population transfer in the limits of the Carpathian high mountain subdistrict is carried out up to 150-200 m, and in low mountain ones up to 200-300 m vertically from the place of seed procurement.

The total area of spruce seed procurement departments is 1260 ha, including 1043 ha under mountain conditions. Spruce plus stands of 221 ha European area are singled out only in the Carpathians.

Gene reserves

Creating a network of forest gene reserves in 1983-1985 became a specific method of genepool conservation of forest tree species in the Ukraine. Genetic reserves were selected in all geobotanical and forest districts, high-altitude ecological belts in the mountains and the main forest types. It should be noted that only well-preserved natural forests were taken as a basis for selecting genetic reserves. That is why in some cases genetic reserves were included in already exisiting reserves and protected localities. Therefore, there exists a double control on these objects.

Any economic activity which can affect genetic structure and natural development of these reserve plantations is forbidden. Seed and vegetation material procurement in a genetic reserve is allowed only in exceptional cases (scientific research, conservation of a given population *in situ* or *ex situ*), when reliable natural regeneration is available and only in high-productive years (Shvadchak 1990).

A reserve needs a protection zone not less than 100 m in width. The main task of management in a protected zone is conservation and regeneration of the native genetic reserve plantations. Complex cutting combined with intermediate fellings is allowed in this zone. If natural regeneration in the protected genetic reserve belt is bad, creation of forest cultures with the help of native material is sometimes allowed.

In order to preserve and rationally use the valuable genepool of common spruce in the Ukraine, 43 genetic reserves with an area of 2773 ha amounting to 4.9% of spruce forests have been selected (see Table 1).

Other units of genepool conservation

Among other objects directed at spruce genepool conservation one can name plus trees (211 plus trees in total) and creation from their vegetative material of clone plantations and test cultures. In all, 2 ha of archive-parent plantations of spruce and 47.8 ha of clone plantations of the first order have been formed, 2.5 ha of which were planted under the flat conditions of Polissya. By means of seed material one spruce family plantation with the area of 1.8 ha has been created. One clone plantation with an area of 12.2 ha has been entered into a constant seed base where seed procurement is done in productive years.

Wide experiments with geographical origin (provenance trails) with spruce in the Ukraine, despite the species' significant spreading, have not been carried out. Some investigations of five west European provenances (planted in 1963) proved unsuitable for the Ukrainian Carpathians (Golubets 1978). Also, the data about parent stands in this investigation were absent. The results of European international experiments with common spruce in 1938 and 1964-1968, including some provenances from the Ukraine, indicate the prospects of east-Carpathian ecotypes for Central Europe. Spruce provenances from Chornogirya stands should be of particular interest. Certain trends to unification of spruce population from Chornogirya stands have been noted in our investigations (Shvadchak 1989). It is interesting that the Chornogirya, according to some scientists (Srodon 1948; Kozij 1963), was one of the most important refuge locations of spruce, from which it spread after the post-glacial period.

Table 1. Forest genetic reserves

Species	Number	Area (ha)	
		General	Protection forests group
Pinus sylvestris L.	114	5780.5	4354.6
Pinus sylvestris L. (relict)	9	480.3	480.3
Pinus sylvestris cretacea (Kalenitz) Komarov	2	7.2	7.2
Pinus cembra L.	5	654.2	654.2
Pinus pallasiana D. Don	7	129.2	129.2
Pinus pityuza Steven	2	42.8	42.8
Pinus strobus L.	1	1.6	1.6
Picea abies (L.) Karst	43	2773.2	1610.5
Abies alba Mill.	24	1314.2	636.3
Taxus baccata L.	3	107.1	107.1
Juniperus excelsa M.B.	2	215.4	215.4
Larix decidua Mill.	4	19.1	12.5
Quercus robur L.	142	7731.2	5649.1
Quercus petraea Liebl.	12	637.7	572.3
Quercus borealis L.	2	14.4	14.4
Quercus pubescens Willd.	1	129.0	129.0
Fagus sylvatica L.	64	3109.2	1779.7
Fagus taurica Popl.	7	141.1	141.1
Fraxinus excelsior L.	6	59.7	30.7
Fraxinus angustifolia Vahl.	1	86.5	86.5
Betula pendula Roth.	2	36.4	33.2
Carpinus betula L.	3	67.8	67.8
Acer pseudoplatanus L.	2	34.2	34.2
Pistacis mutica Fisch. et Mey.	1	5.0	5.0
Arbutus andrachne L.	1	196.0	196.0
Sorbus torminalis (L.) Crantz.	1	6.1	6.1
Ulmus glabra Huds.	1	2.5	2.5
Alnus glutinosa (L.) Gaertn.	15	192.1	144.4
Robinia pseudoacacia L.	1	10.0	10.0
Total	478	23983.7	17153.7

Conclusions

Despite the mistaken actions during forest spruce growing in the Ukrainian Carpathians, a valuable genepool of this species is still conserved having significant importance for further investigations as to European spruce improvement, not only for the Ukraine but also for many countries of central and western Europe. It is expedient to carry out an international experiment in order to study the provenances of common spruce.

There is a necessity to create an all-European database of common spruce genetic resources and to develop a strategy of assessment and conservation of genetic resources of *Picea abies* in Europe.

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Norway spruce genetic resources in Norway and their management and conservation

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Introduction

Norway spruce (*Picea abies*) is a young species in Norway. After the ice age, birch, poplar and Scots pine were the first tree species to establish. During the warm and dry period that followed, high-temperature demanding species such as lime, beech, oak, ash and hazel spread, and the timber line was 200-300 m higher than at present. It was not until approximately 2500 years ago, during a cooler and more humid period, that spruce started its introduction into the Norwegian landscape. The Nordic spruce populations have their origin in the taiga in northern Russia and Siberia. During a period of 3000 years the species spread through Finland and northern Sweden. The earliest identified establishments are from the years 500-400 BC in the border areas close to Sweden in Central Norway (Hafsten 1991, 1992). The invasion of the southeastern lowland area took place during the following 1000 years, but the migration up the valleys to the species' present altitudinal boundary was not completed until the period 1000-1500 AD. The coastal spruce forest in Central Norway was established rather late (approximately 1300 AD). The species never established naturally in western Norway, except for a few scattered populations, which have a late establishment and most likely are spread from the nearest source stands east of the mountain range (Hafsten 1991).

The present natural occurrence of Norway spruce is in southeastern Norway from sea level and up to 1000 m, and in Central and North Norway, north to lat. 67°N, at decreasing altitudes in the north. Outside this area the species has in this century been planted both in western Norway and north of its natural boundary in northern Norway. In both regions it has become an important timber species.

The Norway spruce forests have been strongly influenced by human activities. An excessive harvest started more than 300-400 years ago and strongly depleted the forest resources in some regions. At the beginning of this century the annual harvest in Norwegian forests exceeded annual growth, while the harvest is at present only around 50% of the gross annual production.

Norway spruce is the most important species in Norwegian forestry. The total forest area is 12 million hectares or 37% of the total land area. Productive forests cover 23% of the land area (7 million hectares), half of which is spruce forest. More than one-third of the forest is older than 80 years. The total annual harvest is 10 million m^3, of which spruce amounts to 70%.

Legal framework

Norway has no laws or regulations specifically dealing with the conservation of the forest genetic resources. The Norwegian Forestry Act, however, provides general measures for the long-term preservation and sustainable utilization of the forests, which also relate to management of the genetic resources. Special recommendations are given for forestry activities in areas which have such location, conditions or characteristics that they should be managed with particular care. Where restrictions are deemed necessary, such areas may be classified as protection forest and be subject to regulations. Protection forests comprise approximately 20% of Norway's total forest area and are in particular located at high elevations, along coasts or in the far north. The Forestry Act is administered by the Ministry of Agriculture.

The maintenance of genetic diversity is one of the main motives in the regulations for the classification, trade and use of reproductive materials in forestry. Specific recommendations are given for the transfer of provenances and use of vegatatively propagated materials. Seed from native Norway spruce stands should not be transferred more than 200 km in the northern or southern direction. Vertically, transfers should be within the range of 300 m. Close to the altitudinal and boreal timber line only local provenances should be used. Seeds from Norway spruce seed orchards should be tested for growth rhythm and frost hardiness, which should determine their regional use.

Two other components of Norwegian legislation, administered by the Ministry of Environment, have importance in the management of the forest genetic resources. These are the Building and Planning Act and the Nature Conservation Act. The first one provides fundamental principles for land management limiting nonforestry development and urban expansion on forest land. The Nature Conservation Act provides for the classification of specific areas which are to be protected as national parks, nature reserves, landscape protection areas and natural monuments. Opportunity is given, moreover, for combining species protection and the conservation of areas in the form of what is called habitat preservation.

Threats to spruce genetic resources and public awareness

The Norway spruce genetic resources are not considered to be threatened in any part of its native range in Norway. Large areas of old-growth natural stands still exist, even if their abundance has been reduced, in particular in the lowlands in southeastern Norway. New forests are being established by natural regeneration over large areas and this method has gained importance during the last few years. Under certain ecological conditions, however, natural regeneration will not be sufficient for the establishment of a well-stocked Norway spruce stand, and planting is necessary.

Owing to a lack of Norway spruce seeds of local origin, seedlings of Central European provenances were planted in southeastern Norway during a 20-year period starting in the mid-1950s. In one county, Østfold, 35% of the total number of seedlings planted in the period 1960-1980 originated from provenances in Austria and in Schwarzwald, Germany. It was thought that the high altitude of the seed stands, between 800 and 1400 m, would compensate for the southern latitude. However, both practical observations and a recent survey in planted stands (Skrøppa *et al.* 1993) have shown that these stands are not well adapted to the northern climatic conditions. While 30% of the trees in 30-year-old planted stands of native origins were classified as having saw timber qualities, only 7% of the trees in the Central European stands obtained the same classification. These provenance transfers had a negative effect on timber quality, particuarly on sites where frosts commonly occur in late spring or early autumn. The stands established with seedlings from introduced provenances are in many cases mixed with stands of local seed origin and are often not recognizable. The seeds harvested in such areas, even in healthy stands, may be partly from local and partly from provenance hybrid crosses. Critical factors are the abundance of flowering in the stands of introduced provenances, the range of pollen migration and how fast the natural selection process proceeds.

Transfers of Norway spruce provenances from southern to northern latitudes and from low to high altitudes also have been made within Norway. Such transfers have in some cases resulted in plantations that show lack of adapation to the climatic conditions. However, as these plantations in many cases have failed and are rather scattered, they will in a few cases produce pollen or seeds in large enough quantities to have a practical consequences, either for natural regeneration or for seed collections.

The concept of genetic diversity of forest trees has not been an important topic in public discussions in Norway. The introduction of Central European Norway spruce provenances has been criticized, but on grounds of the reduced timber quality in the planted stands and not so much because of a possible threat to the local spruce genetic resources. The introduction of spruce and its replacement of Scots pine and deciduous tree stands in western and northern Norway outside its natural range are debated locally. The negative voices are based partly on ecological considerations from naturalist groups as well as a general reluctance to accept changes in the landscape.

Public awareness of forest genetic resources and the considerations of their importance for the future forests are generally missing.

Conservation activities

The forest tree genetic resources have generally been managed through the reforestation strategies employed after harvesting. Natural regeneration is encouraged where it is a feasible and optimal regeneration method. Thirty-five years ago the annual volume of forest tree seedlings planted exceeded 100 million. This number has been drastically reduced, and in the last 10-year period 50-55 million spruce seedlings have been planted annually. During the last 5-year period there has been a reduction in the number of seedlings planted.

The gene conservation activities of forest trees in Norway are accomplished in three different ways: by nature conservation areas in national parks, protected landscape areas or nature reserves; by recently established conservation areas in productive coniferous forests, and by materials preserved in clonal archives or seed orchards as part of the tree breeding program.

The conservation of forest genetic resources has not been a motive for the establishment of nature conservation areas. Most national parks and nature reserves are located far north and at high altitudes and do not sample representative areas of the Norwegian coniferous forest. In total 20 000 ha of coniferous forest are conserved in these areas. They cannot be considered to play a major role in the conservation of the Norway spruce genetic resources.

Based on a national plan to conserve coniferous forest, altogether 25 000 ha of productive forest have been protected. Norway spruce is the main species in the larger part of these areas. The main intention was conservation of biological diversity in general, but conservation of the genetic resources also was a motive. These areas are distributed in different parts of the country and are stratified to be representative for all major ecological zones. The different areas vary in size, from 10 to several thousand hectares.

The more active gene conservation work is performed by the establishment of clonal archives or seed orchards of grafted Norway spruce clones. Selections of plus trees have been made in natural stands covering the entire distribution throughout the country to be included in breeding populations. More than 3000 selected trees have been grafted, most of these at several localities. They were grouped in breeding populations according to the latitude and altitude of the origin of the natural stand. However, it was soon realized that progeny tests are necessary to assess the genetic value of a selected plus tree, and more than 2000 of the selected trees have been tested by family tests planted in trials at several sites. Traits that have been measured include height and diameter growth, annual growth rhythm characteristics, climatic damage and stem and branch quality. In addition, a large number of families have been tested in artificial freezing experiments.

The grafted clones and their offspring in progeny tests are an important part of the gene conservation activities, as they are the only materials from which specific genetic information is available.

Genetic variation in Norway spruce

So far, no studies of isozyme or DNA genetic markers have been performed to characterize the genetic variability of the Norwegian spruce population. The genetic information available comes from quantitative genetic studies in provenance trials and family and clonal tests. The largest efforts have been made to characterize adaptation to the climatic conditions. Therefore measurements have in particular been made of annual growth rhythm traits: the timing and duration of the annual growth period, frost hardiness development in the autumn and dehardening in the spring, and the occurrence of climatic damage under field conditions. All studies demonstrate a clinal variation in growth rhythm characteristics of natural populations from the south to the north and from low to high altitudes. The southern and low altitude populations have the longest duration of the growth season, and, as a consequence, the highest growth potential. They also have the latest development of autumn frost hardiness. The only well-known characterizations of the adaptative process of spruce populations are the responses to temperature and photoperiod.

The genetic variation is large within all natural populations studied, also for traits that shown clinal variation at the provenance level. Genetic correlations between traits may change dramatically, depending on the genetic level, whether it be based on population, family or clonal means.

Research activities

The general intentions with the genetic research in Norway spruce are: to describe and understand the genetic variability of the species, to develop stategies for breeding for better quality in well-adapted, high-yielding plantations, and to assure that sufficient genetic variability is conserved for the future evolution of the species.

At present the main research interest is focused on the genetic mechanisms behind the variability observed in phenotypic traits having importance for adaptation to the climatic conditions. Based on experimental evidence, our hypothesis is that genetic variation in such traits is not only regulated by classical (Mendelian) gene frequency differences, but also by other mechanisms (e.g. gene regulations), and that these factors are triggered by environmental influences during the generative reproductive process. If this is the case, then it will have large implications both for understanding the evolutionary process and for the conservation of the genetic resources of the species.

These effects were brought into focus by the location of seed orchards in warmer climates. The seedlings produced in Norway spruce seed orchards in Norway where the parental clones are transferred to seed orchard sites 6-8 degrees of latitude southwards or to 500-600 m lower in altitude, do not retain the annual growth rhythm of their parents, see Johnsen (1989a,b) and Skrøppa and Johnsen (1994). Progenies after controlled crosses in such orchards, as well as the open-pollinated orchard offspring, have in particular a later growth start in the spring, a delayed growth cessation and a later development of autumn frost hardiness than their sibs born in their native environment. The effects have been shown in freezing tests of 1- or 2-year-old seedlings, but are verified by growth rhythm studies in experiments with 10-year-old trees (Skrøppa 1994) and after clonal propagation (Johnsen 1989a). The population mean of seed orchard offspring is changed, but the genetic variation between different families for the traits seems to be retained. The environmental influences during the reproductive process have been verified by making identical crosses in a greenhouse and in a nearby seed orchard (Johnsen *et al.* 1995), and early and late in the spring in a heated greenhouse and outside the greenhouse (Johnsen and Skrøppa, unpublished).

Results from field trials and in practical plantings indicate that the observed effects may have practical consequences under extreme climatic situations in the field (Skrøppa, unpublished). The effects may either be positive or negative for the survival and quality of the plantation, depending on how the climatic extremes are related to the annual growth rhythm of the material. The situation seems to be similar to that of a provenance transfer. It will be adavantageous under certain environmental conditions, but the opposite under other conditions.

Concluding comments

Norway spruce is a young species in Norway and shows large flexibility to a wide range of environmental conditions. Its genetic resources are not considered to be threatened, both because of the existence of old-growth natural stands and the extensive use of natural regeneration. When new stands are established by planting, seeds are transferred over rather short distances or are of local origin. An extended use of seed-orchard seed in the future may change the genetic composition of the planted stands. As long as the seed orchards contain a relatively large number of parents, this should not be considered a threat to the genetic resources. However, a combined strategy for the long-term breeding and gene resource conservation should be developed. An understanding of the genetic mechanisms behind the environmental influence during reproduction on the adaptive properties of the offspring will be of fundamental importance for both the breeding and conservation activities.

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The conservation of Norway spruce gene resources in the Federal Republic of Germany

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Summary
In Germany, Norway spruce is the most important timber tree and covers about 35% of the forest area and about 60% of the total fellings in 1993. Beginning in the eastern part of Germany in the 1960s and continuing in the western part of Germany in the 1980s, severe damage of Norway spruce stands caused by air pollution and forest decline could be observed. Recording of these damages started in 1984. In 1994, Norway spruce had the largest area damaged of all tree species because of its big proportion of the total forest area. The heaviest damages could be observed in the higher altitudes of the mountainous regions and the Alps which are mainly part of the natural distribution area of Norway spruce. Stands over 60 years old showed the worst damages. In 1985, the working party Conservation of Forest Gene Resources was established to coordinate the efforts of federal and state institutions concerning the conservation of forest gene resources. Among other tree species, Norway spruce has the first priority. Based on the conservation work already done by different tree-breeding institutions, the working party developed a 'Concept on the Conservation of Forest Gene Resources in the Federal Republic of Germany' in 1989. In the concept, several *in situ* and *ex situ* measures were planned which should be realized within the next decade. The conservation work done since 1989 was mainly concentrated on the *in situ* conservation of Norway spruce stands, the establishment of *ex situ* conservation stands, the collection and storage of seeds and the vegetative propagation of single trees. Finally, research needs and tasks were identified related to the conservation activities planned.

The origin, natural distribution and occurrence of Norway spruce forests

Origin of Norway spruce forests
After the last ice age, Norway spruce most probably remigrated into the area of today's Germany from two refugial areas, the Balkan Peninsula and the Carpathian Mountains. One of the main migration streams led obviously from the Beskides over the Sudeten to the Ore Mountains which were reached about 6500 BC. The other mainstream started in the refugial area on the Balkan Peninsula, followed the edge of the eastern Alps, crossed the river Danube, went west and northwest and came over the Bohemian Forest to the Bavarian Forest in the southeast of Germany. Both migration streams may have met in the Fichtelgebirge, the Frankonian Forest and the Thuringian Forest. About 4000 BC, the Harz Mountains were reached. The southern part of Germany was remigrated by Norway spruce parallel to the northern edge of the Alps, coming from the eastern parts of the Alps and finally reached the Black Forest in 1500 BC (Fig. 1).

Natural distribution
In Germany, Norway spruce occurs naturally in the mountainous and subalpine regions. Its natural distribution area covers the Alps, the higher altitudes of the Black Forest and of the Middle and East German Mountains. In the natural forest societies, pure Norway spruce stands can be found on extreme sites only, e.g. at the high mountainous and subalpine level of the northern edge of the Alps, on cold, wet sites of the Black Forest and the foothills of the Alps, and at the higher altitudes of the Bavarian, Middle and East German mountainous areas. Apart from these particular sites, Norway spruce normally contributes to mixed beech, fir or pine forest societies in different percentages. In total, Norway spruce is associated on about 25% of the natural forest areas.

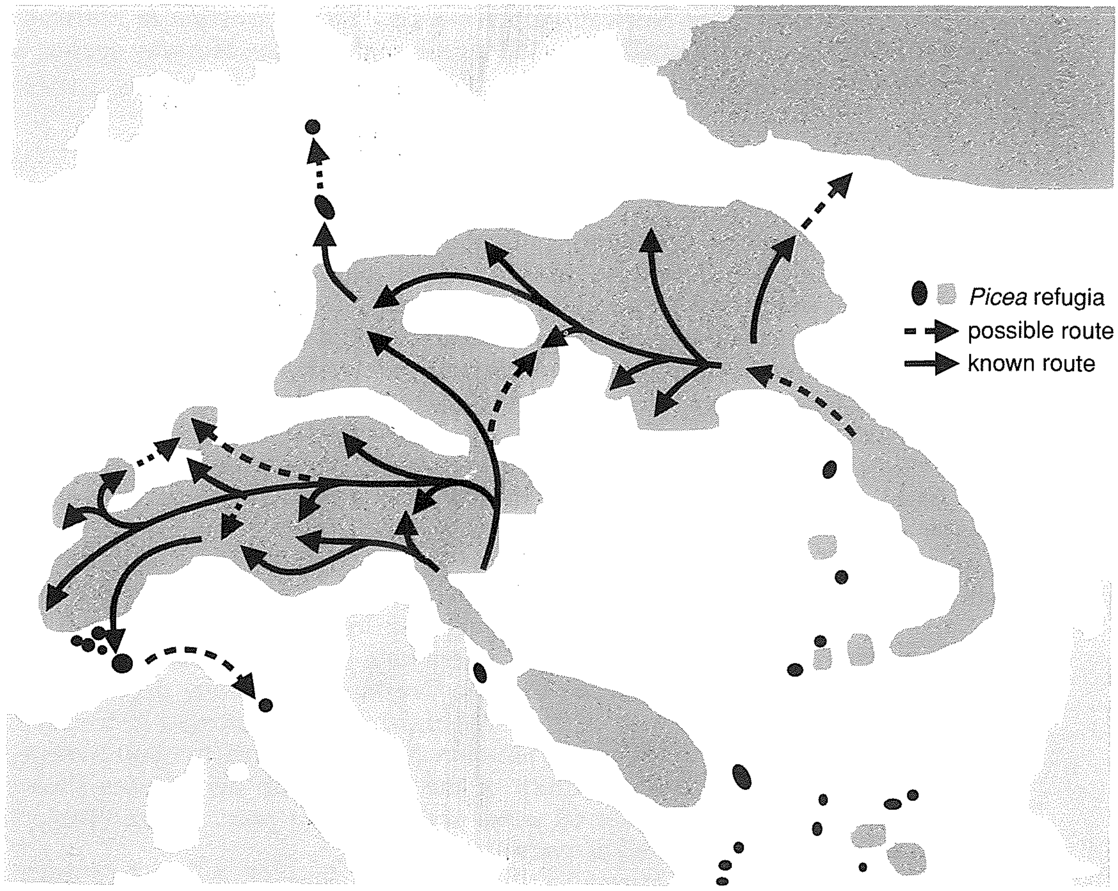

Fig. 1. Probable remigration streams of Norway spruce in the Herzynic-Carpathian and alpine distribution area (Proposal of F. Kral, 1976 in Schmidt-Vogt 1987)

Artifical distribution and occurrence

In consequence of the thorough devastation of the forests until the end of the 18th C and the enormous timber demand in early industrial times, natural forests were changed to artificial forests. Because of its wide ecological range, fast growth rate and ability to cope with clear-cut conditions, pure Norway spruce stands were promoted by forestry apart from Scots pine. These led to an:

— increase of Norway spruce up to 100% on sites on which Norway spruce was represented only partly,

— extension of Norway spruce on sites which were not suitable for Norway spruce within the natural distribution area, and

— extension on sites outside of the natural distribution area.

The promotion of Norway spruce by forestry for two centuries was accompanied by the transfer of reproductive material. In many cases, the origin of this material was not known or not suitable in the long term. These facts make it difficult to identify and delimit natural autochthonous Norway spruce forests from nearly natural or artificial formations of Norway spruce forests. Apart from these, Norway spruce showed good yield and quality performance on very different site conditions which favoured the planting of this species over a long period.

In 1993, about 30% of the total land area of Germany was covered by forests, i.e. the forest area added up to 10.7 million ha, and 3.8 million ha of the forest area (35%)

consisted of mainly pure Norway spruce stands. The proportion of Norway spruce in the total fellings was about 60%, i.e. 16.9 million m^3. Today, Norway spruce is the most important timber species in Germany.

Factors threatening Norway spruce gene resources

In the past, the structures and the character of natural forests in Germany were heavily influenced by exploitation, deforestation, change of species composition, etc. Since industrialization, forest decline caused by air pollution influenced Norway spruce populations locally and regionally. In the eastern part of Germany, the damage of Norway spruce stands began in the 1960s and took dramatic dimensions, especially in the Ore Mountains. In many cases, the locally adapted populations disappeared within the shortest time. Since the beginning of the 1980s, the damages caused by forest decline also increased in western Germany. As opposed to the damages in eastern Germany, these damages could only be related in single cases to a certain emittent of air pollution.

Since 1984, the damages to the forests have been ascertained and published in a yearly report in the western part of Germany and since 1990 in the whole of Germany. The results of visible damages of Norway spruce (loss of more than 25% of needles) show clear differences in the percentages and in the development of the damages in the northwest, east and south of Germany (Fig. 2). In 1994, the highest average damages could be observed in the eastern part of Germany. Norway spruce stands in the higher altitudes of the Thuringian Forests and the Ore Mountains were particularly damaged. Norway spruce stands with more than 30% of damaged trees could be found in the Alps, the Black Forest, the northwestern Hessian Mountains and the southwestern part of Schleswig-Holstein. The distribution of the damages on age classes showed a clear difference between stands over 60 years and under 60 years of age (Table 1). Mixed stands were damaged as well as pure stands.

In summary, Norway spruce has the largest area damaged of all tree species because of its large proportion of the total forest area. The heaviest damages were observed in the higher altitudes of mountainous regions and the Alps, which are part of the natural distribution area of Norway spruce, where stands >60 years old had the worst damages.

In future, climate changes caused by global warming could lead to a threat to Norway spruce populations. However, the consequences are very difficult to estimate. In particular, an increase in temperature connected with higher evaporation and lower precipitation could result in higher susceptibility to pests and diseases.

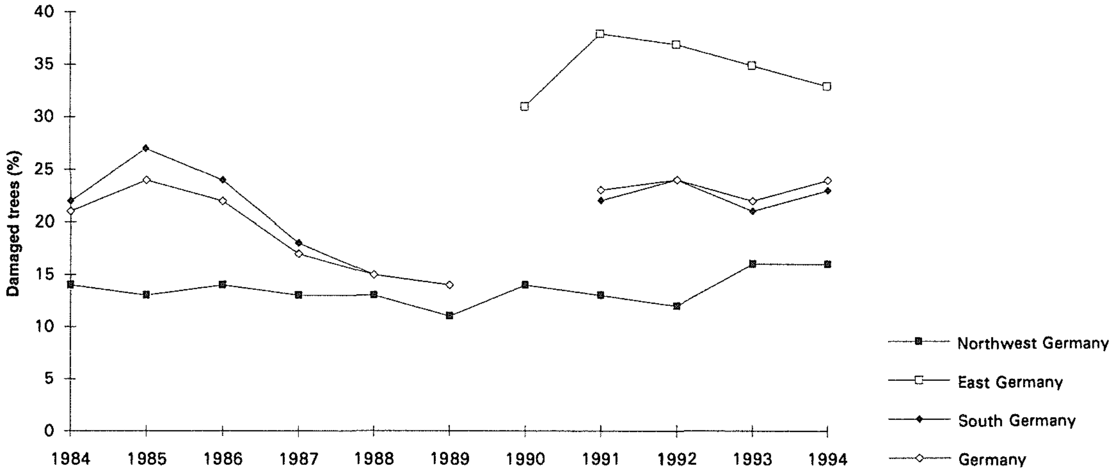

Fig. 2. Development of visible damages (= loss of more than 25% of needles) on Norway spruce, 1984-1994

Table 1. Development of forest damages, 1984-1994, distributed on age classes

	Percentage of Norway spruce trees with visible damages		
Year	Under 60 years	Above 60 years	Average
1984	9	39	21
1985	11	45	24
1986	10	41	22
1987	7	34	17
1988	5	29	15
1989	4	29	14
1990	*	*	*
1991	10	42	23
1992	11	44	24
1993	8	40	22
1994	9	42	24

* No figures available; since 1990, beginning of a new time series including the newly established states after reunification.

Conservation aims and current state of activities

History and organizational structure of Norway spruce gene conservation

Because of its importance for forestry, Norway spruce was one of the major species in tree-breeding programmes. Following the Norway spruce provenance trial of 1936/37 established by Rubner, Germany participated in the 2nd International IUFRO-Norway Spruce Provenance Trial of 1964/68 and in the International (IUFRO) Norway Spruce Provenance Trial of 1972. The conservation of populations and individuals of interest was already part of the breeding programmes in the different research institutions.

Because of the heavy damages by air pollution in the German Democratic Republic, a special programme for the conservation of Norway spruce was established in 1985. In the Federal Republic of Germany, the working party 'Conservation of Forest Gene Resources' was established in 1985 based on a resolution of the Bundesrat (upper house of the German parliament) and an agreement among the Federal Ministry of Agriculture, Food and Forestry and the different State Ministries responsible for Forestry. The working party is composed of appointed representatives of the Federal Government and of the different state governments. The task of the working party is the development of a concept for the conservation of forest genetic resources and the coordination of gene conservation activities. The implementation and realization of gene conservation activities is the responsibility of each state and its research institutions and forest services. After the reunification of Germany, the new estabilished states joined the working party.

Objectives and measures of Norway spruce gene conservation

The general objective of forest gene conservation is to conserve and save the genetic variation of tree and shrub species in the following generations. In the medium term, *in situ* conservation of Norway spruce stands and their natural or artificial regeneration by sowing or planting will not be possible in many regions owing to the continuing air pollution. Consequently, *ex situ* measures will be of great importance, e.g. the establishment of seed orchards and clone collections, the storage of seeds or parts of plants, and vegetative propagation. The following remarks are based on the concept of the working party Conservation of Forest Gene Resources which was published in 1989 before the reunification of Germany in 1990. The figures mentioned below for the planned conservation measures were extrapolated to consider also the Norway spruce forests of the five newly established states of Germany.

It is planned to cover about 1% of the Norway spruce area, i.e. about 38 000 ha, with conservation measures within the next decade beginning in 1989. From this area, 80%, i.e. 30 800 ha, will be conserved *in situ*. It is assumed that it will not be possible to conserve the remaining 20% *in situ* owing to the increase of forest decline. For these 7200 ha, *ex situ* measures will be used. To minimize the risk of loss, it is planned to take double *ex situ* measures for about 3100 ha of the *in situ* area. Norway spruce stands which should be conserved by sowing or planting, i.e. 15 200 ha, will also be conserved by storage of seeds.

In situ measures

In total, 30 800 ha of Norway spruce stands will be conserved *in situ*. The soil of 75% of these stands should be improved by application of lime. The vitality of all *in situ* stands should be increased by regular stand maintenance, thinning and fertilizing. The change in vitality has to be monitored by regular analysis of the soil and the needles. The results of the analysis will be used as a decision-making aid for future management.

On condition of the fructification being sufficient and the soil conditions still suitable, about 300 ha/year of Norway spruce stands have to be regenerated naturally, after having reached a suitable age. The natural regeneration is promoted by specific silvicultural management, e.g. by fertilizing. Additionally, about 300 ha/year should be regenerated artificially using material from stands worth conserving.

Ex situ measures

About 10 300 ha of Norway spruce stands are to be conserved by *ex situ* measures; 3100 ha out of these are included in double measures. This area should be conserved representatively on an area of about 1000 ha. The establishment of seed orchards will be one priority of the *ex situ* conservation.

Especially in the higher altitudes of the mountainous and subalpine regions, various Norway spruce populations have already disappeared. Some of these populations are part of different national and international provenance trials or conserved in clone collections established for breeding purposes. This material can be used to assemble clones in collections or seed orchards.

In the first decade, about 6000 trees should be selected from the 7200 ha to be conserved *ex situ*. These 6000 trees have to be conserved representatively on an area of 600 ha. Additionally, clone collections should be established for the conservation of endangered relict populations and single trees which represent rare genotypes or material important for breeding. For this, 1000 clones can be estimated, thus requiring an additional area of 20 ha.

It is planned to conserve about 13 200 ha of Norway spruce stands by sowing and planting *in situ* and *ex situ*. Together with the procurement of seeds for these measures, seeds for storage purposes have to be collected. In Germany, seed collection of Norway spruce is possible every 3 years on average. In the first decade, about 12 000 ha of Norway spruce stands should be collected with 4 kg seeds per stand.

As an additional conservation measure, pollen of about 5000 selected breeding trees has to be collected and stored. In the first decade, the storage of plants or parts of plants is not planned for. It is much more effective to store seeds. If starting material is limited and cannot be propagated in a different way, macrovegetative propagation is used. For this purpose, about 6000 clones with an additional area of 10 ha will be needed. The microvegetative propagation using tissue culture is not developed yet. But this method is of special interest for the conservation of old trees which are difficult to propagate by cuttings or grafting.

The current state of activities

Among other species, the conservation of Norway spruce gene resources has the highest priority. Because of the different levels of damages, regional priorities have to be set. Generally, the conservation measures are mainly concentrated on Norway spruce stands which are approved according to the federal law on forest reproductive material. In 1993, 44 466.2 ha of Norway spruce stands were approved for the production of selected reproductive material. About 62% of these stands were the property of the states. The remaining stands were mainly distributed between private (19%) and corporate owners (18%). Only a marginal percentage belonged to the Federal Republic of Germany (1%).

Additionally, several *in situ* and *ex situ* measures were taken to conserve Norway spruce gene information until the end of 1993. The emphasis was laid on *in situ* conservation of Norway spruce stands, the establishment of *ex situ* conservation stands, the collection and storage of seeds and the vegetative propagation of single trees by cuttings (Tables 2, 3 and 4). Activities in 1994 and ongoing activities in 1995 will be published in the next report of the working party Conservation of Forest Gene Resources at the end of 1995.

Table 2. Conservation activities in the field

Activity	Up to 1991	1992/93
In situ		
Stands	49	14
Number	61.7	33.9
Area (ha)		
Ex situ		
Stands		
Number	426	40
Area (ha)	359.1	71.3
Seed orchards/clone collection		
Number	33	1
Area (ha)	80.8	2.4

Research activities and needs

In the past, research activities in forestry were mainly concentrated on the growth and yield of forest stands, silvicultural measures and genetic characterization of populations by provenance and progeny trials. Because of the extent of the forest decline, research was started on forest ecosystems but focused mainly on biogeochemical and energy cycles. On the other hand, a certain lack of knowledge could be observed in the field of gene conservation. Normally, measures should be based on scientific results, but gene conservation measures had to be established immediately to avoid the loss of a significant amount of genetic information. In this case, research should accompany the measures of gene conservation.

The research activities and needs can be divided into two categories, the research on practical gene conservation measures and the research on specific problems which are

Table 3. Collection and storage of conservation material

Activity	Up to 1991	1992/93
Seed collection		
Stands		
Number	277	37
Amount (kg)	1068.5	910.2
Trees		
Number	2435	206
Amount (kg)	288.6	—
Seed storage		
Stands		
Number	322	70
Amount (kg)	735.1	714.8
Trees		
Number	2412	97
Amount (kg)	285.1	4.4
Pollen storage		
Number	384	—
ccm	4561.7	—

Table 4. Propagation for conservation

Activity	Up to 1991	1992/93
Number of graftings	24 315	—
Number of cuttings	1 536 830	250 000
Sowings		
Stands		
Number	3	1
Amount (kg)	10.5	1.5
Trees		
Number	204	1019
Amount (kg)	1.0	2.4

related to the necessary methods of gene conservation. The latter includes research on the influence of air pollution on the genetic structure of populations and reproductive mechanism, methods to identify and evaluate genetic variation as well as mechanisms and parameters of resistance.

The research about gene conservation measures related to Norway spruce covers all aspects of *in situ* and *ex situ* measures:

1. **Conservation of stands and natural regeneration**
   In most federal states, several projects are already established. Nevertheless, there are still problems in getting and maintaining natural regeneration in stands thinned out and revitalizing damaged stands.

2. **Artificial regeneration *in situ* and *ex situ* and management of seed orchards**
   In this field, different main problems can be identified: the influence and promotion of mycorrhiza on *ex situ* measures, planting techniques in higher altitudes; management methods of seedling seed orchards with regard to selection, regulation of space and fructification, the stimulation of flowering and the increase of seed production.

3. **Storage of pollen, plants and parts of plants**
   In the past, the collection, preparation and storage of pollen was mainly done for tree-breeding purposes. For gene-conservation measures, the techniques of collection and storage of large amounts of pollen have to be improved. The storage of parts of plants (e.g. cuttings) is only possible in the short term, but the storage of tissues is not possible at all. Research is necessary on the conditions of long-term storage of plants, parts of plants (twigs, buds) and tissues, their survival and regeneration abilities.

4. **Vegetative propagation**
   The vegetative propagation of Norway spruce by cuttings and graftings is well established. The rejuvenilization of vegetative material collected from old trees is still difficult. The vegetative propagation by tissue cultures was possible only in single cases. The development of procedures for the microvegetative propagation seems necessary. On the other hand, there are similar problems with the rejuvenilization of material using tissue cultures.

Facing the climatic change caused by global warming, investigations seem to be overdue on the relationship between the genetic diversity observed and the adaptability of populations, on the influence of silvicultural measures on the genetic structure of populations and on the mechanism generating the variability observed into phenotypic adaptive traits.

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Conservation of Norway spruce gene resources in Denmark

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Overview of the occurrence, origin and distribution of Norway spruce gene resources

The Norway spruce area in Denmark covers 135 000 ha corresponding to 32% of the total forested area. Norway spruce is by far the most important exotic species in Danish forestry.

Norway spruce was introduced into Denmark in the last half of the 18th C and the first imports of seed presumably originated from Germany (Harz and Thüringer Wald). Large quantities of seed were harvested from the first plantings. A good part of the existing Danish Norway spruce stands are probably third or fourth generation from the first imports.

It is assumed that natural selection and domestication activities have led to the formation of landraces, which are especially well adapted to Danish conditions.

During the 19th C and the beginning of the 20th C the Danish seed production was supplemented by new imports, primarily from Germany but also from Finland and Sweden. Seed imports during the last 50 years have been of various origin, mainly from Middle and Eastern Europe.

Conservation aims and the current state of conservation activities

Norway spruce is one of the 75 tree and shrub species included in the 1994 Danish strategy for conservation of forest genetic resources. It is the aim of the strategy to select and conserve two or three Norway spruce stands adapted to climate and growth conditions **west** of the glacial stagnation line and two or three stands adapted to climate and growth conditions **east** of the glacial stagnation line. It is also the aim of the strategy to regenerate, for conservation purposes, particularly healthy and vigorous material that currently is being substituted by improved material.

The strategy for conservation of forest genetic resources is planned to be implemented within the next 10 years. However, no stands have so far been identified/demarcated for gene-conservation purposes.

The Norway spruce genetic resources will be conserved in evolutionary conservation stands where the species will be allowed to adapt to prevailing environmental conditions and their change with time.

The conservation method to be applied in the case of establishing Norway spruce conservation stands in Denmark can be considered as a 'transitional' method between, respectively, *in situ* and *ex situ*, as the species is assumed to have developed landraces.

The abovementioned conservation activities will be supplemented by long-term conservation of selected seedlots and current *ex situ* conservation measures that have already been undertaken in the context of tree-improvement activities.

Some existing tree-seed production areas and breeding populations also serve as *ex situ* conservation areas. A number of genotypes are conserved in clone and family banks and additional tested genotypes can be retrieved from existing clone and progeny tests (see Table 1).

The extent to which Norway spruce genetic resources are threatened and how they are managed/protected

Genetic resources of Norway spruce in Denmark are not considered as being immediately threatened or endangered. However, unless protective measures are taken the genetic variation of Norway spruce will be influenced and possibly reduced in the medium to long term by more intensive use of genetically improved material.

There is a risk that the increased use of genetically improved material will supersede landrace material. This development may result in an unfortunate situation where it will be impossible to retrieve useful basic material for breeding purposes.

Norway spruce genetic resources will be protected as described above.

Table 1. Existing tree seed production areas, clonal banks and breeding populations that also serve as *ex situ* conservation areas. Up to 90% of the material in the trials is available.

Ex situ conservation	Conserved material
Clonal seed orchards	
West continental material	500 clones
East continental material	100 clones
Clonal banks	800 clones
Provenance trials	149 provenances
Plus tree selection	1600 plus trees
Progeny tests	1628 progenies
Clonal trials	4531 clones

Research activities and needs relevant to the survey of genetic resources for further development of conservation strategies

Research concerning forest genetic resources in Denmark has so far been focused on indigenous species. However, there is a need for research on the important exotic species, i.e. scientific verification of whether evolvement of landraces actually has taken place and how the genepool has been affected by strong selection under the environmental conditions in Denmark. Further, significant genetic variation in fertility has been observed and there is a need for information on causes as well as the long-term consequences of this phenomenon.

Intensive breeding activities and provenance trials have contributed greatly to the current knowledge about Norway spruce.

Finally, much research regarding forest dieback is currently being carried out in Denmark, and Norway spruce plays an important role in this research since it is one of the species that is most threatened by forest dieback.

Levels of public awareness of the importance of forest genetic resources

Generally the public awareness of the importance of **conservation of forest ecosystems** as a whole is very large and it has grown over the last few decades. The public interest in forests has led to various government initiatives, e.g. a strategy for conservation of natural forests and other forest types of high conservation value in Denmark.

The overall objective of the strategy is to conserve the biodiversity of the Danish forests, including the forest genetic resources. The preparation and implementation of the strategy has been covered by the news media and followed closely by all major Danish NGOs interested in environmental issues.

However, conservation of genetic resources of trees probably has lower priority among the public than conservation of forest ecosystems.

Information needs in Norway spruce conservation activities from the perspective of Denmark

As Norway spruce is not a native species in Denmark, the conservation activities in the species' natural distribution area are obviously regarded as very important.

It follows from this view that information on specific conservation activities concerning Norway spruce in other European countries is very important from Denmark's perspective.

Conservation of Norway spruce gene resources in the Czech Republic

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Introduction

Czech Republic forestry has the following problems limiting all activities and also the conservation of genetic resources:

— large-scale air pollution damages and dieback of thousands of forests,
— not very convenient tree species composition,
— too high a deer population (mainly red deer, *Cervus elaphus*),
— the present transformation of forestry including restitution and privatization process and changes in administration of forest management.

The stability of most spruce stands has decreased to various levels because of emissions and acid rains. In total, 60% of all Czech forests are affected by air pollution at the present time (forested area was 2 641 000 ha in 1994).

Forest tree species, mainly coniferous, are damaged to a catastrophical extent. Gene sources in some localities and regions—mainly in the northwest and the northern borders of Bohemia—are damaged and destroyed, industrial pollution being the main cause. The negative impact of dryness, destructive effect of abiotic agents multiplied by some insect pests and parasitic fungi and some incorrect silvicultural measures are also important causes of forest damage.

The 10-year forecast predicts further dieback, mainly of spruce stands as Norway spruce represents the main timber-tree species.

Occurrence, origin and distribution of Norway spruce forests

Spruce covers 55% of forest land (Table 1). Results of regional palynological investigations indicate that postglacial immigration of *Picea abies* into Czech lands occurred in the East Carpathian region. Norway spruce probably could be found only at two areas in 11 500 BC: in Eastern Bohemia (Broumov bassein) and along the north Moravian borders with Slovakia. Norway spruce probably spread in our territory in two main streams: Carpathian-Sudeten and Hercynian. The first one came from the Tatra region, Hercynian way and started probably around the Vienna Forest. The contact of both streams occurred in the Ore Mountains region about the Atlantic period and in the Subboreal the maximum extent of spruce occurred. Several regions are discerned as well as local ecotypes (*Picea hercynica, -bavarica, -saxonica, -harcyniana, -corcontica, -silesiaca, P. carpatica - beschidiaca*).

Originally, pure stands were created mainly in higher elevations of border mountains with optimum altitude between 600 and 1000 m above sea level. Norway spruce was the most frequent companion of beech and European silver fir (so-called *hercynian* mixture).

Secondary distribution began in the 18th C as a result of the Czech Directive for Forest and Timber (1754) which recommended cultivation of conifers mainly. Residues of natural forests were preserved only in inaccessible localities. Planting of Norway spruce monocultures outside its natural range resulted in increasing wood production, but forest calamities of various origin became more and more frequent. Unsuitable spruce ecotypes, repeated planting of the same species resulting in deprivation of forest soil, and spruce stands on labile soils affected by underground water are the main reasons for considerable problems.

Table 1. Norway spruce (*Picea abies*) in the Czech Republic (according to Comprehensive Forest Management Plan 1993)

	Spruce	Conifers	Total
Actual area (ha)	1 402 566 (54.3%)	1 994 794	2 542 658
Schwappach's site index	3.4		
Average age	60	61	60
Growing stock (1000 m^3)	374 297.3 (64.5%)	495 041 (85.3%)	580 200 (100%)
Area by age classes (ha)			
1	130 996		
2	101 703		
3	115 628		
4	83 715		
5	102 942		
6	148 590		
7	138 506		
8	143 265		
9	153 547		
10	117 544		
11	72 389		
12	42 910		
13	22 858		
14	12 707		
15	7 709		
16	2 948		
17	4 609		
Annual allowable cut (1000 m^3)			
Final cutting	5 902.9	8 050	9 041
Thinnings	1 712.0	2 052	2 493
Total	7 614.9	10 102	11 534
Annual planned restocking (ha)	16 976.0 (48.9%)	26 294 (75.8%)	34 692 (100%)
Share of area: species composition (%)			
Natural (by Plíva 1986)	11.2	34.7	
(by Šindelář 1994)	15.0	35.0	
Actual	54.3	77.0	
Optimum	40.0	68.0	
Target (1985)	50.0	73.4	
Reforestation plan, 1993-2002 (%)	49.9	75.6	

It is supposed that originally in the natural species composition Norway spruce covered 12-15% of the forested area. The current extent is 55%, an objective derived from management models (52%), the Comprehensive Forest Management Plan, 1991 (48%) and the supposed optimum (40%).

Information about the current status of Norway spruce is presented in Table 1 and Fig. 1. Norway spruce is present in various levels in several Forest Vegetation Zones (FVZ; based on climatic characteristics, elevation above sea level, average temperature, annual precipitation and length of vegetation period), usually from FVZ 2 (beech-oak) to FVZ 8 (spruce).

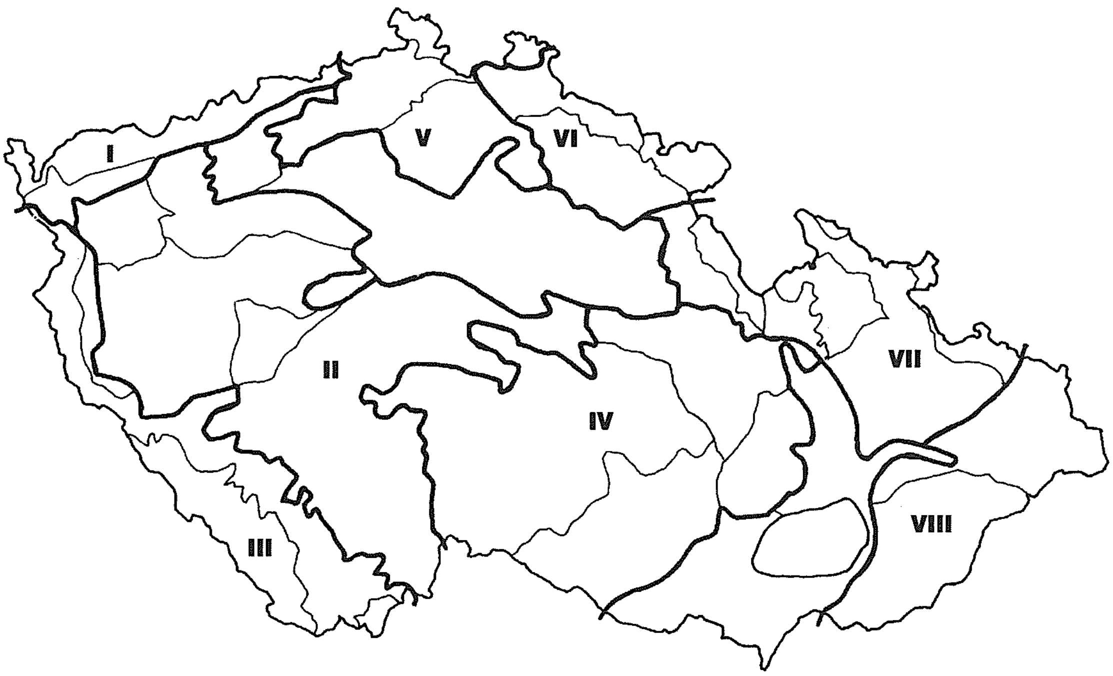

Fig. 1. Natural Norway spruce seed zones of the Czech Republic: I, Ore Mountains; II, Central Bohemia; III, South Bohemia; IV, Bohemia Moravian Uplands; V, North Bohemia; VI, East Bohemia; VII, East Sudets; VIII, West Carpathians

Conservation aims and the current state of conservation activities

Application of the principle of sustainable development in all forests (through special management and use of forests in such a way and extent that their stability, biodiversity, production and regeneration capacity fulfill useful roles in the forest) is one of the basic strategic continuous targets of the Czech forest policy. Current results of provenance research gave us information on geographical variability of qualitative and quantitative characteristics and reactions of various populations to different site conditions. These results are used in forestry practice as 'Directives for certification and ensuring of reproductive material sources and its transfer' (valid from 1988), taking into account the use of different provenances in the Czech Republic and following a definition of seed-collection regions and recommendations for the transfer of seed material within and among the regions. Slight modification of the respective rules is in preparation.

The basic principle for designation of seed zones and seed material transfer is to use certificated reproductive material of local origin. Transfer of seed material, seedlings and transplants to other forest regions is realized in the same seed zone and vegetative forest type (admissible tolerance is ± one degree). Seed zones are defined for Norway spruce; the Czech Republic adopted respective regulations many years ago. There is a fear that all these principles could be neglected in the present period of transformation.

The Ministries of Agriculture and Environment are responsible for conservation of genetic resources of all forest tree species. The Forestry Research Institute has a special charge by a MoA to solve tasks relevant to gene resources conservation.

The concept of gene-resources preservation of existing institutions administering state forests (Forests of the Czech Republic - LČR) is based on standard approaches and long-term experience and research recommendations. Considering the economic limitations the concept is minimal; nevertheless it is the base that should be used in legislation focused on preservation and improvement of forest gene resources. Besides natural regeneration, which is preferred, there are other measures (both *in situ* and *ex situ*) for protection and reproduction of gene resources of forest-tree species which have been realized in practical forest management and investigation programmes in individual Forest Zones:

- seed collection, certified stands .... basic measurements
- gene bases .... basic measurements
- seed orchards, clonal archives .... supporting measurements
- seed stands .... supporting measurements
- mother stands .... supporting measurements
- selected trees, plus trees .... supporting measurements
- forest seed material bank .... supporting measurements
- trial/testing plots .... supporting measurements

For Norway spruce the following means are available:

Means	Number	Area (ha)
Certified forest stands approved for seed collection	103 777	
Gene bases		
Approved	135	66 889
Proposed (containing Norway spruce)	140	57 974
Seed orchards		67
Seed stands†		2 338
Selected plus trees	3059	

† Newly planted stands representing, in our view, certified stands approved for seed collection of the best A category. Their role is to save the genepool and later to be a source of seed; 2337.70 ha of such seed stands (1583.42 ha by artificial planting, 750.04 ha through natural regeneration) have been established for Norway spruce.

Concerning the aim of preservation of the whole genetic spectrum, not only partial populations and important single trees are subjects of our interest. Populations from marginal areas and extreme localities also have to be preserved. Such populations and single trees can be provided by genes important for breeding (adaptability, resistance). Different experimental plots, e.g. provenance ones, are also the form of preservation of spruce gene sources.

Provenance research is important from the viewpoint of the choice of suitable provenances, of their transfer and following designation of seed zones. FGMRI Jíloviště-Strnady takes part in the most important international Norway spruce trials (IUFRO 1938, IUFRO 1964/68) and, including bilateral collaboration in spruce provenance research, a total of 1522 populations (791 Czech ones) on more than 76 ha of plots are tested.

Of course, the Nature Preserves are of great importance for the revitalization and regeneration of natural or seminatural, and thus more stable, forest communities. Improving collaboration of employees and experts on nature protection and representatives of the forests of the Czech Republic resulted, in addition to other effects, in refusing demands to prevent any intervention in National Protected Regions. Some valuable elements of the protected zones often could be barely preserved without minimal management interferences. Seed collecting, self-seedlings and advanced growth can be used in other stands, often under the special management regime as gene bases (see above).

The protected areas at the present time are listed in Table 2. In two-thirds of them the Norway spruce plays an important role.

Table 2. Protected forest areas in the Czech Republic, 1995

Protected forestry areas	Number	Area (ha)
Large-scale protected territories		
National Park	3	111 120
Landscape Protected Area	24	1 042 365
Total	27	1 153 485
Small-scale protected territories		
National Nature Preserves	124	26 882
National Nature Monuments	100	4 801
Nature Preserves	450	16 491
Nature Monuments	866	25 752
Total	1 540	73 926
Land area		7 886 417
Forest soil		2 641 000

Information on populations already conserved by different methods

The areas most affected by industrial pollution are in the northern part of the country, in the infamous Ore Mountains. As reintroduction of the Norway spruce local populations is possible only after a substantial change in the current ecological conditions, an *ex situ* breeding programme was started 10 years ago. Where seed collection was still possible, cultivated seedlings were used as ortet for the next cutting propagation. From so-called 'resistant trees', grafts were prepared; about 150 clones are available.

Breeding programmes represent one form of genepool preservation. Their aim is preservation of autochthonous spruce populations. They are gradually prepared for individual regions.

Allochthonous populations also are taken into consideration. The first programmes prepared by Šindelář for the Krkonoše-Giant Mountains and the Bohemian-Moravian Uplands were based mainly on cuttings. Later the FGMRI started with complete programmes including testing of cultivated material (Ore Mountains, Jizerské hory Mountains and Šumava Forest regions).

The unsuitable situation of our forests necessitates development of new methods of vegetative propagation. *In vitro* propagation of trees by organ cultures and somatic embryogenesis is being tested and used for rapid multiplication and production of individuals with desirable genetic traits. These biotechnological methods are also used for production of more resistant or the most threatened trees.

It is supposed that cryopreservation is not the method which should be used for conservation of Norway spruce or other species genepools in the Czech Republic. Ongoing tests, e.g. with Norway spruce from Jizerské hory Mountains in 1993, seem to be too expensive. A seedbank with deep freezers is probably the best method. Before storing, the seed material is treated and then stored in vacuum polythene containers and kept at 25-35°C below zero. Experiences by others suggest that for Norway spruce the storage period should be 30-40 years. A larger number of smaller samples of regional-population seeds should be stored in the genebank of the Crop Production Institute.

Threats to Norway spruce genetic resources, their management and protection

Mainly around developing industrial agglomerations the symptoms of emission impact are visible. Usually higher elevations have been damaged heavily and local spruce populations in some regions are seriously threatened.

It could be stated that all high-mountain and mountain ecotypes are threatened in every forest region. Their situation is usually critical because they are the remainders of original populations and have decreased ability of fructification. (On the other hand, we can find the fructification on some exposed localities but collection is not economical.) Considering the insufficiency of spruce seeds in the highest areas, part of the planting stock is grown vegetatively, usually through cuttings.

Damage to spruce development (according by ICP Forests):

Defoliation (%)	Year						
	1986	1987	1988	1990	1992	1993	1994
0 - 9	23.1	21.9	9.0	7.6	1.9	6.5	9.2
10 - 19	24.1	37.1	23.8	19.0	14.8	19.4	30.8
20 - 29	26.4	21.0	26.8	23.2	25.5	24.2	54.4
30 - 59	20.2	17.8	36.2	35.6	50.5	43.2	3.7
60 - 100	4.2	2.2	4.2	4.6	7.3	6.7	1.9

Important populations

Uplands ecotype

Forest Vegetation Zone (FVZ) (1) 2-4

It is not important as regards the area covered but it is supposed that it could have merits which should be used if the forecast of climatic changes become true. This ecotype, characterized by narrow cylindrical crown and thin branches, is already very rare in forest stands.

Populations from Central Bohemia and the central part of the Vltava River valley are of the main importance.

Higher elevation ecotype

FVZ 5-6

Ecotype of mid-elevations is the best one from the productivity point of view. Original populations are also rare; many labile monocultures of unknown origin prevail here.

Populations from Beskydy Mountains and the Bohemian-Moravian Uplands are considered to be the most valuable.

Mountain ecotype

FVZ 8

Characterized by very narrow crown with thick branches to the trunk. Artificially replaced by lower-elevation spruce in many localities in the past. Usually in a mixture with higher-elevation ecotype in FVZ 7.

The most important regions are: Šumava Forest, Slavkovský les (Kaiserwald), Jizerské hory Mountains, Krkonoše - Giant Mountains, Orlické hory Mountains (Adlergebirge), Jeseníky Mountains (Altvatergebirge), Beskydy Mountains. Populations from Beskydy region are known as very adaptable, with broad ecovalence and viability in old age (200 years and more). They usually have abnormal productivity and should be used in other natural forest regions of the Czech Republic.

It is supposed that our Norway spruce gene resources are, except for spruce from FVZ 8, sufficient if we are able to use all the available reproductive sources in the framework of relevant programmes for conservation and reproduction of this species.

Weakened forest stands and changed climatic conditions (winters without frosts, dry and hot springs and summers) are serious causes of the increasing trend of various damaging insects. As regards Norway spruce, except for bark beetle (*Ips typographus*), outbreaks of the following insects should be of importance: *Lymantria monacha* (about 622 000 ha were infested in 1994), *Zeiraphera diniana, Cephalcia abietis, Pristiphora abietina, Pissodes* sp., *Orgyia antiqua, Pachynematus montanus, Epinotia tedella, Pachynematus scutellatus.*

Relevant research activities and needs; further development of conservation strategies

General breeding strategies and conservation programmes have been prepared for all species, including Norway spruce.

The responsibility for practical genepool conservation in general is with the Forestry and Game Management Research Institute (FGMRI), Dept. of Biology and Breeding of Forest Tree Species (Beran, Buriánek, Frýdl, Hynek, Malá) and Research Station FGMRI at Uherské Hradiště (responsible for gene sources certification and evidence and seed testing). Forestry faculties are involved in spruce conservation in central Bohemia (Kostelec n.Č.l.) and Jeseníky/Beskydy region in northern Moravia.

Administration of Landscape Protected Areas (under the legal force of Ministry of Environment) is in some cases in collaboration with FGMRI, and special regional conservation programmes.

Of course, the activities of administration state forests (LČR) have to be mentioned. The 'genepool experts' of LČR deal with the abovementioned matters in the forestry practice of eight administrative regions.

Public awareness of the importance of forest genetic resources

In the State programme on environment protection, there are different projects prepared in many regions (e.g. in protected zones), aimed at gradual regeneration of forest communities, characterized from the species composition, provenance and spacing view as 'semi-natural forests' or nature stands. The fact that in many cases the positions and statements of nature protection authorities and forestry institutions are similar is considered as very positive, as such an approach results in concrete local or regional agreements on cooperation.

Unfortunately we are still waiting for a new Forest Act and subsequent legislation. Forests became a political matter and not only 'environmentalists' but also practical foresters are afraid of a new situation: there are about 145 000 new small owners of forests in our country (small forest means less than 50 ha, but unfortunately the average area of such 'small forests' is about 2 ha).

We are afraid that the public has other troubles in mind. In this situation foresters need more competent and skilled access to public education and information at all levels (from schools to MPs). It seems that in the present transformation period nobody has an interest in forests—after all, they grow by themselves and for a long time—except new owners and their lobby groups.

As there are too many other money-consuming problems, forests are usually put off as in the past (GDP of forestry is less than 1%). Consequently, long-term activities, research and education are in a bad state because of drastic cuts in research budgets and huge staff reductions.

The most urgent needs in Norway spruce conservation

Devastating anthropogenic impact on forests, in spite of the better conditions of air pollution in the last 2 years, is continuing.

The transition to multiple-resource management of forests is additionally complicated in consequence of current economic reform, especially restitution of private and public ownership and changes of organizational structure in forestry management.

The realization of necessary forest management practices is more expensive and budgetary problems can make difficulties during implementation of all respective needs.

The most important common needs of Czech forestry are:

- solving the ongoing problems mentioned above
  - air pollution (and depositions),
  - unsuitable tree species composition of forests,
  - too many hoofed game in forest stands,
- finishing the transformation processes,
- adopting a new Forest Act,
- changing the approach to the forest and forestry in general,
- step-by-step solving of the problem of the relationship between foresters and environmentalists,
- creation of a stable and long-lasting system of education and research activities funding.

The establishment of the 'forest seed bank', prepared by the Forests of the CR Seed Enterprise in Týniště nad Orlicí, will be an important measure. Recently its status is under discussion, and collaboration with the genebank of Crop Production Research Institute (VÚRV Ruzyně) is expected.

The preservation of gene resources and the use of proper genetically suitable seedlings by the new forest owners has to be ensured by continuing education programmes, but mainly by the new Forest Act and Directives, which should be finalized as soon as possible.

An important part of current forestry is finishing the process of reprivatization and ensuring management control of all forest stands by experts. Failure to do so will have negative impact also on gene resources, bearing in mind that, in forests not professionally managed, overlogging, insufficient management of calamities, clear-cutting, neglecting the regeneration, and generally deterioration of forest state and stability can occur.

The creation of a functional system of state administration that associates small owners, expert consultations and control of management, instruments for motivation and compensation of forest owners' interests will be of importance.

All the abovementioned items may be considered as too general but it concerns mainly Norway spruce, which has a wide distribution and occurrence.

Last but not least, moral and financial support of people dealing with the forest problems is necessary, considering that forests, in which the Norway spruce plays an important role, whatever their current state, are an important part of the state welfare.

Basic targets

- preservation and improvement of species variability
- rational use of gene resources (national system for better forest seed use, organization of forest seed supply and creation of seed inspection is recommended)
- support of natural regeneration
- education of foresters and the public
- approaching the positions of nature protection bodies and foresters at all levels.

Other targets

- own forest seed material sources
- selection of plus trees and populations not considering the species origin
- closing of the programme of clonal archives establishing the mountain spruce.

All measurements have to be based on the new legislation reflecting social and economic changes but respecting the forestry ecological approach in forest management. Following common principles, foresters must overcome the pressure of economic lobbies or/and too green ideas to be able save our forests as the most important part of the environment and a heritage for future generations.

FAO activities in forest genetic resources with special reference to activities related to EUFORGEN

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Introduction

According to its Constitution, the main functions of the Food and Agriculture Organization of the United Nations (FAO) are (i) to serve as an international forum and secretariat for food and agricultural matters (including fisheries and forestry), (ii) to provide technical assistance in its field of competence, and (iii) to promote exchange of information and know-how between nations. Assistance to member nations in the conservation and wise utilization of natural resources is clearly mentioned as being the responsibility of the Organization.

Plant genetic resources have been a concern of FAO since its early years. A Panel of Experts on Plant Exploration and Introduction was established in 1962 and the Organization housed the International Board for Plant Genetic Resources (IBPGR) from its establishment in 1974 until 1994 (IBPGR is now the International Plant Genetic Resources Institute, IPGRI).

This paper briefly presents FAO's activities related to forest genetic resources, with emphasis on activities related to the European Forest Genetic Resources Programme (EUFORGEN).

Mode of operation

FAO's activities related to forest genetic resources are guided by the Panel of Experts on Forest Gene Resources, a Statutory Body of FAO established in 1968. The 15 members of the Panel are appointed by the Director General of FAO in their personal capacity. They all have wide-ranging experience and knowledge of activities and issues related to forest genetic resources in their country, subregion or region of origin. The Panel meets every 3 or 4 years. In addition to its recommendations for action in the short, medium and long terms, the Panel draws up and regularly updates a list of priority species by region and operation (exploration, collection, evaluation, conservation, utilization). The last (8th) session of the Panel took place in June 1993; its report is available in English, French and Spanish.

In essence FAO works through, or in cooperation with, the national organizations of its member countries. Although FAO is a technical assistance organization rather than a financing agency, modest Regular Programme funds are available for use as 'seed money' to support actions in response to needs identified by the Panel. In addition, externally procured funds contribute importantly to FAO activities, particularly in technical assistance projects in the developing countries. FORTIP is a good example of such projects.

FAO cooperates closely and regularly with other international organizations (such as Unesco, UNEP, IPGRI and IUFRO), with regional and subregional organizations and with bilateral cooperation agencies.

FAO activities in forest genetic resources

General activities: technical support, information, coordination

Technical support, especially to developing countries, for the conservation and wise use of forest genetic resources is an important task of FAO's Forestry Department. This support includes all aspects of work, from programmes for the *in situ* conservation of forest genetic resources to assistance for the development of sound tree improvement programmes, the establishment of seed centres, and advice on sustainable forest management, incorporating conservation concerns, and on appropriate seed sources for tree planting and reforestation projects. Assistance is provided, on request, directly to the national organizations or via field projects.

In addition to its supervision of and contacts with approximately 200 forestry field projects, the Department maintains close relations with over 60 seed centres and a similar number of research institutes and departments concerned with forest genetic resources conservation and improvement in developed as well as developing countries. The quality and wide range of contacts the Department maintains with institutions active in the field contribute to the fulfilment of its information and coordination mandate and helps it promote cooperation between developed and developing countries, as well as among developing countries.

FAO has over the years prioritized the dissemination and exchange of information to avoid overlap and duplication of efforts on a global level. Coordination of activities is facilitated by the work of the FAO Panel of Experts on Forest Gene Resources, which considers reports and information on ongoing and planned activities of all relevant organizations. The FAO Forestry Department Newsletter, Forest Genetic Resources, published annually in three languages, is a valuable additional medium in this regard, and regularly includes contributions from a range of institutions active in the forest genetic resources field.

Workshops and symposia are other means for information exchange, coordination and collaboration. FAO regularly organizes, cosponsors or contributes to such meetings in cooperation with other national and international institutions, including IUFRO.

Exploration, collection, evaluation of forest genetic resources

One of the first internationally coordinated works in the field of forest genetic resources which convincingly demonstrated the value of systematic exploration/evaluation was the wide-ranging collections of *Eucalyptus camaldulensis*, carried out in the 1960s by the Forestry and Timber Bureau in Canberra, Australia, with technical and financial assistance from FAO's Forestry Department. FAO-coordinated provenance trials were subsequently established on 32 sites in 18 countries.

Subsequent seed collections, followed by internationally coordinated provenance trials, include collections of pines and hardwood species in Central America and Mexico, *Tectona grandis*, *Gmelina arborea*, *Acacia*, *Casuarina* and *Eucalyptus* species, *Azadirachta indica* (neem), and moist and arid-zone hardwoods in West Africa. All these collections have systematically been made in cooperation with national institutes, and where moderate funding has been available from FAO, such funds have been channelled to permit the full and active participation of such institutes in the work.

Conservation of forest genetic resources

Comprehensive trials are of little value if the tested provenances have disappeared by the time the results are known. FAO has given due attention to conservation of forest genetic resources both *in situ* and *ex situ*.

In collaboration with CSIRO, OFI and DANIDA, 'semi-bulk' quantities of seed of proven provenances or provenances in danger of genetic depletion have been procured for the establishment of *ex situ* conservation stands in interested countries, as a medium-term conservation measure. The species concerned so far are mainly tropical pines, eucalypts and *Acacia* and *Prosopis* species.

Through a recent UNEP-assisted FAO project on *in situ* conservation of forest genetic resources, pilot *in situ* conservation areas have been established in collaboration with the Governments of Cameroon, Malaysia, Peru and Yemen.

Utilization of forest genetic resources

Wise and appropriate use of forest genetic resources requires building up or strengthening the national expertise and facilities in developing countries, including assistance in establishing/strengthening national or regional tree seed centres and related improvement/conservation programmes. A large proportion of FAO's field projects includes these activities within the framework of wider development programmes. Exchange of know-how, information and genetic resources, and technical collaboration between countries, are also promoted, i.e. through the establishment of regional and international networks, as well as networking of institutes working in similar ecological conditions.

Activities in relation to EUFORGEN

The European Forest Genetic Resources Programme (EUFORGEN) was established as a follow-up to resolutions of the Ministerial Conference on Forest Protection in Europe, in its meetings in Strasbourg (1991) and Helsinki (1993). FAO is participating in the management committee of EUFORGEN, chaired by IPGRI. The general link between EUFORGEN activities and follow-up to the FAO Panel of Experts on Forest Gene Resources is evident. Furthermore, the activities of species-based EUFORGEN networks (the first four networks concern black poplar, cork oak, Norway spruce and 'noble hardwoods') are undertaken in coordination with other relevant FAO programmes. For instance, the first meeting of the black poplar network took place in conjunction with a meeting of the Executive Committee of the International Poplar Commission, a Statutory Body of FAO. FAO further provides coordination with relevant activities undertaken by research networks of Silva Mediterranea, a Statutory Body of FAO, concerning species which are found on both sides of the Mediterranean Sea, such as cork oak or the Mediterranean conifers.

The Fourth International Technical Conference on Plant Genetic Resources, which will be convened by FAO in Germany in June 1996, is another framework where activities of EUFORGEN should produce useful inputs. The International Conference and Programme for Plant Genetic Resources (ICPPGR) coordinates the preparation of the Conference. During the preparatory process, a costed Global Plan of Action for plant genetic resources will be developed, based on a Report on the State of the World's Plant Genetic Resources. Country Reports, requested from each country, will provide the foundation of both documents. The process is integrating Regional or Subregional meetings and scientific studies on important issues. The International Conference will formally consider the adoption of the Global Plan of Action. IPGRI is collaborating in the preparation of the Conference at the national and regional/subregional levels.

Two workshops, taking place in June 1995, will provide inputs to the international Conference: (i) the Workshop on Genetic Resources of North American Temperate Forest Species organized by the US Forest Service, and (ii) the Workshop on Genetic Resources of Boreal Zone Forest Species, organized by the Canadian Forest Service, which is of particular interest to the EUFORGEN Norway Spruce Network. Both workshops are organized in technical collaboration with FAO. They are very timely for providing inputs to the next session of the FAO Panel of Experts on Forest Gene Resources, planned to be held in October 1995, and in the International Technical Conference on PGR. EUFORGEN would be a good framework to undertake similar regional synthesis for European forest species.

Appendix I. List of participants

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Appendix II. Agenda

1. Introduction
   - 1.1. Welcome address — L. Paule
   - 1.2. Welcome address — E. Frison, J. Turok
   - 1.3. History of the Norway spruce gene conservation network — V. Koski

2. Presentations of the current situation by countries

3. Definition of the objectives of the Norway spruce network — H. Wolf

4. Descriptors and database for Norway spruce — T. Skrøppa

5. Criteria for the selection of populations for genetic conservation: current practice — H. Wolf

6. Identification of common research needs — A. Nanson

7. Identification of contact points in all countries — V. Koski

8. Agreement on network tasks and development of a workplan

9. Discussion on the International Technical Conference on Plant Genetic Resources
   - 9.1. Introduction — E. Frison
   - 9.2. Information on the Boreal Forest Workshop to be held in Toronto, Canada in June 1995 — T. Skrøppa
   - 9.3. Contribution of EUFORGEN to the ICPPGR process

10. Final session: Approval of the report