

Sustainable forest genetic resources programmes in the Newly Independent States of the former USSR

*Proceedings of a workshop
23-26 September 1996
Belovezha, Belarus*

G.G. Goncharenko, J. Turok, T. Gass and L. Paule, editors



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Introduction

Beyond their contribution to ecological balance, forests rich in genetic diversity provide social and environmental benefits and help meet increasing timber demands in a sustainable way. Forests in the countries of the former Soviet Union cover 28% of the global forest surface. More than 570 species of forest trees and over 1050 shrubs grow in these forests. They hold genetic resources of global importance which consequently deserve great attention.

A comprehensive document "Regulations for the designation and conservation of gene pools of tree species in the forests of the USSR" adopted in 1982, represented the basis upon which activities on forest genetic resources were implemented until the dissolution of the former Soviet Union. Research on genetic variation, evolutionary history and adaptation, *ex situ* methodologies and tree breeding was conducted by numerous scientific institutes. The scientific knowledge provided by these studies for implementation in forestry practice is often unknown to the western world because of language barriers and other isolating factors such as divergences in scientific approaches and methodologies.

The political and economic changes of the early 1990's have considerably changed the socio-economic and institutional context in which the conservation and management of forest genetic resources are carried out. In the Newly Independent States, coordination committees have been established or re-created, and comprehensive national programmes initiated. Nevertheless, the future of forest genetic resources conservation in the countries of the former Soviet Union gives rise to serious concern. Despite the presence of elaborated national strategies, institutional structures and human resources, restricted budgets are the main constraint for further development of forest genetic resources programmes.

The early 1990's also brought about a number of new collaborative projects with partners in the western world. Scientific contacts and cooperation between institutions, previously maintained at limited levels despite the political barriers, achieved a new quality and intensity.

At the international level, important political processes have been underway since the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, in June 1992. These need to be translated into concrete strategies and actions. In Europe, a number of initiatives in forestry have begun to take action to meet these expectations. The Ministerial Conferences on the Protection of Forests in Europe (Strasbourg 1990, Helsinki 1994, and Lisbon 1998) set the basis for specialized international networks on forest genetic resources.

Within the above-mentioned context, the International Plant Genetic Resources Institute together with the Forest Institute, Gomel, Belarus, convened a Workshop on sustainable forest genetic resources programmes in the countries of the former Soviet Union. Although, the Workshop was a first opportunity to meet and renew collaboration since the dissolution of the USSR, it benefited greatly from the strong expertise and the long tradition of cooperation among the participants and their institutions well before the beginning of the 1990's. The objectives of the Workshop were to provide an overview of the current activities, to reassess needs and priorities, and to emphasize the interest and capacities of the Newly Independent States to be proactive in international cooperation.

These Proceedings result from the Workshop which was held in Belovezha, Belarus in September 1996. They should be seen as merely a status report, reflecting

a period when pieces of the old system are still in place, when enormous challenges are being faced and new programmes must be defined to secure sustainability in the long term. Some of the important players in the area of forest genetic resources may not be represented or were unable to attend this Workshop. It is hoped that they will be able to participate in future workshops of this kind.

Translation of the text from Russian into English followed the original papers as closely as possible. However, the particular scientific terminology, and different forestry concepts in general, make direct translations of Russian terms rather difficult. The papers were, therefore, edited for clarity to readers not acquainted with the forestry terminology used in the former USSR. Detailed explanations of the specific terms and concepts exceed the ambitions of these Proceedings; their knowledge is helpful but not essential for reading the English text. The order of papers does not imply any sequence of importance or priorities; the presented order was found convenient with regard to geographic coverage, species concerned and the similarity of problems faced.

The organizers would like to express their thanks to the management and staff of the Forest Institute in Gomel for their efficient logistics and their overwhelming hospitality. The very useful participation of Drs. C. Mátyás, H. Muhs and L. Paule in the technical discussions is also acknowledged with thanks. Our thanks for the original translation of submitted texts are due to E. Guseva, Belarus. The Workshop was organized with financial support from INTAS (project INTAS-93-1181).

Status, protection and rational use of forest genetic resources in Moldova

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The Republic of Moldova is a sparsely wooded country. According to the data obtained, the forest fund covers 379 100 ha, including 317 600 ha (83.8%) of forest area. The total growing stock is 35.2 million m³. The area of the forest fund covers 11.2% of the total area of the country. The corresponding proportion of forest area is 9.4%. For each inhabitant of the country there is only 0.07 ha of the forest area and 8.6 m³ of timber.

A major part of the forest fund is under responsibility of the State Association "Moldsilva". An area of 325 000 ha or 85.5% of the total area of the forest fund is within the jurisdiction of the above organization. The rest of the forest fund (54 000 ha) is managed by other enterprises.

The principal forest-forming species of the natural stands are oaks, which cover 135 000 ha. These forests are composed of three oak species: sessile oak (*Quercus petraea*) covering 54 400 ha, pedunculate oak (*Q. robur*) covering 48 500 ha and pubescent oak (*Q. pubescens*) covering 4700 ha.

Distribution of forests is influenced by the zonal and vertical division of the territory. *Quercus petraea* occurs on separating ridges and slopes with different exposures in the central part of Moldova (180–400 m above sea level). *Quercus robur* occurs in lowlands of the central part of Moldova. It predominates in the natural forests of the northern part of the country. *Quercus pubescens* grows in the southern part of Moldova. Willow, poplar and oak riparian forests occur in the deltas of rivers and cover 15 000 ha.

Hence, there is a great diversity of forest vegetation in spite of the small territory of the country. We distinguish 12 zonal and 6 azonic forest types.

In Moldova, 140 species of the dendroflora can be found, including 50 tree species and 94 shrub species. Of all the tree and shrub species 22 fall under the category of rare species, many of which occur at the boundaries of their distribution areas. For example, *Carpinus orientalis* and *Pyrus elaeagnifolia* are Mediterranean species growing at the northeastern boundaries of their ranges. *Prunus avium* and *Betula pendula* occur at the eastern boundaries of their distribution.

In 1975 the Government of Moldova arrived at a decision to establish nature protected areas aimed at the conservation of genetic resources. Three protected forest areas, 5 nature reserves, 10 protected areas of natural landscapes and 22 nature monuments were designated for this purpose. Two systems of forest belts and 372 centuries-old trees were placed under state protection. The protected forests cover 35 000 ha or 9.1% of the total forest area or 14% of the area covered by natural forests.

Another way of genetic conservation of species is to transfer valuable and seriously endangered species into botanical gardens. In this connection in 1972 in the Botanical Garden of the city of Chisinau an area of 12 ha was designated for the establishment of expositions of main forest types and forest associations of Moldova. To date, plots for 12 principal forest types have been established. These stands are 20–24 years old. The trees are 15–20 m tall and 20–30 cm in diameter. In

these plots, individuals of the main tree, shrub and grass species characteristic for each forest type were planted.

A breeding inventory of about 40% of the most valuable oak plantations (*Quercus robur*, *Q. petraea* and *Q. pubescens*) was conducted in the state forest fund of Moldova. Once certified and registered (in May 1992), the following seed production units became a part of the permanent seed base:

1. Permanent seed production areas covering 1409 ha (Table 1).
2. Twelve *Quercus robur* and *Q. pubescens* clonal and seedling seed orchards covering 57.8 ha. These plantations reached their productive age. In addition, there are *Q. robur* and *Q. pubescens* clonal and seedling seed orchards but have not been certified yet. They cover about 30 ha.
3. Forest genetic reserves: eight reserves cover 713.2 ha (Table 2). Principal forest genetic reserves are located in the Bender and Straseni forestry districts.
4. Plus trees: a total of 81 trees were selected, including 32 trees of *Q. robur* and 49 trees of *Q. pubescens*.

A number of examples of the decrease of artificial forest stands have been documented over the last few decades. For example, *Robinia pseudoacacia*, which was introduced into Moldova about 150 years ago, covers presently some 30% of the total forest area. Over this period no examples of decrease of the acacia stands were recorded. After the winter of 1994–95, stands of this species suffered greatly in all regions of Moldova. The decreasing stands cover some 40% of the total area covered by this tree species.

There are a few documented examples of more serious decrease of the man-made oak stands. For example, in 1996 a 40-year-old oak plantation covering 80 ha was observed which suffered heavily from drought during the last two years. The percentage of damaged trees was about 95%. This is probably because it was an artificial plantation established with the acorns collected from trees in a completely different zone of seed origin (western Ukraine).

We also documented some decreasing, damaged stands which had been established from seed material collected in autochthonous stands in Moldova. Their decline is associated with the use of acorns collected from stands growing in different ecological conditions.

Table 1. Permanent seed production areas

Species	Number	Area (ha)
<i>Quercus robur</i> L.	52	467.2
<i>Quercus petraea</i> (Mattuschka) Liebl.	22	355.2
<i>Quercus pubescens</i> Willd.	7	179.3
<i>Quercus borealis</i> Michx.	2	31.6
<i>Fagus sylvatica</i> L.	7	54.1
<i>Robinia pseudoacacia</i> L.	12	162.5
<i>Juglans nigra</i> L.	5	68.3
<i>Carpinus betulus</i> L.	3	43.8
<i>Sorbus torminalis</i> (L.) Crantz.	1	2
<i>Cornus mas</i> L.	2	8.5

Table 2. Forest genetic reserves

Species	Number	Area (ha)
<i>Quercus robur</i> L.	2	433.5
<i>Quercus petraea</i> (Mattuschka) Liebl.	3	175.5
<i>Quercus pubescens</i> Willd.	3	104.2

Such cases made us revise the basic terms of establishment of forest stands in our country. The key issue is to establish forest stands respecting the ecological and genetic basis. Theoretically the ways to its solution are clearly defined. At present some researchers of the Institute of Botany and other institutions in Moldova work along this line. Unfortunately, the capacity employed is insufficient, and it is currently impossible to extend the scope of work.

To date, many natural populations of the principal forest-forming tree species, *Fagus sylvatica*, *Quercus robur* and *Prunus avium*, have been investigated. We embarked on the study of population variability in *Q. petraea* and *Q. pubescens*. The results of these investigations were published in journals of Moldova and in Romania. On the basis of the investigations performed, guidelines for the designation of oak seed zones (zones of seed origin) and the creation of permanent forest seed base were drawn up.

Forest genetic resources of the Ukraine

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The Ukraine is a sparsely wooded country. Although the area of the Republic is 603 700 km², its forest area covers somewhat more than 7 million hectares. The proportion of forest area is 14.2%. However, there are a few regions in the country which are favourably endowed with forests, such as the Carpathians (the proportion of forest area is 35.9%), the Crimea (30%) and Polissya (29.8%). At the same time in the southern and northern steppe zones, the forest area hardly amounts to 2 and 5.2%, respectively. The main Ukrainian forests are concentrated in Polissya and in the Carpathians. The forests of these regions, particularly those growing in the Carpathians, are notable for the rich species composition of stands and their high productivity.

Beech, beech-fir, beech-fir-spruce and oak-beech forests growing on the slopes of the Ukrainian Carpathians fulfil important soil protection, water regulation and climate-forming functions. Mature climax stands that have not been disturbed by humans still persist in high mountains which are inaccessible to modern heavy-duty harvesters.

Polissya is the principal plain forest region of the Ukraine. As in other flat parts of the country, in Polissya there are very few mature forests because of excessive felling. *Pinus sylvestris* L. and *Quercus robur* L. are the main species. At the same time the original, climax forest of the Ukrainian Polissya is genetically very valuable since it is precisely the Polissya pine forests that are the most productive of those occurring in the entire distribution range of the species.

The main functions of forests occurring in the forest-steppe, steppe and the Crimea are: field and soil protection, water conservation and recreation. Resistance of the man-made forest ecosystems in the steppe regions of the Ukraine has decreased in the last few years. As a result the main species, pine and oak, decline, are damaged by pests and diseases and even vanish. Often improper choice of the seed material which does not correspond to the adaptive site conditions is the primary cause. The results of the investigations show that avoiding mistakes and establishing more resistant stands is possible if intraspecific diversity with regard to both geographic and typological aspects is fully taken into account.

In the Ukraine scientists have been deeply involved in research on the conservation of genetic resources of forest tree species for about 30 years. To date, more than 500 genetic reserves for 30 species have been designated in the natural stands. The total area of the reserves covers more than 27 000 ha, including about 6500 ha covered by *P. sylvestris*, more than 7700 ha covered by *Q. robur*; more than 3300 ha covered by *Picea abies* (L.) Karst., about 1500 ha for *Abies alba* Mill. and more than 4300 ha covered by *Fagus sylvatica* L. Genetic reserves were also designated in the stands of relict species such as *Pinus stankewiczii*, *P. cembra* L., *P. pallasiana* Lamb., *P. mugo* Turra, *Juniperus excelsa* M.B., *Taxus baccata* L., *Pistacia mutica* Fisch. et Mey and others.

The results of the investigations of about 200 sample plots established in the reserves showed that these genetic reserves adequately reflected the typological structure and composition of the stands in the territory of the country. For the most

part, these are highly productive stands. Low densities and productivity are typical of the reserves designated for rare relict species.

In the genetic reserves more than 3000 ha of seed stands for 9 species were selected, including about 800 ha covered by Scots pine and about 1900 ha covered by pedunculate oak. More than 4000 plus trees of 33 species, including more than 1000 Scots pine trees and about 1300 pedunculate oak individuals, were selected in the reserves and seed stands. The genetic resources of the Ukrainian forests being depleted, a decision was taken to select two categories of plus trees. The trees whose height and diameter values were higher by no less than, respectively, 10 and 30% than the mean ones exhibited by the whole of the stand and whose stems were flawless belonged to the first category. The tree individuals whose height and diameter values were higher by as much as, respectively, 10 and 30% and whose stems were of high quality fall under the second category ("the best normal trees"). Plus trees, essentially Scots pine trees, are also being selected in the Exclusion Zone around the Chernobyl Atomic Power Plant for resistance to radioactive contamination. To date, 20 trees have been selected. Forty-nine highly resinuous Scots pine individuals have also been selected.

Outside their habitats, the populations and ecotypes are conserved as seed progenies in provenance trials and other experimental plantations. In the Ukraine a wide network of such plantations has been established with 14 species since early in this century. The total area covers more than 260 ha with more than 1700 provenances, including some 400 Ukrainian ones. The rest of the provenances were brought from abroad.

Clonal archives are intended for *ex situ* conservation and propagation of plus trees. In the Ukraine around 120 ha of clonal archive plantations of principal forest-forming species have been established with more than 1800 clones. In the largest Scots pine clonal archive (the national archive) there are more than 500 Scots pine plus trees represented, originating from various Ukrainian regions. A similar clonal archive was also established for pedunculate oak.

Clonal seed orchards are being established with vegetative progenies of plus trees in order to supply forestry practice with seeds of principal forest-forming tree species. In the Ukraine, clonal seed orchards have been established with 18 tree species covering more than 1400 ha, 64.4 ha being of second and next generation seed orchards.

To date, more than 100 ha of seedling seed orchards have been established with 360 plus tree progenies of 6 species.

As well as being a source of seeds and cuttings, clonal archives are used to study phenotypic and reproductive peculiarities of clones, to carry out experiments on stimulation of production, hybridization and other investigations.

Field tests are established with seed progenies of plus trees, from seed orchards and natural populations to study heritability of traits in selected tree species. By 1 January 1996 more than 160 ha of field tests were established with about 3600 half-sib and full-sib progenies. In 15 to 20-year-old experiments the trees show differences in height, diameter and stem quality. Some individuals that are of obvious breeding interest are selected. Researchers have already selected 114 Scots pine and 40 pedunculate oak trees (secondary selection). They are used for the establishment of seedling and clonal seed orchards. Seed progeny trials are also performed.

On the basis of the results of the studies in the field tests (half-sibs) carried out for many years, candidates for best performing, 'elite' trees were selected out of the

individuals whose progenies excelled considerably in growth rate. A total of 36 candidates for 'elite' Scots pine trees and 15 candidates for 'elite' pedunculate oak trees were selected. Second-generation experimental plantations are being established with their seeds to analyze their combining ability.

In collaboration with the Forest Institute of the Academy of Sciences of Belarus we undertook investigations into genetic structures of conifers by means of molecular genetic methods. To date, interpopulation genetic diversity and differentiation in 7 *Pinus sylvestris* and 3 *P. mugo* populations have been studied using isoenzyme markers. Three *Abies alba* populations are being analyzed. *Pinus densiflora*, *P. hamata* and *P. cembra* were also studied. Isoenzyme investigations of *Abies alba* seed orchards are also being carried out.

The understanding of resistance to both biotic and abiotic factors is being developed. Efforts are underway to determine molecular genetic markers of resistance and their use in breeding of various species. In the conditions of the southeastern arid steppe of the Ukraine wide research has been conducted on the resistance of various ecotypes of Scots pine to drought for more than 20 years. The linkage of biochemical genetic markers with different levels of organization of the plant organism is studied. In the future such investigations will make it possible to identify and select at an early age the most adaptable plants and those possessing valuable genotypes. Unfortunately, to perform research along this line and to implement the early results in the large scale is not possible owing to the lack of financial support.

At the present time forest geneticists and breeders in the Ukraine are challenged with the task of increasing productivity and resistance of new stands on the basis of conservation, profound study and rational use of the available genetic resources. However, research along this line is retarded due to the lack of financial and material support. For the same reasons the risk of losing valuable *in situ* genetic resources of forest species is high. Scientific research and practical work on *ex situ* forest genetic conservation are delayed drastically.

We express our gratitude to the international scientific community for giving us solid support. Thanks to the assistance of international organizations we became better informed and were given an opportunity to participate in international fora. Further expansion of international cooperation which assumes more concrete and effective forms has considerable promise and its necessity is beyond question.

Protected areas of the Crimea as the basis for conservation of the plant diversity

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Protected areas should be a core of the future forests of the Crimea. They should assure a natural ecological balance of the processes occurring on mountain slopes and contribute to preservation of the unique climatic conditions and landscapes.

To date, 62 nature protected units in forests have been designated and divided into different categories of protection. Their total area is 55 787 ha or 17.9% of the total forest area or 2.1% of the total area of the Crimea (Table 1), which corresponds to international standards.

All these protected units of the Crimea were designated in conformity with their scientific, historical, cultural, aesthetic and economic importance. Among them are various protected areas, state nature reserves, nature monuments, protected forests, etc. At the same time they are true islets of undisturbed nature in the region.

It should be noted that both the results of the studies carried out for many years by the Crimean Mountain Forest Experimental Station and the data found in the literature support the fact that the protected vegetation is unique not only for this territory, i.e. the protected areas, but the whole of the region as well. Hence, the larger the nature protected area, the better the core of each unit will be protected.

Table 1. Categorized nature protected units designated in the forest fund of Crimea*

Name	Number	Total area (ha)
State nature protected areas	3	57599
State nature reserves, including:	8	4054
landscape	3	2167
botanical	3	1487
hydrological	2	400
State nature monuments, including:	8	359
complex	2	140
botanical	2	132
Hydrological	1	24
Geological	3	63
State protected forests	4	936
State nature reserves of local importance, including:	8	2190
Forest	1	128
Botanical	7	2060
Nature monuments of local importance, including:	30	133
Complex	4	25
Botanical	3	80
Geological	23	28
State nature parks – landscape/ orchards monuments of local importance	1	76
Total	62	65347

*) The state nature protected areas include 9560 ha of the Black Sea (part of the State Nature Reserve "Swan Islands").

In the conditions of intensive recreation one should adhere to a common principle irrespective of the category of the valuable protected unit when arranging its area. Essentially, the principle is to designate a strictly protected zone, or in other words, a core area which should be protected along with the designation of two additional zones.

The first one is the buffer zone which by its very nature is similar to the core area, protects the latter one and serves as a reserve which includes elements of the original vegetation (native forest types). The other zone is protective. Within this zone roads may be built and paths may be made. One can clear them through adjacent parts of the buffer zone in order to distract visitors from the strictly protected core areas.

The necessity for such an approach is based on the ideas of the insular biogeography and mathematical calculations performed by "Diamongs" programme. The results obtained show that the smaller the protected area, the sooner the conserved species will vanish. The larger the zones of a protected area are, the better its core will be protected. Hence, this approach to the arrangement of protected areas being put into practice, we shall be able to conserve the principal forest ecosystems in all woodland habitats. It is essential that this approach be applied to the arrangement of the area around genetic reserves and seed stands designated in the territory of the forest fund of the Crimea (Tables 2 and 3).

It should be noted that 25 genetic reserves (the total area is 981 ha) and seed stands (the total area is 7.3 ha), which embrace major Crimean pine (*Pinus pallasiana* D. Don.) populations, have been designated.

Genetic reserves and seed stands form a very important category of protected areas. They are the carriers of genetic evolutionary information. Their importance for the formation of future forests of the region must be emphasized.

In the future genetic and breeding programmes will serve as a basis for regenerating forest ecosystems in the mountains of Crimea, emphasis being given on the use of hybrids obtained from controlled crossings among plus trees taken from genetic reserves and seed stands. This may be explained by the fact that reproduction of phenotypically best individuals ensures the conservation and reproduction of valuable traits in next generations of trees.

Hence, only with hybrids will it be possible to obtain 'elite' seeds from second and succeeding generation seed orchards in the unfavourable site conditions of the Crimea noted for a chronic shortage of moisture. In this case, not only grafted material but morphologically and physiologically superior individuals (hybrids) as well should be used as seed sources.

Such an approach to the establishment of seed orchards and the collecting of seeds with high inherited qualities is scientifically justified. It is proved that the capacity for high growth rate, i.e. heterosis, may be observed only in trees of the second or third generations. Therefore, when creating a seed base according to the genetic and breeding criteria with the aim to collect seeds of high inherited qualities one may use the following programme of actions. The initial stage: clones of plus trees taken from the first generation seed orchards should be used as parent trees of first generation hybrids; the next stage: second and next generation seed orchards should be established with the use of these hybrids.

Table 2. Genetic reserves of principal tree species designated in Crimea

Tree species*	Locality	Site type	Age (yrs)	Area (ha)	Growing stock (m ³ /ha)
Crimean pine	Alushta state forest enterprise, Zaprudnenskoe for., c. 27	C ₁	100	23	430
Crimean pine	Crimean State Nature Reserve, Yalta for., c. 264	C ₂	100	4.7	360
Crimean pine	Yalta SFNR, Gurzuf for., c. 6	C ₂	100	31	440
Crimean pine	Yalta SFNR, Gurzuf for., c. 37	C ₁	110	9.1	420
Crimean pine	Yalta SFNR, Gurzuf for., c. 34	C ₂	110	7.4	720
Crimean pine	Kuibyshev state forest enterprise, c. 20	C ₂	90	40.1	260
Stankevich pine	Sudak state forest enterprise, Sudak for., c.s 43, 44	B ₀	240	25.8	210
Stankevich pine	Sevastopol state forest enterprise, Chernorechensk for., c. 54	C ₀	95	17	160
Crimean beech	Alushta state forest enterprise, Alushta for., comp. 24	D ₂	90	37	330
Crimean beech	Crimean State Nature Reserve, Izobilnoe for., comp. 73	D ₂	180	24	260
Crimean beech	Crimean State Nature Reserve, Central for., comp. 200	D ₂	340	8.7	510
Crimean beech	Simferopol state exp. for. enterprise, Perevalnoe for., comp. 26	D ₂	140	25	390
Crimean beech	Simferopol state exp. for. enterprise, Perevalnoe for., comp. 43	D ₂	110	16	350
Crimean beech	Kuibyshev state forest enterprise, Sokolinoe for., comp. 30	D ₂	90–150	19.4	260
Crimean beech	Belogorsk state exp. forest enterprise Ushchelnoie for., comp 30	D ₂	170	11	310
Sessile oak	Bakhchisarai state forest enterprise, Verkhorechie for., comp. 59	D ₂	90	5	230
Sessile oak	Belogorsk state exp. forest enterprise, Priyailinskoe for., comp. 41	D ₂	110	4.4	260
Sessile oak	Crimean State Nature Reserve, Izobilnoe for., comp. 78	D ₂	90	5.3	310
Sessile oak	Crimean State Nature Reserve, Bakhchisarai for., comp. 172	D ₂	100	19	300
Grecian juniper	Sudak state forest enterprise, Sudak for., comp. 45	B ₀	190	166.4	20
Grecian juniper	Sevastopol state forest enterprise, Chernorechensk for., comp. 83	B ₀	220	55	25
Yew	Simferopol state exp. for. enterprise, Perevalnoe for., comp. 11	D ₂	210	32	280
Wild pistache	Sevastopol state forest enterprise, Sevastopol for., comp. Ushakova Gully	C ₀	210	5	120
Strawberry tree	Sevastopol state forest enterprise, Laspinskoe for., Batiliman Forest	C ₀	140	196	110
Pubescent oak	Alushta state forest enterprise, Zaprudnenskoe for., comp. 32	C ₁	60	192	315
Total				978.3	

*) Crimean pine – *Pinus pallasiana* D. Don., Stankevich pine – *P. stankeviczii*, Crimean beech – *Fagus taurica*, Sessile oak – *Quercus petraea* Liebl., Grecian juniper – *Juniperus excelsa* Bieb., Yew – *Taxus baccata* L., Wild pistache – *Pistacia vera* L., Strawberry tree – *Arbutus unedo*, Pubescent oak – *Quercus pubescens* Willd.

Table 3. List and characteristics of the Crimean pine seed stands in the state forest fund of Crimea

Locality	Area (ha)	No. of trees	Plus trees	Normal trees	Minus trees
Yalta State Forest Nature Reserve Gurzuf for., comp. 37	0.64	396	63	280	53
Gurzuf for., comp. 34	4.9	2813	804	1764	245
Kuibyshev state forest enterprise, Sosnovoe for., comp. 20	1.8	867	83	661	123
Total	7.34	4076	950	2705	421

1. In the conditions of intensive recreation, forest ecosystems of the mountaineous Crimea may be conserved principally at the expense of arrangement of territories, by designation of natural core areas which are of particular value as well as buffer and protective zones *in situ*, with a consequent 2- to 3-fold increase of the total area to be protected (up to 200 000 ha).
2. Regeneration of forest stands should rest on a seed base created according to genetic and breeding criteria to intensify accumulation of phytomass in the specific arid conditions.

We believe that the principal measure for conservation of the diversity of forest tree species is the increased designation of protected areas and the division of genetic reserves into strictly protected core, buffer zone and protective zone, considering the category of protection.

Study of forest genetic resources of western Ukraine

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Work on the conservation of forest genetic resources initiated by a panel of experts of FAO in 1968 was supported by a number of other international organizations (UNESCO, UNEP, IPGRI, IUFRO, IUCN, WWF). To date, a number of international programmes has been launched (e.g. EUFORGEN for Europe and NAFC for North America). In the Ukraine this activity is coordinated by the Ukrainian Research Institute of Forestry and Forest Amelioration in Kharkiv. Other research institutes and universities (including Ukrainian Mountain Forestry Research Institute) are also engaged in this scientific field. The current review is devoted to the activity of the Ukrainian State University of Forestry and Wood Technology in the area of forest genetic resources.

Brief characteristics of the region and scope for studies

The forests of the western regions of the Ukraine cover 26.5% of the total area of the state forest fund and concentrate up to 47% of the growing stock of the Republic. Forests of the Ukrainian Carpathians (part of the Eastern Carpathians) which include a great variety of economically valuable forest tree species play a dominant role. The mean growing stock in the forests of the Ukrainian Carpathians is 379 m³ and the average increment is 5.1 m³ per hectare. Forests in the region are distributed unevenly; the proportion of forest area varies from 1.9% in the Ternopol Province (Podolya) to 28% in the Lviv Province and 50% in the Transcarpathian region. The forest area is 2 632 000 ha.

It should be noted that nowadays the Carpathian forests are not only unique valuable genepools but they also can serve as a unique model for population genetic studies and natural development of forest associations. Since some forests are not easily accessible to be exploited and timely decisions were adopted on the preservation of some mountain forests (in the early and mid-20th century in particular), some forest stands which can be classified as virgin forest still persist in the Ukrainian Carpathians. Hence at present in the Ukrainian Carpathians virgin beech forests cover 11 000–16 000 ha. Spruce virgin forests cover more than 6500 ha, while fir covers about 1500 ha.

Unique natural territories are relatively well preserved in Rostochye which extends north-westerly from Lviv to Lublin in Poland and is situated at the interfaces between three different floristic regions, the Carpathians, Polissya and Podolya. This is the northeastern boundary of *Fagus sylvatica* distribution area, the southeastern boundary of *Pinus sylvestris* distribution area and the eastern boundary of *Juniperus communis* range. In regard to *Abies alba* and *Picea abies*, one can find only insular populations of these species (Saran and Shevchenko 1972). There are also rarely found in Europe pine-beech forests which nowadays are considered to be vanishing forest associations.

Problems of scientific research and experimental work

Studies on forest genetic resources are carried out by 2–3 research groups at the University. They carry out studies of *Pinus sylvestris*, *P. cembra*, *Picea abies*, *Larix*

decidua, *Fagus sylvatica*, *Acer pseudoplatanus*, *Populus nigra* and some other, introduced species (e.g. *Abies grandis*, *Larix japonica*).

Within the framework of morphophysiological line of forest tree breeding at the University, considerable attention has been focused on the study of individual variation of trees of coniferous populations occurring in the west of the Ukraine. Tree improvement aimed at acceleration of the primary physiological and biochemical processes (ensuring active growth, phytomass accumulation and biological stability) is also given much attention. Investigation techniques for the study of integral physiological and biochemical parameters of vital activity of trees are being devised. As a result it was proposed that the following physiological and biochemical parameters be included in the system of genetic improvement tests. These are values and character of biopotential dynamics, impedance value and polarization capacity (which show the general level of metabolism and vital activity of plants); parameters of photosynthesis, pigment content (which determine production process) and terpenes as molecular and genetic criteria (Krynytsky 1993). In the course of these studies experimental plots covering 3.3 ha (these are now *ex situ* conservation units) and clonal archives of *P. sylvestris* covering 1.5 ha have been established.

In collaboration with scientific workers of the State Reserve Rostochye, Rostoczanski National Park and the Lublin University (Poland), scientists of the University in Lviv embarked on a study of the present condition of flora and fauna of the region within the framework of the international programme "Rostochye". Studies of forest genetic resources were included in the programme.

For several years, in collaboration with researchers of the Technical University in Zvolen, Slovakia, studies have been carried out on the genetic diversity of European beech occurring in the Carpathian region. Genetic diversity, variation and differentiation of the beech populations have been studied using electrophoresis. The results obtained indicate that there is a distinct spatial structure for a portion of allelic diversity of the populations studied. The progressive change of heterozygosity values in the populations assayed relative to the altitude gradient is an evidence in favour of existence of the spatial organization of genetic diversity in the area studied. These studies revealed the tendency for an increase in the mean values of observed and expected heterozygosities from the low mountain populations (up to 550 m above sea level) to the high mountain ones (over 1100 m asl). Obviously under unfavourable environmental conditions (at the upper boundary of the beech range), individual trees which show higher values of heterozygosity offer advantages over those that exhibit lower values. The analysis of differentiation among populations revealed a good grouping of some beech populations which permits the identification of three geographical groups representing the southwest and northeast oriented slopes of the Ukrainian Carpathians as well as the marginal populations at the eastern boundary of the range. Allelic frequencies were often correlated with not only geographical distribution, but distribution of populations with elevation as well. It turned out that populations belonging to definite elevation zones are clearly grouped together and distinct from each other and not distributed randomly. It should be noted that the elevation trend formed by the three groups of populations (at heights up to 550, 550–1100 and over 1100 m asl) is in quite good agreement with the zoning of the beech forests in this part of the Carpathians (Vyšný *et al.* 1995). The results obtained contribute to solving the problem of designation of an optimum number of genetic

reserves in each elevation belt, and to analyzing critically the current practice of beech seed use in this region as well.

The enrichment of the genepool of the forests is also possible with regard to the use of prospective populations from other regions. In 1975 the researchers of the University in Lviv began to conduct tests and initiated work on *ex situ* conservation of different origins of Scots pine, and appropriate experiments were established. Provenance trials cover 13.3 ha with 34 origins from all over the former USSR.

In 1995 provenance trials of European beech were established on 2.4 ha in the area of the experimental training forest complex of the University. There were 70 origins from west, central, south, and east European countries. These studies are carried out within the framework of the international programme "European Network for the Evaluation of Genetic Resources of European Beech for Forestry Use" coordinated by the Institute of Forest Genetics and Forest Tree Breeding in Grosshansdorf (Germany).

To conserve valuable genotypes of white sycamore with decorative wood texture ("bird's eye"), the scientists of the University established a seed orchard (20 clones) covering 2.0 ha. They have already established experimental plots using the seeds collected from this seed orchard. Since the plantations are young it is too early to say anything about inheritance of traits.

For several years the scientific workers of the laboratory of tissue culture have been working on the optimization of the process of cultivation of highly productive hybrids of poplars of *Leuce* section for large-scale reproduction. In addition, research is performed on the clonal reproduction of black poplar, white sycamore, European beech, pedunculate oak, and sweet chestnut.

The Ukraine possesses a considerable scientific potential and legislative possibilities to solve the problems of conservation and rational use of the forest genetic resources, but to implement them it is required that research carried out in collaboration with scientific institutions of other countries be better coordinated and financial and technical support be offered by international institutions.

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Conservation and rational use of genetic resources of forest tree species in the Ukrainian Carpathians

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Information about the region and its forests

The Ukrainian Carpathians are a part of the Eastern Carpathians. They extend from 47°40' to 49°35'N latitude and from 22°50' to 25°50'E longitude, covering 37 000 km² along with the foothills, the Precarpathians and the Transcarpathians. This is the most densely wooded area in the Ukraine. The proportion of forest area in the Carpathians (37.5%) is almost 3 times higher than the average in the Ukraine.

The total area of the forest fund of the Carpathian region covers 1 465 300 ha, including 1 231 200 ha of the forest area containing a growing stock of 324 million m³. Here are located 15.7% of the total forest area and 33.4% of the growing stock of all the forests of the state. The productivity of the Carpathian forests is much higher than that in the whole of the Ukraine or in the countries of eastern Europe. The mean growing stock is 269 m³/ha. This value is 1.4 times higher than the average reported for the forests of the state (Holubets *et al.* 1988).

As well as being an important resource, the Carpathian forests are also of great recreational, social and environmental importance. That is the reason why about 14% of the forests growing in this region were withdrawn from economic use. The soil and climatic conditions of the region are very favourable to the development of many valuable tree species. Spruce forests cover 523 200 ha (46.9%), beech 419 900 ha (38.3%), fir 80 900 ha (7.4%) and oak 45 700 ha (4.2%). The remaining 32% of the area is covered with pine, larch, maple, ash, hornbeam, birch and alder.

At present young stands cover 40% of the total forest area, middle-aged stands 33.4%, ripening stands 12.4%, mature and overmature stands 14.2%.

In the Ukrainian Carpathians both natural regeneration and reforestation take place. However, in the majority of areas, artificial stands are being established. They cover every third hectare of the forest area. This is a forced measure which is explicable on the basis of imperfect felling techniques and inadequate mechanization. Most artificial stands have been established in recent years. Annually 5000–5500 ha of forests are planted.

Forest genetic resources of the Ukrainian Carpathians

An intensive forest exploitation in the past and use of imported seeds for reforestation caused the distortion of the centuries-old natural selection which resulted in adapted native ecotypes. Biologically tolerant and highly productive uneven-aged beech and fir stands were replaced by even-aged spruce monocultures that were often subjected to the impact of severe mountain conditions (windbreaks, snowbreaks, mud and rock streams, pests and diseases). This all contributed to the imbalance of the forest ecosystems and degradation of genetic structures of the mountain forests. Diminishing pedunculate oak, sessile oak, European beech, European ash, silver fir, mountain elm and service tree wild populations are an example of the negative impact of human activity on the Carpathian forests.

In the region special attention is given to the conservation of genetic resources. To achieve this goal we studied intraspecific variation of the principal forest-forming tree species on the basis of analysis of their morphological and anatomical

characters. In the early 1980's the data obtained enabled us to designate 174 genetic reserves in the Carpathians and nearby areas covering 10 800 ha. They included phenotypically best performing, little changed mature stands. Preference was given to the surviving Carpathian virgin forests that presumably possess a set of genes sufficient for their adaptation in the course of ontogenesis. It is common knowledge that natural stands which have experienced the millennial natural selection are the most productive and best adapted to the environmental conditions under which they occur.

Included in the reserves are stands of the most common forest types, stands of all the main and associated species as well as rare, vanishing and relict ones occurring under various site conditions (Table 1). Special attention was given to the main native Carpathian species, namely, spruce (*Picea abies* (L.) Karst.), beech (*Fagus sylvatica* L.) and fir (*Abies alba* Mill.). When designating genetic reserves some difficulties emerged. They were associated with setting population boundaries, defining their sizes sufficient for the conservation of the biotypes or subpopulations involved in the population complex.

Table 1. Genetic resources of forest tree species in the Ukrainian Carpathians and adjacent areas (Lviv, Ivano-Frankivsk, Trans-Carpathians and Chernovtsy Provinces)

Species	Genetic reserves		Seed stands (ha)	Plus trees (no.)	Seed Orchards (ha)
	No.	Area (ha)			
<i>Picea abies</i> (L.) Karst.	31	2216.3	107.2	239	17.9
<i>Abies alba</i> Mill.	24	1269.0	16.7	223	20.3
<i>Pinus sylvestris</i> L.	10	589.2	112.8	74	6.9
<i>Pinus sylvestris</i> L. (relict)	9	545.0	—	12	—
<i>Pinus strobus</i> L.	—	—	—	34	—
<i>Pinus cembra</i> L.	4	632.1	—	19	—
<i>Pinus nigra</i> Arn.	—	—	4.5	13	—
<i>Pinus mugo</i> Turra.	1	1.5	—	—	—
<i>Larix decidua</i> Mill.	—	—	2.5	93	24.0
<i>Larix leptolepis</i> Gord	—	—	—	30	—
<i>Taxus baccata</i> L.	2	75.1	—	—	—
<i>Pseudotsuga menziesii</i> Franco	3	23.7	1.2	62	—
<i>Fagus sylvatica</i> L.	51	3855.5	10.0	177	—
<i>Quercus robur</i> L.	26	1141.8	14.7	184	14.0
<i>Quercus petraea</i> Liebl.	3	70.2	—	63	—
<i>Fraxinus excelsior</i> L.	3	174.7	—	6	—
<i>Fraxinus angustifolia</i> Vahl.	—	—	—	3	1.9
<i>Acer pseudoplatanus</i> L.	1	32.4	—	2	—
<i>Acer platanoides</i> L.	—	—	—	1	—
<i>Ulmus glabra</i> Huds.	1	2.5	—	—	—
<i>Betula pendula</i> Roth.	1	33.2	—	—	—
<i>Alnus glutinosa</i> Gaertn.	2	47.4	—	—	—
<i>Carpinus betulus</i> L.	2	61.0	—	—	—
Total	174	10771.0	269.6	1235	85.9

Over a period of 10 years we conducted an inventory of the genetic reserves aiming at the assessment of their condition and functional potential. In the analysis it was revealed that the condition of some reserves for individual species had been impaired owing to climatic anomalies (especially windfalls), industrial pollution and other anthropic factors. The density of stocking and the growing stock decreased by 40% in Norway spruce reserves, by 25% in silver fir reserves and by 36% in European stone pine (*Pinus cembra* L.) ones. On numerous occasions the condition of these forests was aggravated by inadequate felling procedures

36% in European stone pine (*Pinus cembra* L.) ones. On numerous occasions the condition of these forests was aggravated by inadequate felling procedures (sanitary and improvement fellings) that are allowed here. Therefore, the major task of genetic reserve management is to contribute to preserving natural evolutionary processes. Conservation of protective and buffer zones adjacent to the reserves should also be regarded as a high priority. This will partially contribute to protecting the genetic resources from human interventions and civilization pressure. Attention also should be given to natural regeneration of some reserves by gradual substitution of damaged mature stands with their offspring. Such examples of successful natural regeneration already exist.

In addition, to conserve forest genetic resources in the Carpathian region the researchers selected seed stands covering 270 ha, 1235 superior (plus) trees, 80 promising candidates for forest tree varieties, two of which have been entered in the Plants Variety List of the Ukraine. The researchers have also designated seed production areas covering 2860 ha, clonal seed orchards 86 ha, and established provenance trials and other experimental plantations (progeny trials, testing for introduction of genetic material into high elevations and for testing varieties) covering more than 150 ha.

Research potential of the region

In the Carpathian region the forest genetic conservation and research programme is being implemented by the Ukrainian Mountain Forestry Research Institute, its Carpathian Forestry Research Station and the Ukrainian State University of Forestry and Wood Technology. We conduct genetic studies at the molecular level of relict Scots pine, mountain pine, European stone pine and silver fir in collaboration with the Forest Institute of the Academy of Sciences of Belarus.

The Ukrainian Carpathians offer a relatively new area for genetic research. In this respect the region is highly diversified, scientifically promising and is scantily known. Its research potential gives a good basis for solving many of the suggested problems. But it will be possible to carry out the projects provided that international organizations give financial and technical support.

Proposals for further cooperation

1. Drawing up and carrying out international programmes of conservation and investigation into genetic resources of the mountain forests.
2. Holding international meetings in various regions and setting up training centres for young specialists concerned with forest genetic conservation and use.
3. Carrying out joint research to study unresolved problems, namely, setting population boundaries, determination of their sizes sufficient for conservation of the biotypes and subpopulations involved in the population complex, forest management in the reserves containing valuable genepools and adjacent protective and buffer zones.
4. Exchange of scientific information and computer programmes.
5. Establishment of a network of joint experimental plots (provenance, ecological, and population trials).
6. Coordination and exchange of data during the preparation of principal standard technical documents relating to forest genetic conservation.

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Forest genetic resources of the Republic of Belarus

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The total area of the forest fund in Belarus covers 8 676 100 ha, including 7 371 700 ha of the forest area. The total growing stock is 1093.2 million m³ (State forest fund of the Republic of Belarus 1995). Protected forest areas constitute 5.9%, protection forests 29.5%, and commercial forests 64.4%. State forests represent 87.9% while the rest of the forests are communal ones (Natural environment conditions in Belarus 1994).

In Belarus there are no virgin forests totally unaffected by human activity. Natural forests (this is considered to mean only strictly protected areas designated in national parks and nature reserves) cover an area of 62 400 hectares or 0.8% of the total forest area. Semi-natural forests (i.e. natural forests affected by the human activity) cover an area of 5 970 700 ha or 72.2% of the forest area. At present, artificial forests cover 2 231 400 ha or 27% of the forest area.

With regard to the composition of the forests, conifers prevail (65.3%). In the forests of Belarus deciduous hardwoods form about 3.9% while softwoods constitute 30.8% of all the forests of the country. Figure 1 shows the age and species composition of the forests according to data as of 1 January 1994 (State forest fund of the Republic of Belarus 1995).

It should be noted that before World War II forests aged over 80 years comprised 15.9%. During the war and especially after it the percentage of mature stands decreased drastically and only in the 1970's did it become stable and was maintained at a level of 4.5–5.0%. The proportion of different tree species in the forests of Belarus remains practically constant.

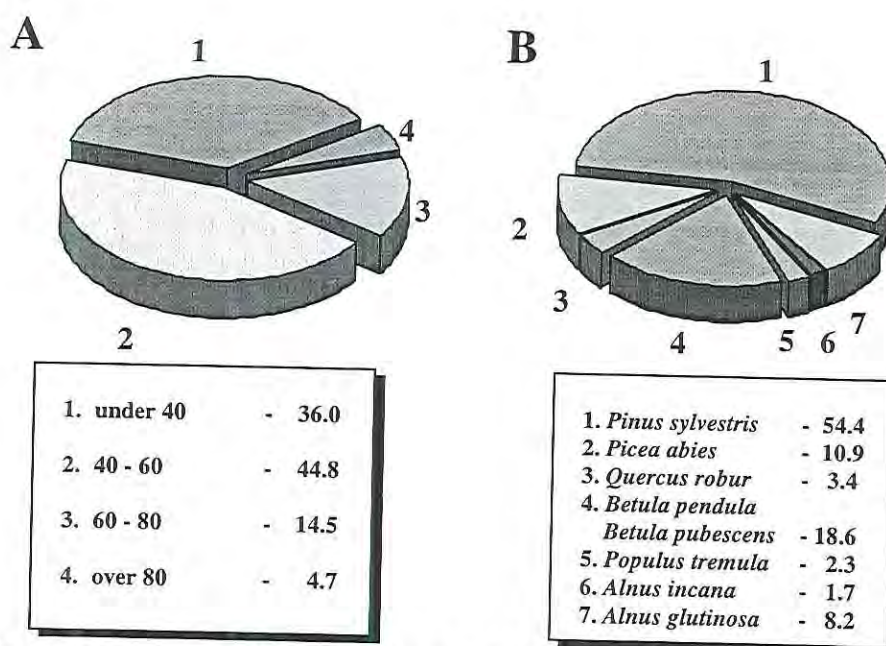


Fig. 1. Age (A) and species (B) composition of the forests of Belarus (%).

Belarus is situated at the junction of two large geobotanical areas, the Eurasian coniferous forest (taiga) area and the European broadleaved forest area and, therefore, is subdivided into three clearly defined subzones, I, II and III (Fig. 2).

Forests occurring in the northern part of Belarus belong to oak-coniferous type of forests (40.5% of the total forest area) with the sufficient participation of elements of the boreal flora (subzone I). Occurrence of mixed broadleaved-coniferous stands (29.5% of the forest area) with the significant participation of western European elements is characteristic for the southern part of the country (subzone III). In the central part, at the junction of the two areas, hornbeam-oak-coniferous forests (30.0% of the forest area) occur, the equal involvement of both western European and boreal elements being evident (subzone II). Figure 2 also illustrates the relationship among principal groups of forests in the different subzones of Belarus (Yurkevich *et al.* 1979, Geltman 1982).

Of the forest-forming species pine, spruce, oak and birch are of significant economic importance.

The most valuable species in Belarus is Scots pine. In some areas, the proportion of pine forests is 70–80%. They are almost evenly distributed throughout the whole territory of Belarus (Table 1). The mean age of the pine stands is 49 years. The most widespread types of pine forests are moss pine forest (*Pinetum pleuroziosum*), heath pine forest (*P. callunosum*) and bilberry pine forest (*P. myrtillosum*). More than 68% of all the pine stands belong to these types (Yurkevich *et al.* 1979).

The proportion of spruce forests in Belarus is 10.9% of all the forests, while in some regions this amounts to as much as 30–40%. Spruce forests are concentrated mainly in the northern part of Belarus (Table 1). The border of the continuous distribution of this species follows the southern part of the Republic and almost coincides with the border between hornbeam-oak-coniferous and mixed broadleaved-coniferous forests. As with pine, the mean age of spruce stands is 49 years. The most widespread and productive type of the spruce forest is *Piceetum oxalidosum* type – 41.9%. The proportions of moss spruce forests (*P. pleuroziosum*) and bilberry spruce forests (*P. myrtillosum*) are somewhat smaller and represent 22.4 and 20.7%, respectively (Yurkevich *et al.* 1979).

The oak stands are concentrated mainly in the southern part of Belarus (Table 1), though the penetration of oak into the northern part, where it did not occur before, has been noted recently. The following types of oak forests dominate: *Quercetum oxalidosum*, *Q. pteridiosum*, *Q. myrtillosum* and *Q. aegopodiosum*. They together account for 78% of all the oak forests of Belarus (Yurkevich *et al.* 1979). The mean age of oak forests is 62 years. Considerable recent attention has been focused on the issue of decreasing oak forests, particularly floodplain oak forests.

Similar to the pine forests, the birch ones almost evenly cover the whole of the territory of Belarus (Table 1), the artificial birch forests constituting 65.8% while primary ones such as sedge (*Betuletum caricosum*) and marsh fern birch forests (*B. dryopteriosum*) forming 34.2% (Yurkevich *et al.* 1979). The mean age of the birch forests in Belarus is 36 years.

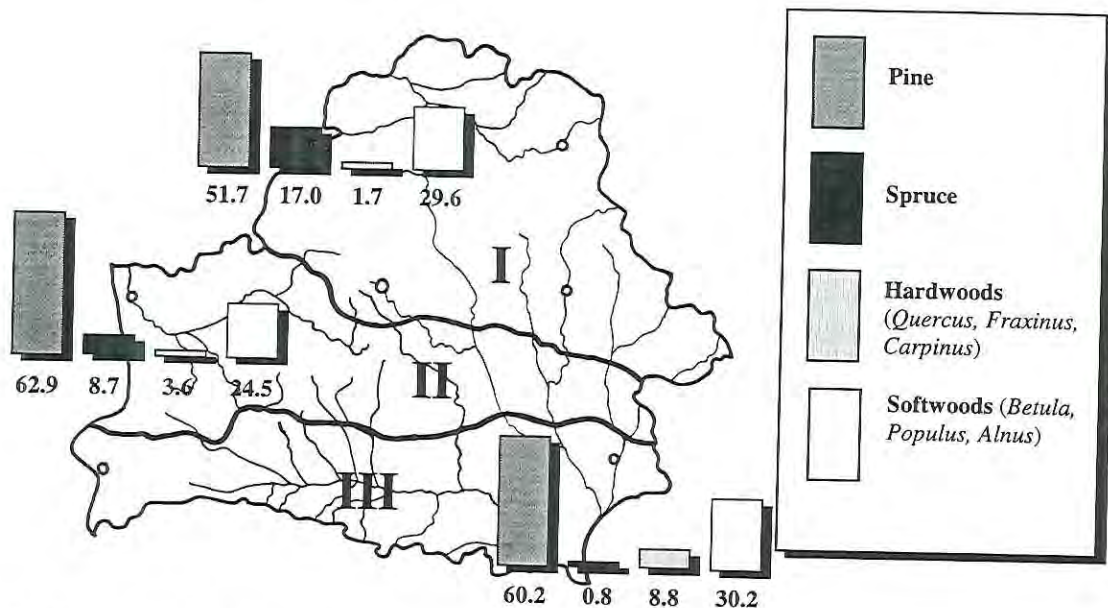


Fig. 2. Division of the area of Belarus into subzones and relationship among principal groups of forests in each of them. Subzones: I – Northern part of Belarus: oak-coniferous forests; II – Central part of Belarus: hornbeam-oak-coniferous forests; III – Southern part of Belarus: mixed broadleaved-coniferous forests.

Table 1. Distribution of principal forest-forming tree species in the territory of Belarus

Species	Northern part	Central part	Southern part
<i>Pinus sylvestris</i>	35.5%	32.5%	32.0%
<i>Picea abies</i>	70.2%	27.2%	2.6%
<i>Quercus robur</i>	14.4%	23.9%	61.7%
<i>Betula pendula</i> + <i>Betula pubescens</i>	45.3%	25.6%	29.1%

A variety of organizations and institutions of higher education are involved in the relevant forestry research. On a limited scale, investigations are pursued by the Institute of Botany of the Academy of Sciences of Belarus (ASB) in Minsk, Central Botanical Garden, ASB (Minsk) and the State Technological University (Minsk). However, a more considerable volume of research, including research on forest genetic resources, is carried out by the Forest Institute of ASB (Gomel). In 1959 at the Belarus Forestry Research Institute (now the Forest Institute), a Department of Forest Seed Breeding was established around which A.I. Savchenko, E.G. Orlenko and Z.S. Podzharova pioneered in conducting inventories of forests, selection of qualitatively and quantitatively best performing stands and trees in Belarus. This work is being continued at the Laboratory of Molecular Genetics and Forest Tree Breeding. To date, more than 2300 plus trees (1391 Scots pine, 584 Norway spruce and 396 pedunculate oak) have been selected, 1308 ha of seed stands have been designated and 81.1 ha of experimental plots have been established, including 43.1 ha of clonal archives (Podzharova *et al.* 1991).

In addition, since 1986 at the Laboratory of Molecular Genetics and Forest Tree Breeding intensive research into genetic structures of forest populations has been performed by isoenzyme electrophoresis. Currently isoenzyme methods for all the

coniferous species occurring in the territory of the former Soviet Union were developed and genetic structures of most of them were studied. The most considerable attention was given to genepools of tree species of Belarus. To date, we have obtained a great amount of information which provides an idea of the condition of pine and spruce genepools. It is determined that in Scots pine the mean number of alleles per locus varies from 2.476 to 2.952, about 90% of genes are polymorphic and trees are heterozygous for 29% of loci. These values are the highest ones in the territory of the former Soviet Union, suggesting that the pine genepool of Belarus is quite broad. At the same time the results of the investigations show that the genetic structures of some *P. sylvestris* populations have distinctive properties. For instance, the pine populations of Belovezhskaya Pushcha with a high proportion of giant old trees exhibit higher heterozygosity values in comparison with a number of other populations (see Goncharenko *et al.*, this volume). In addition, we revealed eight unique allelic variants of genes which were not found in the other populations. However, regardless of the fact that there are insignificant differences among some populations, the *P. sylvestris* populations in Belarus as a whole differ to only a small extent. On the basis of F_{ST} (Wright 1951) and G_{ST} (Nei 1975) values we calculated that only 2% of the total variation is due to interpopulation variation, whereas approximately 98% of the detected variation resides within populations. Somewhat different data were obtained on the genetic structures of Norway spruce populations. In the analyses it was revealed that allele diversity in the populations occurring in the southern part of the Republic is reduced drastically because only 55 allelic variants of 26 genes compared to 73–75 alleles in the populations growing in the central and northern parts of Belarus were observed. We have also analyzed the unique natural relict population of silver fir (*Abies alba*). The results obtained demonstrate that regardless of the small size of the population (only 20 trees) and isolation from the continuous distribution of this species its genepool is broad, the population was not subjected to inbreeding and is unique. At the present time the researchers of the Laboratory are investigating genepools of the broadleaved species occurring in Belarus.

Forest genetic resources are conserved in three national parks which occupy an area of more than 250 000 ha, one nature protected area (81 000 ha) and 42 nature reserves of national significance covering total area of 370 220.5 ha (Fig. 3). The Polesye "Radioecological Reserve" is excluded from this list because it was designated for other purposes and its territory is covered mainly with artificial forests. In addition, 100 nature monuments of Belarus are among the strictly protected units. These are particularly valuable stands, unique ancient parks, single trees and groups of trees (mainly old oak trees). All the strictly protected areas and units are under the authority of the Belarus President's Affairs Management Department. Besides, 17 genetic reserves for pine, spruce and oak, covering 4162 hectares, were designated. They do not have the status of strictly protected units and are under the authority of the Ministry for Forestry (Fig. 3).

In the genetic analysis of the stands selected from some strictly protected areas we revealed that they possess comparably rich genepools and can contribute to achieving the genetic conservation of principal forest-forming tree species of Belarus. At the same time, in a similar analysis of a number of genetic reserves it was revealed that the reserves, which up to the present have been designated on the basis of their phenotypic traits, do not all correspond to the notion of the genetic reserve in their genepools. It is expeditious for the Ministry for Forestry to conduct a full genetic inventory of the designated genetic reserves and those to be

designated. In addition, it is desirable to give them a legal status of particularly protected units and remove them from the authority of the Ministry for Forestry to harmonize protection of the reserves selected.

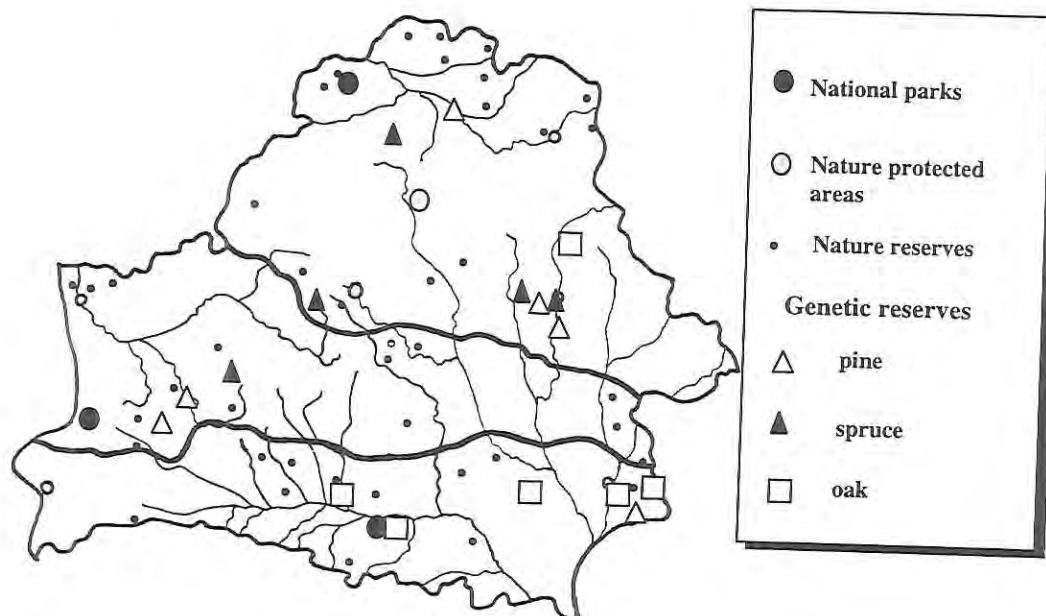


Fig. 3. Locations of the strictly protected areas and genetic reserves in Belarus.

In the Republic of Belarus purposeful work on the long-term conservation and use of forest genetic resources is being carried out. In 1994 the modified "Law on strictly protected areas and units" and in 1996 the "National plan of action on the conservation and sustainable use of biodiversity in the Republic of Belarus" were adopted. At the present time a "Strategic plan for development of forestry of the Republic of Belarus" is being drawn up. A specific programme of genetic conservation of the principal forest-forming tree species of Belarus, based on the results of population genetic studies, should be a part of the above Strategic plan.

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Investigation and conservation of genetic resources of forest tree species in Lithuania

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Introduction

Over the last 25 years in Lithuania a wide network of forest genetic reserves, reserves aimed at seed production ("seed restricted areas"), plus trees, clonal archives, seed orchards and test plantations has been designated and established to investigate, conserve and utilize genetic resources of forest tree species. However, the genetic diversity of natural forests is inadequately represented from geographical, population structure and ecological standpoints, because until the present time the trend has been mainly toward breeding and not conservation of genetic resources. The principles and methods of investigation, enhancement, conservation and purposeful utilization of genetic resources could not be appropriately applied to the conservation of the selected genepools.

Under the impact of intensive forest management, influence of atmospheric pollution on forests, climate changes as well as other negative factors the genetic potential of forests is decreasing. Destructive processes are observed leading to the vanishing of individual populations or their partial degradation.

Characteristics of the region

Lithuania is situated in the zone of mixed forests and occupies an area of 65 300 km². It extends from 53°54' to 56°27'N latitude and from 21°00' to 26°50'E longitude. The climate is transitional from maritime to continental, greatly affected by the Baltic Sea and thus comparatively mild. The average air temperature in June is +17 °C, in January -4.8 °C, while the average annual temperature is +6.1 °C. The vegetation period lasts 187–202 days. Annual precipitation averages 662 mm. The relief of Lithuania is plain (25 to 291 m above sea level). The country is crossed by the northern boundary of *Carpinus betulus* (L.) range. Forests in Lithuania are of great economic and ecological importance.

Forest area

Forests in Lithuania cover an area of 1 860 300 ha. The proportion of forest area in the country makes up 30.1% (Lithuanian For. Res. 1994). In the 14th century this comprised 60%. The proportion of forest area varies from 8 to 64%.

The largest forest tract is the Dainavos forest covering 150 000 ha. Forests of Kazlu Rûda, Labanoras, and Karuva cover 44 000–58 000 ha. Another 7 forest tracts cover 20 000–30 000 ha (Gabrilavicius and Danusevicius 1996). The remaining forests cover smaller areas. They are situated in the eastern and southern parts.

Species composition of the forests

Coniferous forests prevail and comprise 61.6% of the total forest cover (Table 1). Hardwoods represent only 4.4%. Almost all ripening and mature forests are of autochthonous origin. Their investigation and conservation are very important to sustain the genetic diversity and to regenerate new stands.

Table 1. Lithuania's forest resources

Species	Area (ha)	Percentage of the total forest area
<i>Pinus sylvestris</i>	695 300	37.4
<i>Picea abies</i>	450 200	24.2
<i>Betula pendula</i>	363 400	19.5
<i>Alnus glutinosa</i>	104 000	5.6
<i>Alnus incana</i>	103 800	5.6
<i>Populus tremula</i>	50 400	2.7
<i>Fraxinus excelsior</i>	49 300	2.7
<i>Quercus robur</i>	32 400	1.7
Other species	11 500	0.6

As a result of intensive management, virgin forests (untouched by human activity) may be found only in reserves. Therefore, the so called semi-natural forests predominate in the country. Mature stands comprise 9.6%, ripening 17.9%, middle-aged 44.7% and young stands 27.8%.

Genetic research and breeding practice

For breeding purposes all the ripening and mature stands of the principal species in Lithuania are divided into three groups by their quality, productivity and stability. Selection and study of valuable genepools is carried out in stands. The number of the genetic conservation and breeding units is given in Table 2. The studies are conducted on the genotypic structures of pine, spruce and oak populations, the associations between genotypic diversity and productivity, inheritance of traits, genetic variation and the levels of genetic differentiation depending on geographical, climatic and ecological conditions under which their offspring grow, as well as the selection effect within population, family and among individuals (Pliûra and Gabrilavicius 1994, Gabrilavicius 1994, 1996).

To increase diversity of native species and reveal combining ability under hybridization, interspecific and intraspecific crossings for spruce and pine were made. A number of perspective hybrids (F_1) were obtained (Danusevicius and Cesnavicius 1992, Danusevicius 1995). The best provenances (by F_1) were identified for the introduction of Scots pine, lodgepole pine, yellow pine and Douglas fir.

Table 2. Genetic conservation and breeding units for species (number/ area in ha)

Genus	Genetic reserve	Restricted areas		Plus trees	Clonal archives	Seed orchard	Test plantations
		Genetic	Seed				
<i>Pinus</i>	2/5273	112/2382	28/307	475	3/8.5	18/225.6	61/117.4
<i>Picea</i>	1/384	19/337	21/150	589	5/15.5	27/339.1	22/51.5
<i>Larix</i>	—	2/2	—	34	1/10.0	9/37.6	2/1.7
<i>Pseudotsuga</i>	—	—	—	—	—	1/4.5	—
<i>Quercus</i>	—	31/392	8/170	66	—	1/1.2	—
<i>Fraxinus</i>	1/296	11/100	—	16	—	—	—
<i>Alnus</i>	—	18/198	13/79	57	—	—	—
<i>Betula</i>	—	44/354	—	45	—	—	—
<i>Populus</i>	—	—	—	53	—	—	1/3.0
<i>Tilia</i>	—	2/13	—	21	—	—	2/2.8
<i>Salix</i>	—	—	—	—	—	—	—
Total	4/5621	256/3915	70/706	1356	9/25.0	56/608.0	93/177.4

Investigations and measures on the conservation of genetic resources

Forest genetic resources encompass the species, population and individual levels based on the value and necessity of conservation.

Criteria by value:

- degree of natural character and levels of genetic diversity;
- autochthonous origin (for native provenances);
- adaptability (for non-local and introduced provenances);
- ecogeographic and ecotypic representativeness;
- economic value – productivity, quantity;
- viability and potential for natural regeneration;
- ecological and nature protection value;
- rarity (uniqueness) and distribution patterns;
- breeding value of reproductive material;
- location of populations in marginal parts of species' distribution areas.

Criteria by necessity:

- parts of the genetic resources which are damaged or the most sensitive to damage or are on the verge of extinction;
- vanishing species or their components under the impact of natural evolution;
- populations, ecotypes and individuals under artificial selection (breeding);
- obtained hybrids.

Under these conditions, when the environment is changing rapidly, the criterion of adaptability occupies the first place.

General criteria for *in situ* conservation of populations and provenances:

- autochthonous origin;
- adaptability of introduced species;
- representativeness for ecogeographic region;
- age of stands;
- good productivity, phenotypic quality and viability;
- priority features: old-growth forests, forms, species composition, rare genotypic structures, natural state;
- good regeneration;
- minimum area for provenances 10 (3) ha, for populations 100 ha;
- remaining resistant stands or parts of stands within damaged populations.

Criteria for *ex situ* conservation:

- damaged or vanishing populations under the threat of extinction;
- particularly valuable populations and stands which are characterized by high productivity, good phenotypic quality and viability as well as peculiar genetic features and diverse structure;
- populations improved by breeding measures and holding sufficient genetic diversity.

A population conserved in *ex situ* conditions should be represented by no less than 200 genotypes.

Successful conservation of genetic resources depends upon the quality of the obtained information on conservation units and on relevant documentation. A standardized system of information, documentation, and designation of genetic units to be conserved is being worked out in conformity with information systems in other countries. A computerized system is prepared for the collection and evaluation of data. Descriptions of genetic units are being compiled.

New standards for the selection of plus trees (pine), designation of forest genetic reserves and restricted areas have been prepared. In collaboration with seven other institutions, work on the study and conservation of plant genetic resources (programme "Genetic resources of cultivated plants") is being carried out.

Difficulties in the conservation and study of genetic resources, possible solutions and prospects

In 1994 the percentage of forests damaged in Lithuania was 28% (Ozolincius and Stakėnas 1994). Although no forest tree species is under the threat of extinction, some forest stands are significantly damaged, while some species regenerate with great difficulty. At present more than 40% of middle-aged and older spruce stands are damaged by *Ips typographus*. About 15 500 ha of spruce stands have been destroyed. Clear-cutting was performed in an area of 12 500 ha. Over the last five years, outbreaks of *Diprion pini* and *Lymantria* were observed. They damaged about 45 000 ha of the pine stands. Damage of oak stands is increasing.

Damages were observed in many stands and populations, including a major part of *in situ* genetic units. Researchers of the Lithuanian Forest Research Institute and the Forest Seed and Tree Breeding Centre conduct regular inventories of genetic units, designate new reserve areas (genetic reserves and seed restricted areas) and select plus trees for further conservation of genetic resources and their utilization in reforestation.

A serious problem is regeneration of genetic reserves and seed restricted areas, especially with spruce. It is very important to determine the potential for their regeneration in order to maintain stands. In the genetic units where natural regeneration is insufficient, measures should be taken to promote regeneration. These should be supplemented or established using seedlings grown from the seeds collected in these stands. Such measures are taken in genetic reserves and restricted areas.

Conclusions and prospects for future cooperation

In order to preserve genetic resources all measures should be intended to regeneration of valuable natural (autochthonous) stands, selection and conservation of valuable stands, best families and individuals tested in progeny trials, permanent assessment of genetic units, designation of new ones, extension of the clonal archives and the network of experimental plantations.

To carry out the whole spectrum of measures aimed at the conservation and investigation of genetic resources is impossible due to the lack of up-to-date equipment and financial support. Forest genetic conservation becomes a complicated problem. Many valuable natural populations may decrease or vanish, while a part of the valuable genotypes selected may disappear forever.

To continue investigations and forest genetic conservation great financial resources are required. Sometimes one country is unable to solve such complex problems which go far beyond its borders. Therefore, bilateral or multilateral cooperation and coordination is sought to implement joint programmes.

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Estonian forests and conservation of their genetic resources

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The Republic of Estonia is situated in the northeastern part of Europe, on the coast of the Baltic Sea. The area of the country is 45 227 km². The total forest area is 2 016 600 ha (data as of 1 January 1994) (Estonian Forest and Forestry 1995). The proportion of forest area is 47%, of which and state forests constitute 57%. Thirty-five per cent of forests are under the control of various agricultural organizations. Private forests represent 8%.

Pine forests are the most widespread and cover 38% of the total forest area. Next are birch forests (silver birch, *Betula pendula*, and pubescent birch, *B. pubescens*) constituting 30%, spruce forests 24%, grey alder forests 4% and aspen forests 1.5% (Fig. 1). Forest stands composed of other species (common alder, oak, ash, etc.) make up only 2.5% of the Estonian forests. The total growing stock is 6.8 million m³ or 155 m³ per hectare (Aastaraamat Mets' 1996).

The total growing stock and other parameters from forest inventories are quite different depending on the type of ownership. Regardless of the relatively small number of pine stands and the abundance of grey alder stands in private forests, the latter ones are more productive than state forests. The comparative data on growing stock in private and state forests are shown in Figures 2 and 3.

The amount of growing stock per capita is about 190 m³. Estonia tops the world average and shows higher levels of this parameter than many European countries.

Only three forest-forming tree species are economically important. These are pine, spruce and birch. Spruce forests are the most productive (the mean growing stock is 171 m³/ha). The average age is 54.5 years, which more or less corresponds to half of the rotation age and even exceeds it, no matter whether calculated as a general average or for each tree species individually (Estonian Forests and Forestry 1995).

Several conservation units have been designated to protect forests. The oldest one is the Nature Reserve in Jarvselja (19 ha; untouched by human activity since 1923) (Etverk 1986). There is also a protected natural oak stand (91 ha) with trees over 200 years old and two protected nemoral forest areas (the total area is 143 ha).

Large forest tracts are protected in national parks (53 300 ha), nature reserves (5600 ha), landscape (27 800 ha) and swamp (10 300 ha) reserves. Thus, an area of about 100 000 ha can be regarded as a genetic reservoir of the forests in Estonia. The conservation of these forests is ensured by the Act of Nature Protected Units endorsed by the Estonian Parliament on 1 June 1994. In these areas different protection regimes are applied, from restricted fellings to visitor access regulations.

Seed stands and plus trees occupy a highly important place. In Estonia selection of plus trees has been carried out since 1959. Height of trees and crown shape are considered to be the most important factors for the selection of plus trees since a narrow-crowned tree usually has thin limbs. The most significant criterium for a plus tree is naturally its stem (Pihelgas 1991).

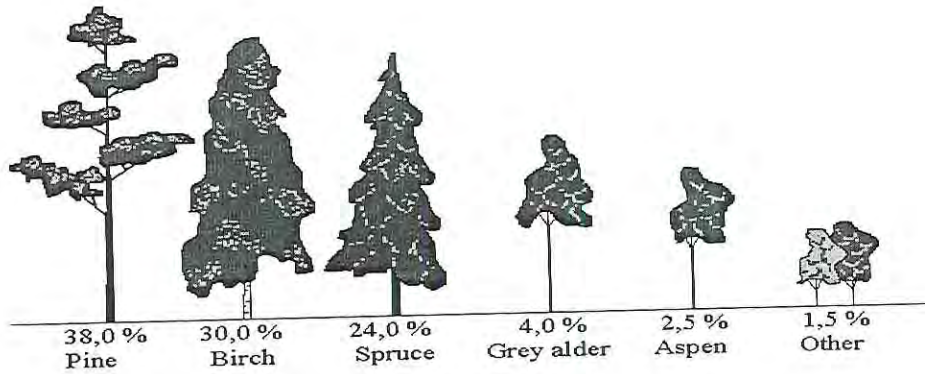


Fig. 1. Distribution (%) of the forest area by principal tree species in Estonia.

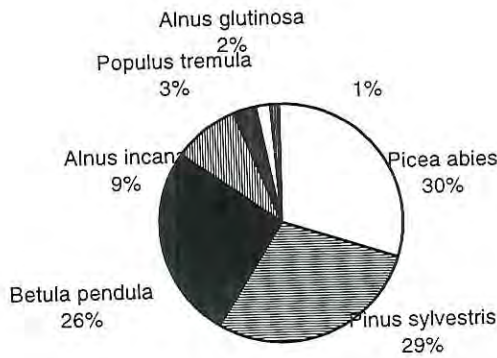


Fig. 2. Growing stock by dominant tree species in private forests (1995).

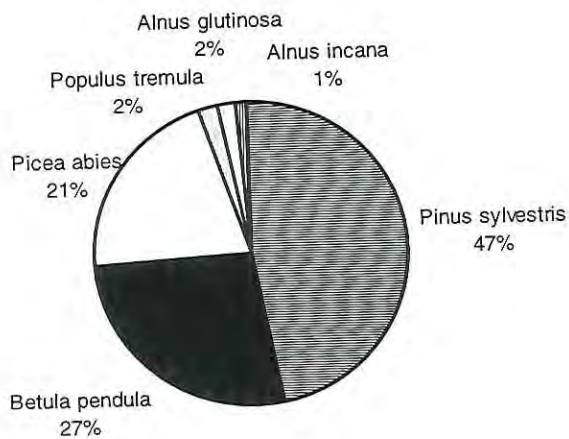


Fig. 3. Growing stock by dominant tree species in state forests in (1995).

The selected plus trees of Norway spruce are assessed on the basis of their productivity (Etverk 1972).

To date, 443 plus trees of pine, 135 spruce, 13 larch and 23 silver birch trees have been selected in Estonia. Most of these trees have been propagated and are now represented in clonal archives, seed orchards and progeny trials. Early clonal seed orchards of coniferous trees were established in 1965 under the supervision of professor E. Pihelgas and professor I. Etverk. All the existing seed orchards were established in the years 1965–1986. At present there are 180 ha of pine and 32 ha of spruce seed orchards. Altogether 503 clones of pine and 178 clones of spruce are included in the seed orchards (Kurm 1996, Kurm *et al.* 1996).

In addition to plus trees and clonal archives, 10 genetic reserves were established in 1985 in order to conserve the genepools of main species. Their total area is 3540 ha or 0.2% of the forest land. When designating genetic reserves it was considered that each genetic reserve should be a forest stand typical for the given area and that at least part of the populations of predominant species or an ecological type should be represented. In four genetic reserves (the total area is 1987 ha or 56%) pine predominates, in five genetic reserves (the total area is 1136 ha or 32%) spruce prevails while in only one (the total area is 417 ha or 12%) birch is predominant (Tamm 1996).

The following activities are prohibited in genetic reserves: clear-cutting, resin-tapping, surface soil layer disturbance, afforestation with seeds collected outside of reserves and any kind of activities that could affect the maintenance of the genepools and the growing conditions of trees. Fellings carried out in order to improve sanitary conditions of forest stands and other measures aimed at the protection of stands are permissible.

At the present time genetic reserves are being confronted with management problems resulting from the damage caused by bark beetles and the elk. Natural regeneration of Scots pine is often troublesome.

Over the last 35 years conditions were provided in Estonia for forest genetic conservation. They are supported by several laws and regulations adopted in the Republic of Estonia.

In connection with the closing of the Estonian Forestry Institute, silvicultural research, particularly in the field of forest tree breeding, will apparently be problematic as the leading officials in the field of forestry regard forest breeding as a seasonal undertaking which does not produce a quick profit.

When the results of forestry research obtained in Estonia are compared with those obtained in neighbouring countries, it is apparent that good levels were reached in the field of forest genetics and breeding. As for international cooperation, we have established the Baltic Council of scientists engaged in the research on forest tree breeding. Its work is coordinated between the three republics. We were admitted to a forest tree breeding association of the Nordic countries. We have started close cooperation with Finland, our neighbour situated in the north, both in research and exchange of practical experience. We also continue to cooperate with Russia and Poland.

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Status and conservation of tree genepools in the forests of Russia

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In the Russian Federation, as in other republics of the former Soviet Union, a great amount of work on the conservation of forest tree genepools was done in 1982–1990 once the “Regulations for the designation and conservation of genepools of tree species in the forests of the USSR” had been approved (Moscow, 1982) and related activities under the responsibility of the State Committee on Forests performed.

In Russia, forest genetic reserves cover 185 600 ha (data are as of 1 January 1996). However, their list does not take account of the reserves available in a number of regions, in the Urals in particular where about 500 genetic reserves were designated (Mamaev and Makhnev 1996). The fact that these reserves are not completely registered is caused by the interruption of work on designation and certification of the conservation units during the last 5 years, despite that objectives of forest genetic conservation in Russia have not been accomplished yet and that the world community is paying an even greater attention to the issues of biodiversity conservation. The most crucial situation regarding the conservation and rational use of genepools of forest tree species is in Siberia and the Far East regions. This can be shown in an overview of permanent seed base (breeding) units and designated forest genetic reserves for a number of forest-forming species in the economic regions of the country (Tables 1, 2 and 3).

The character and volume of genetic and breeding activities foreseen by the Federal Forestry Service of Russia until 2000 will not change substantially the current situation in the regions if tasks specifically focussing on forest genetic conservation are not set.

In view of the fact that it is essential to continue work on the conservation of the genepools of trees and shrubs in Russia and to improve its legal, theoretical and methodological frameworks, the authors of the “Regulations for the designation and conservation of genepools of tree species in the forests of the USSR” revised the wording of this document for the Russian Federation, wherein they established principal conceptual regulations on the basis of the experience acquired.

The federal “Law on Strictly Nature Protected Areas” (1995) adopted in the country did not address the functionality of the “Regulations”. The category of forest genetic reserves is missing from the list of strictly protected areas in the above Law. It is close to the notion of “microreserves” mentioned in Article 2.2 of the Federal Law among “other categories of strictly protected areas established by the Government of the Russian Federation and appropriate agencies of executive authority of entities of the Russian Federation”, the draft of which is presently being adopted at the State Duma, Council of Federations and Administration of the President.

It is believed that conservation of genepools of forest tree species can not be warranted without its reflection in statutory acts and enactments of the Government of the Russian Federation.

Table 1. Breeding units and genetic reserves for stone pine species in Russia (data are as of 1 January 1996) and the recommendations by Federal Forestry Service for their development until 2000 (in parentheses)

Species / Region	Plus trees (no.)	Seed stands (ha)	Seed orchards (ha)	Clonal archives (ha)	Mother tree archives (ha)	Field trials (ha)	Genetic reserves (ha)
<i>Pinus sibirica</i>							
Pre-Urals	192	—	1	1	—	—	—
Urals	124(50)	62	28	—	—	—	—
Western Siberia	1205	214	215(40)	12	25(8)	14	999
Eastern Siberia	771(190)	270	68(10)	2	—	—	5062
Beyond range	—	—	79	—	—	—	—
Total	2292(240)	546	391(50)	15	25(8)	14	6061
<i>Pinus koraiensis</i>							
Far East	879	125	63(20)	1	-(5)	—	—

Table 2. Breeding units and genetic reserves for larch species in Russia (data are as of 1 January 1995)

Species	Plus trees (no.)	Seed stands (ha)	Seed orchards (ha)	Clonal archives (ha)	Mother tree archives (ha)	Field trials (ha)	Genetic reserves (ha)
<i>Larix sukaczewii</i>	781+	260.5+	512.5	28.9	11.6	14.0	2039**
	+651*	+20.0*					
<i>L. sibirica</i>	958	268.0	343.5	19.0	3.0	8.5	1378**
<i>L. gmelinii</i>	22	—	—	—	—	—	—
<i>L. cajanderi</i>	15	—	—	—	—	—	2626
<i>L. czekanowskii</i>	—	—	—	—	—	—	1817
<i>L. kurilensis</i>	20	—	—	—	—	—	—
<i>L. olgensis</i>	10	0.5	—	—	—	—	—
<i>L. amurensis</i>	166	—	7.0	—	—	—	—
<i>L. decidua</i>	191	16.6	—	—	—	—	—
<i>L. kaempferi</i>	14	—	—	—	—	—	—
<i>L. maritima</i>	—	—	—	—	—	—	—
<i>L. lubarskii</i>	—	—	—	—	—	—	—
<i>L. komarovii</i>	—	—	—	—	—	—	—
<i>L. ochotensis</i>	—	—	—	—	—	—	—

*) Designated as *Larix sibirica*.

**) Without those reserves where larch is not a dominant species.

Rapid changes of the forest cover in vast areas of Russia (associated with extensive logging, forest fires, industrial pollution and transformation of the forest fund into other landuse categories) and definite prospects for new patterns of ownership motivate the necessity of taking immediate actions aimed at conservation of the genepools of forest trees and shrubs. In this regard critical remarks are to be made about the opinion of supporters of the designation of reserves exclusively on the basis of genetic structures of the tree species studied, as well as 'optimists' believing that the species with vast distribution areas, showing low levels of interpopulation variation (at a number of gene markers), are in no danger of losing their genepools.

Table 3. Representativeness of breeding units and genetic reserves of larch in economic regions of Russia (data are as of 1 January 1995)

Region	Plus trees (no.)	Seed stands (ha)	Seed orchards (ha)	Clonal archives (ha)	Mother tree archives (ha)	Field trials (ha)	Genetic reserves (ha)
Northern	205	10	30	—	—	—	4198
North-Western	63*	—	67	—	5.0	—	—
Central	616*	27*	123	3	—	2	—
Volga-Vyatsk	152	60	149	26	0.2	—	—
Central Chernozem	5*	—	—	—	—	—	—
Povolzhe	226	8	110	—	6.0	12	—
Urals	477	190	34	—	0.4	—	578
Western Siberia	206	24	36	—	1.0	0.5	178
Eastern Siberia	619	244	307	19	2.0	8	3017
Far East	225	0.5	7	—	—	—	2626
Baltic	34*	2*	—	—	—	—	—
Total	2828	565.5	863	48	14.6	22.5	10597

*) Designated in artificial stands.

The principal objections to the above concepts are: increasingly unproportional rate of investigations with the actual loss of biodiversity throughout the planet and extremely discrepant assessments of taxonomic relationships and values of intraspecific (mainly geographical) variation in forest tree species as a result of application of different methods and criteria.

In the latter case the most profound is the contrast between, on the one hand, the values of interpopulation variation revealed by isoenzyme electrophoresis in species with vast ranges (Scots pine, Siberian larch, Siberian stone pine) and, on the other hand, the results of the progeny trials and provenance experiments established in different regions. In the former case the observed level of interpopulation genetic variation is 3–5% (from 0.5 to 12%), while in the latter one it is 20–30% and more. At the same time in a number of populations (both marginal and those from the optimum site conditions), the full elimination of progeny occurs when grown in contrasting environmental conditions within the range.

So far, the integral evaluation methods for progenies of populations, applied in parallel trials established under different ecological backgrounds have not provided perfect information on specificity of the genepool (clearly, without any genetic parameters used in population genetics), in comparison with the estimates obtained on the basis of allele composition at isoenzyme gene markers. The latter ones represent chiefly neutral traits and only about 1% (10% at most) of the genome (El-Kassaby 1991). Aminoacid and nucleotide sequencing as well as the combination of nuclear and mitochondrial markers have considerable promise for studies of the genome. However, in studies of species evolution, development of intraspecific taxonomy, and particularly in drawing up the genepool conservation strategies, it is important to take into account results of investigations achieved in a number of different biological disciplines.

Considering the fact that intraspecific genetic differentiation in principal forest-forming tree species is not yet fully understood and reasoning with the 'no harm' argument, the "Regulations" advice specialists to use mainly the natural zoning principle reflected in the schemes of seed zoning for principal forest-forming species when designating a network of forest genetic reserves. The seed zones

species when designating a network of forest genetic reserves. The seed zones define, within certain limits, populations or series of populations developed under the influence of natural selection and other evolutionary factors.

To conserve the allelic pools of populations of a species within each natural (seed) zone it is important to follow the known principles of adequacy and reliability (Müller-Starck 1995). In this regard the "Regulations" envisage:

- representation of (sub)populations growing under contrasting site conditions (i.e. different forest types) in forest genetic reserves, with sufficiently large numbers of trees in the productive age to reflect the composition of alleles (including rare ones) in autochthonous stands not affected by industrial pollution;
- designation of no less than three reserves covering 100 to 1000 ha in each seed zone;
- representation of uneven-aged stands in the reserves;
- designation of buffer and/or protective zones around the core of the reserves and incorporation of other forest areas into them (up to 30% of the area);
- taking active measures on the protection of the reserves from fires and other damaging effects (including pollution of the genepools) and providing assistance to re-establish native forest communities;
- *ex situ* conservation of genepools of populations beyond the distribution ranges.

Forest genetic reserves in Russia are being designated under the leadership of the Research Institute of Forest Genetics and Breeding in Voronezh, regional research institutes of the Federal Forestry Service, the Russian Academy of Sciences, the Russian Academy of Agricultural Sciences and institutions of higher education. Software and methodical supply are provided by the Scientific Board for Forest Genetics, Seed Science, Tree Breeding and Introduction. The Board gives its best attention to the following items:

- legal framework for the designation and conservation of genepools of forest tree species;
- genetic and breeding inventories of forest genetic reserves and other corresponding units with the same status;
- continuation of work on the designation of forest genetic reserves in all the economic regions of the country;
- exchange of information and experience in different aspects of the study and conservation of forest tree and shrub genepools;
- environmental education of foresters and the public;
- drawing up programmes and devising methods of *ex situ* conservation;
- development of efficient techniques for re-establishment of native forest in the genetic reserves;
- development of modern techniques for the long-term conservation of genetic materials from different species (including cryopreservation).

The amount of work to be done and the progress of its performance are limited chiefly due to the lack of budgetary (both federal and local) means.

The efficiency of work on gene conservation also depends on how the negative attitude of a particular part of the public (in the different spheres and structures) to the withdrawal of some forest areas from intensive use (even to a limited extent) is overcome. This attitude can still be demonstrated in different ways such as

administrative and legislative acts but especially in lawless actions (unauthorized felling, damage to trees, etc.).

The conservation of biodiversity in general is a serious problem that combines moral, socioeconomic and legal aspects. The settlement of this problem is much dependent upon the cultural and educational level of the world community.

A number of decisions, instructions, declarations and conventions adopted by the United Nations Conference on Environment and Development (Rio de Janeiro, 1992) and elsewhere are known to be aimed at overcoming different constraints in the different countries.

Conservation of the gene pools of forest trees and shrubs is closely linked to the development of the country (and its regions), stable overall development and measures on the implementation of the Convention on Biological Diversity. Our task is to improve the coordination of appropriate works on the conservation of the gene pools of forest tree species in Russia, the Commonwealth of Independent States, other Eurasian states and the whole of the boreal zone with the aim to improve the strategies, methodologies and priorities as well as increasing the material support.

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Table 1. Age distribution of the forest stands in the Central Chernozem Region

Species	Young	Middle-aged	Ripening	Mature and overmature stands
Pine	52.3	36.4	7.6	12.4
Oak	21.3	63.0	9.4	6.2
Birch, aspen, maple, lime, alder	29.5	39.8	14.7	19.7

Table 2. Nature reserves in the Central Chernozem Region

Reserve	Total area ('000 ha)	Forest ('000 ha)
Voronezh State Biospheric Reserve	31.0	28.6
Hoper State Nature Reserve	16.2	12.5
Central Chernozem State Biospheric Reserve	4.9	1.7
Total	52.1	42.8

Table 3. Overview of breeding units in the Central Chernozem Region

Province	Plus trees (no.)	Seed stands (no.)	Seed orchards (ha)	Permanent seed production areas (ha)
Belgorod	240	0	4	565
Kursk	338	0	25	2863
Lipetsk	171	56	3	233
Tambov	129	20	20	256
Voronezh	174	129	30	386
Total	1052	205	82	4312

At present genetic reserves designated in the Central Chernozem Region cover 4046.2 ha, including oak (3798.1 ha) and Scots pine (248.1 ha).

In addition to working on the designation and conservation of forest genetic resources, the Research Institute undertakes studies on population genetic structures of forest tree species.

Two isolated natural Scots pine forest stands were investigated by starch gel electrophoresis using 12 enzyme-coding loci. Seed material was collected from 24 *Pinus sylvestris* trees growing in the Khrenovskoe forest and from 31 individuals in the Usmanskoe forest. Both stands demonstrate high levels of genetic diversity. In both populations the mean observed heterozygosity values H_o were higher than the mean expected heterozygosity H_e . Despite similar mean values of the parameters of genetic variation, the allelic and genotypic structures of these stands are different. Specific allelic variants occurred in each of the two pine stands.

The differences in qualitative composition of the gene loci are considerable. For instance, of 22 allelic variants at *Skdh-1* and *Lap-2* loci discovered in both samples, only 2 are found in both stands. Nei's genetic distance between the Khrenovskoe and Usmanskoe populations is 0.019. These stands exhibit higher levels of genetic diversity than European *Pinus sylvestris* populations (Prus-Glowacki 1994).

The exceptional genetic variation and peculiar genetic structures of the insular pine forests occurring in the southern part of Russia call for conservation of the remnants of the natural forest resources of Scots pine in the Central Chernozem Region.

In order to study genetic consequences of logging and forest fires on the population structure we analyzed 12 samples (6 pairs of natural parent stands and their subsequent regeneration) from pine and 6 samples (3 pairs) from spruce

Forest genetic resources of the Central Chernozem Region of Russia: some results of investigations into genetic structures of conifers

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The Central Chernozem Region (CChR) is situated in the forest-steppe zone in the south of the European part of Russia. It involves five provinces: Belgorod, Voronezh, Kursk, Lipetsk and Tambov. The area covered by forests is 1 176 700 ha or 8.9% of the total area of the Region. All stands belong to Group I of forests (mainly recreation and protection forests). The greater part of the forest area is covered by oak (53%) and pine (31%). Birch and aspen cover 7% each; maple, lime, spruce and larch taken together cover less than 2% of the forest area (Fig. 1).

The age structure of the stands, notably that of Scots pine forests, is disproportional (Table 1). There are three state nature reserves in the Central Chernozem Region, with a total area of 52 100 ha (Table 2).

The Voronezh State Biospheric Reserve was founded in 1927. It incorporates steppe and multi-layer pine stands with the typical forest-steppe fauna, including native populations of beaver and Russian muskrat. The Hoper State Nature Reserve was founded in 1935. It is situated in the flood basin of the Hoper river and includes highland and streamside common oak forests as well as common alder (*Alnus glutinosa*) and white poplar (*Populus alba*) stands. In the reserve 33 rare plant species can be found. Like the Voronezh Reserve, the Hoper Reserve is inhabited by beaver, Russian muskrat, roe deer and wild boar. In the Hoper Reserve the introduced dapple deer and European bison adapted to the local environmental conditions. The Central Chernozem State Biospheric Reserve is the most recent; its territory is the smallest. Pedunculate oak (*Quercus robur*) prevails in this reserve.

Institutions such as the Province Forest Administration, the Research Institute of Forest Genetics and Breeding and forest seed stations use a number of measures on forest genetic conservation. Work on the conservation of genepools of the forests is complicated by the fact that the genetic reserves category is not provided in the Laws concerning forests and forestry; thus, there is no way to protect the designated genetic reserves from logging operations. Table 3 gives overview data on breeding units within the seed base in the Region.

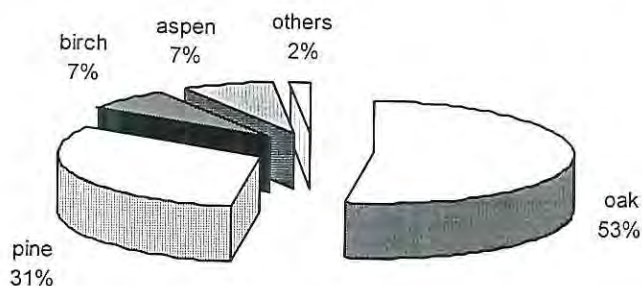


Fig. 1. Distribution of the principal forest-forming species in the forest area of CChR.

forests growing in the European North of Russia. The levels of genetic variation measured as mean values of observed and expected heterozygosity in the regeneration were not lower than in the parent stands. We revealed a loss of a portion of allelic variants in the regeneration due to the absence of genotypes in the trees that remained after fires or clear-cutting. In the analysis of the combined sample of trees it became obvious that the regenerated Scots pine populations had multi-loci allelic combinations which were absent in the parent populations. The interpopulation component of gene diversity (G_{ST}) in the regeneration increased by 26% compared with that in the parent stands, suggesting that the population structure of the pine stands experiences disturbance (Altukhov 1994, 1995).

The Institute now proceeds to a study of mechanisms forming the population genetic structures. The level of self pollination in two Siberian spruce trees separated from each other and from the parent populations was studied, in addition to the study on the genetic structure of their 25–45 years old progeny. It was observed that the level of self pollination in these model trees is very high (about 70% of the total number of viable seeds), varying from 35% in the upper part of the crown to 88% in its middle and 81% in its lower parts. The marker allele at *Skdh* locus (which is absent in parent trees) is found, on the average, in about 5% of the embryos. We detected growth depression in the progeny of these trees, together with a low level of observed heterozygosity and a significant deviation from Hardy-Weinberg equilibrium (excess of homozygotes). Hence, under the conditions of spatial isolation, regardless of the influence of the pollen pool, scattered seed bearing trees demonstrate a very high level of self pollination which leads to the formation of genetically defective populations.

The results presented in the current paper were obtained at the early stage of the study related to the conservation of natural genetic diversity in conifers under unfavourable conditions.

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Activities on the conservation of genepools of principal forest-forming tree species in Russia: the tasks of CENTRLESSEM

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The total area of the Russian Federation's forest fund is about 1180.9 million hectares. The proportion of forest area is 44.7%. Of the total area of the forest fund, 1110.5 million ha (94%) are in the control of the Federal Forestry Service of Russia (Rosleskhoz), of which 33.1 million ha have been placed under long-term use by different agricultural and other institutions and organizations. Conifers constitute 71.9% of the forest area, broadleaves constitute 18.5% (hardwood species 2.5% and softwood species 16%). The rest of the forest area is mainly covered by shrubs.

Table 1 gives the distribution of the forest area in the Central economic Region of Russia which is the main territory of the scientific activities by CENTRLESSEM in the field of forest gene conservation. Table 2 presents the data on forest genetic reserves in the Russian Federation. In Table 3 are shown the results of the designation of forest genetic reserves in the Central Region. Table 4 gives an overview of the conservation units which belong to the programme of genetic and breeding activities on forest species in the Russian Federation as a whole, and in the Central Region in particular.

The data presented indicate that the areas designated to conserve forest genetic resources are extremely differentiated and are not related to the extent of the forest fund, its structure and quality. In the Central Region the necessity of stimulating further work is most urgent in the Vladimir, Tula and Oryol Provinces. It is necessary to initiate the conservation of the genepools of broadleaved species such as *Quercus*, *Betula* and *Populus*.

Table 1. Distribution of forest area in the Central economic Region of Russia by principal forest-forming species ('000 ha)

Provinces	Principal forest-forming species *									
	<i>P. syl.</i>	<i>Pic.</i>	<i>Lar.</i>	<i>P. sib.</i>	<i>Ab.</i>	<i>Quer.</i>	<i>Ac.</i>	<i>Tilia</i>	<i>Bet.</i>	<i>P. trem.</i>
Bryansk	282.1	81.7	0.4	—	—	45.4	0.4	1.3	186.8	75.3
Vladimir	504.9	89.4	0.4	—	—	7.2	—	0.8	258.4	57.3
Ivanovo	266.1	167.2	1.1	—	—	2.4	—	0.7	250.1	64.4
Tver	595.0	555.6	1.2	0.1	—	0.2	0.1	0.5	663.2	194.8
Kaluga	93.4	167.9	0.5	—	1.6	29.4	0.3	7.4	253.5	118.1
Kostroma	914.7	784.7	0.9	—	0.1	0.3	—	1.3	1264.1	287.0
Moscow	335.8	394.1	2.4	—	—	30.3	0.2	9.8	574.4	141.8
Orel	18.6	5.0	0.5	—	—	46.8	0.3	1.2	19.4	15.4
Ryazan	300.5	12.8	0.5	—	—	75.5	0.2	10.7	233.3	66.8
Smolensk	108.1	307.9	0.3	—	—	1.7	0.7	2.2	317.5	110.2
Tula	11.5	14.7	1.7	—	—	94.7	0.6	23.8	53.8	38.5
Yaroslavl	114.6	217.1	0.4	—	—	1.7	—	0.2	363.8	127.8
Total	3545.3	2798.1	10.3	0.1	1.7	335.6	2.8	59.9	4438.6	1297.4

* *P. syl.* = *Pinus sylvestris*; *Pic.* = *Picea*; *Lar.* = *Larix*; *P. sib.* = *Pinus sibirica*; *Ab.* = *Abies*; *Quer.* = *Quercus*; *Ac.* = *Acer*; *Bet.* = *Betula*; *P. trem.* = *Populus tremula*.

Table 2. Forest genetic reserves in the Russian Federation (data are as of 1 January 1996)

Economic regions / Reserves	Registered (ha)		Genetic reserves for species (ha) *						Other	
	Total	In 1995	P. syl.	P. sib.	Picea	Larix	Quer.	Fagus		Bet.
Northern	72560.1	-	19545.1	-	47880.0	4198.0	-	-	937.0	-
North-Western	1692.2	-	731.2	-	961.0	-	-	-	-	-
Central	13539.8	-	6761.3	-	5512.0	-	476.7	-	673.0	116.8
Volga-Vyatsk	7557.9	-	4135.5	-	1304.7	-	2117.7	-	-	-
Central	4046.2	258.0	248.1	-	-	-	3798.1	-	-	-
Chernozem	3123.0	1126.8	2439.4	-	-	-	652.9	-	30.7	-
Povolzhe	2444.0	216.0	-	-	-	-	616.0	1700.0	-	128.0
North Caucasus	49506.7	1168.0	31899.5	-	5741.0	578.0	4498.9	-	5085.0	1704.3
Urals	4611.0	504.0	3433.6	999.4	-	178.0	-	-	-	-
Western Siberia	18108.7	-	8629.2	5061.5	1401.0	3017.0	-	-	-	-
Eastern Siberia	8156.0	-	637.0	-	4893.0	2626.0	-	-	-	-
Far East	1029.9	-	-	-	-	-	1029.9	-	-	-
Voronezh Reserve	1118.0	-	-	-	-	-	-	-	-	1118.0
Hoper Reserve	185345.6	3272.8	78459.9	6060.9	67692.7	10597.0	12160.3	1700.0	6725.7	1949.1
Total Fed. Forestry	187493.6	3272.8	78459.9	6060.9	67692.7	10597.0	13190.2	1700.0	6725.7	3067.1
Service	-	-	-	-	-	-	-	-	-	-
Total in Russia	187493.6	3272.8	78459.9	6060.9	67692.7	10597.0	13190.2	1700.0	6725.7	3067.1

* P. syl. = *Pinus sylvestris*; P. sib. = *Pinus sibirica*; Quer. = *Quercus*; Bet. = *Betula*.

Table 3. Genetic reserves in the Central economic Region of Russia (data are as of 1 January 1996)

Provinces	Registered (ha)		Genetic reserves for species (ha) *						Other	
	Total	In 1995	P. syl.	P. sib.	Picea	Larix	Quer.	Fagus		Bet.
Kostroma	3733.1	-	2025.3	-	918.0	-	-	-	673.0	116.8
Moscow	2030.0	-	1460.0	-	570.0	-	-	-	-	-
Ryazan	309.9	-	-	-	-	-	309.9	-	-	-
Tula	166.8	-	-	-	-	-	166.8	-	-	-
Smolensk	7300.0	-	3276.0	-	4024.0	-	-	-	-	-
Total	13539.8	-	6761.3	-	5512.0	-	476.7	-	673.0	116.8

* P. syl. = *Pinus sylvestris*; P. sib. = *Pinus sibirica*; Quer. = *Quercus*; Bet. = *Betula*.

Table 4. Conservation units included in the programme of genetic and breeding activities (data are as of 1 January 1996)

Forestry administrative Units	Seed orchards		Mother tree archives		Clonal archives		Permanent seed production areas (ha)		Field trials	
	ha	clones	ha	clones	ha	clones	ha	clones	ha	clones
Total by the Fed. Forestry Service incl.:	7534.7	6414	274.2	1958	353.8	3361	75255.8	547.7	5465	
Scots pine	3715.1	7183	113.4	1116	129.4	2193	34578.5	273.0	2964	
Spruce	1910.0	6072	35.7	387	29.9	672	7786.4	191.1	1811	
Larch	884.2	658	51.1	152	16.1	280	5119.2	27.7	308	
Siberian st. pine	447.6	3510	35.7	168	21.2	151	15012.9	15.8	122	
Fir	30.4	—	24.0	46	—	—	215.5	12.4	45	
Oak	284.4	193	3.8	75	—	—	9756.1	11.9	106	
Others	263.0	198	10.5	14	157.3	65	2787.2	15.8	109	
Central Region incl. Forest Admin. Boards:	1570.0	2202	39.5	315	4.3	55	9157.3	89.5	591	
Bryansk	110.5	175	—	—	1.5	20	911.0	11.3	31	
Vladimir	39.0	—	—	—	—	—	362.0	7.5	—	
Ivanovo	248.1	61	4.8	55	—	—	337.3	—	—	
Kaluga	20.7	20	2.5	20	—	—	457.0	1.0	15	
Kostroma	80.5	96	—	—	—	—	959.5	—	—	
Moscow	315.8	220	—	—	—	—	1021.5	—	—	
Oryol	6.0	—	2.0	—	1.0	—	218.8	46.4	401	
Ryazan	182.6	230	5.8	114	—	—	1339.9	5.0	—	
Smolensk	98.1	220	2.5	15	—	—	669.0	3.0	21	
Tver	251.6	619	11.3	101	—	—	1548.0	—	—	
Tula	—	—	—	—	—	—	620.8	0.5	14	
Yaroslavl	174.2	127	4.0	10	—	—	712.5	—	—	
Hunting farm "Rusky les"	42.9	434	6.6	—	1.8	35	—	—	—	
								14.8	—	109

One of the immediate tasks is to designate genetic reserves for *Pinus sylvestris* in the Vladimir Province. The gene pool of this species is considered very valuable. The lack of systematic research on genetic structures of the stands occurring in the Region is a serious gap. This is partly due to the fact that CENTRLESSEM has no relevant laboratory and the research task is not provided with any financial support.

In Russia as a whole the intensity of work on the designation of forest genetic reserves is rather low, for the following major reasons.

- Although principal regulations for the designation of genetic reserves in Russia are available, there is currently no relevant federal programme. Forest genetic conservation is not considered to be a priority area, despite the necessity of conservation indicated in the approved international documents. Since the scope and content of the work to be done in the future still remain to be defined, there is no financial support for carrying out this work. In the absence of these prerequisites the designation of genetic reserves *in situ* and the establishment of forest gene conservation units *ex situ* are not systematic. The work currently undertaken depends upon the personal initiative, scientific interests and qualification of the staff involved mainly at research institutions and other organizations.
- With the reduction of financing for forest research institutions and the Russian Academy of Sciences the operational possibilities for research become more scarce, including those directly relevant to forest genetic conservation. At present only five branch institutes (Federal Forestry Service of Russia) are engaged in research on forest genetic conservation in one way or another. They are the Institute of Forest and Forest Chemistry in Arkhangelsk, the Forestry Institute in St. Petersburg, the Research Institute of Forest Genetics and Breeding in Voronezh, the CENTRLESSEM and the Far East Forestry Research Institute in Khabarovsk. The latter one is the only branch institute situated in the eastern part of Russia.
- Most forest resources are situated in the Asian part of Russia (Siberia), where the system of roads and infrastructure are not developed.
- The procedure of the designation of forest genetic reserves requires their approval by entities of the Russian Federation (at the level of Republic, Region, Province), including forestry administrative units, environmental control bodies and executive authorities. However, forestry administrative units, and local authorities in particular, are not always interested in the exclusion of commercially valuable stands from the normal forestry management and the subsequent special protection regime required for the genetic reserves. It is obvious that the lack of interest may slow down the process of coordination of action on the designation of a genetic reserve and even stop it.
- The influence of mass media on the formation of the public opinion in favour of carrying out work on the forest genetic conservation is not sufficient.
- Another problem of the Central Region where forests are exploited intensively is to select a single forest area larger than 100 ha, as requested in the regulations for the designation of forest genetic reserves.

It appears to be necessary to act in the following main directions. The first direction—"from above"—calls for implementing the mechanism of the decisions of the UN Conference on Environment and Development held in 1992 (Rio de Janeiro) and Resolution S2 "Conservation of forest genetic resources" endorsed by Ministers responsible for forestry of the European countries (in 1990, Strasbourg) for ensuring

the development of a national strategy and financially supported federal programme of forest genetic conservation in Russia. The second direction—this could be called “intermediate”, though it is the most urgent in the current situation—calls for the conservation of forest genetic resources through implementing concrete projects in the framework of cooperation between research organizations in Russia and the International Plant Genetic Resources Institute with financial support from foreign sponsors. The third direction—“from below”—calls for the stimulation of the activities of research institutions (and even re-assessment of their research priorities), teams and individual scientists engaged in the designation and establishment of conservation units within the limits of the present budgetary means.

The specific problem with which CENTRLESSEM is now being confronted is determined by the multiple functions of this organization. The organization pursues technical policy and exercises monitoring of both the designation of genetic reserves (*in situ*) and the establishment and maintenance of conservation units (*ex situ*) included in the programme of genetic and breeding activities through its regional departments (34 subordinated seed stations) and special forest seed and tree breeding units located in Russia. Hence, according to the decision approved by the Federal Forestry Service, with the participation of CENTRLESSEM, forest genetic conservation may be planned analogically to the planning of work for “plus” (selection) breeding. However, planning of work on the conservation of gene pools in individual regions and for the relevant species (within species) in the categories of conservation units *in situ* as well as *ex situ* can be effective only with the availability of a modern documentation and information system.

Prospects for the study and conservation of forest genetic resources in the Komi Republic

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In studies of forest genetic resources and development of measures on their conservation it is necessary to take into account environmental and forest conditions as well as the current economic infrastructure which is of prime importance for large forest regions such as the Komi Republic.

The total area of the forest fund of the Komi Republic is 39 million ha, of which the forest area covers 28.6 million ha. Nearly all the forests have autochthonous origin. Artificial stands form only about 1% of the forested area.

Coniferous stands cover about 80% of the forest area. Mature and overmature stands constitute about 70%. The total growing stock is 2.8 billion m³ or more than 50% of the total timber volume available in commercial forests growing in the northern part of European Russia. The mean annual increment is about 1 m³/ha. The annual increment varies from 2.2 to 2.4 m³/ha in the south and 0.4–0.6 m³/ha in the north.

Forest genetic resources of the Komi Republic are of great interest to forest genetic science and breeding. This is caused by a number of natural and historical circumstances. The territory of the Republic is situated at the interfaces between two large geobotanical regions, namely, the North European and the Urals-West Siberian. In this area, formation of coniferous taiga ecosystems began late in the Pliocene (around 10–12 million years BC) and ended when the Miocene was phasing into the Pleistocene (around 5–6 million years BC). In the mid-Pleistocene (around 1.5 million years BC) dark coniferous forests predominated at the latitude of the middle Pechora river. Early in the Pleistocene and Holocene, forests occurred on the banks of the Vorkuta river. It was then that the main penetration of conifers into the northern part occurred.

Such a long history of the forests in the northeastern part of Europe and repeated oscillations of ranges of coniferous and deciduous species have resulted in the formation of ecosystems which are characterized by a fairly high diversity of species composition. In the forests of the Komi Republic 8 coniferous and 17 deciduous tree species as well as more than 50 shrub species can be found. Among conifers there are *Pinus sylvestris* L., *Picea obovata* Ledeb., hybrids of *P. abies* × *P. obovata*, *Abies sibirica* Ledeb., *Larix sibirica* Ledeb., *Juniperus communis* L., *J. sibirica* Burgsd., *Pinus sibirica* Du Tour and *Picea abies* (L.) Karst. The latter two species have insular distribution patterns. Among deciduous tree species there are *Betula pendula* Roth., *B. pubescens* Ehrh., *B. tortuosa* Ledeb., *Alnus incana* (L.) Moench. and *Populus tremula* L. In small areas the elms (*Ulmus laevis* Pall., *U. glabra* Huds.) occurs. The changes in forest areas covered by principal forest-forming species are shown in Table 1.

In the Komi Republic, artificial Siberian stone pine (*Pinus sibirica*) stands have been established in recent years. Natural stands of this species are distributed mainly in the upper reaches of the Vychegda and the middle Pechora rivers.

In the course of historical development stable taiga communities have been formed. At present the greater part of all virgin forests occurring in the European

North are located in the Komi Republic. Many of them are characterized not only by rich gene-pools of forest trees and shrubs, but the availability of rare, strictly protected plants and medicinal herbs as well. A broad spectrum of ecological conditions (plain and 'terrace' forests occurring on the banks of the Pechora, Mezen, Vychegda and other rivers, mountain stands of the Central and Sub-Polar Urals and the Timan Ridge as well as pre-tundra forests) make the natural genetic diversity of the forests of the Komi Republic unique.

However, large clearcut areas (about 5.5 million ha) which are a result of extensive logging activities during the last 40 years, windfalls, windbreaks, influence of industrial pollution and forest fires are inevitably responsible for the reduction of the area covered by virgin and natural forests, the erosion of their diversity and possibly irreparable losses of the genetic resources. The most serious and often disastrous changes in the composition, productivity and sustainability of forest ecosystems take place in the zones of large industrial and transportation projects. These are petroleum, gas and non-metallic mineral producing areas and those areas where oil and gas pipelines are being laid (for example, Jamal Centre, and others). It is necessary to take measures for the long-term conservation and effective use of gene-pools of the boreal taiga forests. One such measure is the designation of a network of strictly protected areas such as nature protected areas, reserves, genetic reserves, nature monuments, etc. Since investigations into genetics and breeding require a lot of time, the designation and conservation of forest genetic resources should be given top priority in the Komi Republic.

At the present time there is the Pechora-Ilych State Biospheric Reserve (the total area is about 700 000 ha), the National Nature Park Ugyd-Va (the total area is 1.9 million ha), about 300 protected areas and reserves with the total area more than 6 million ha (about 15% of the total area of the Republic). To conserve the forest ecosystems about 40 stands (the total area is 48 000 ha) have been designated, the insular populations of Siberian stone pine being the most valuable among them. In collaboration with the Forest Department of the Komi Republic the researchers of the Institute of Biology have designated the first group of genetic reserves (38) with a total area of about 28 000 ha. This was implemented in accordance with a special resolution of the Council of Ministers of the Komi Republic adopted in 1990. In 1996 UNESCO declared the National Nature Park Ugyd-Va a strictly protected area.

Among the designated reserves there are highly productive stands characterized by a high growing capacity and valuable economic properties. For instance, in a genetic reserve of pine (Priluzhsky forest enterprise, Loemskoe forest division, compartment 11) of age classes V-VI and site quality classes I-II the growing stock is 250-260 m³/ha at the density of stocking 0.7-0.8. In a genetic reserve of spruce (Pechora forest enterprise, Ust-Voiskoe forest division, compartments 176, 177, 214) of age classes VII-VIII and site quality classes IV-V the growing stock is up to 260 m³/ha at the density of stocking 0.7-0.8.

The identification and conservation of gene-pools of economically valuable forest-forming tree species is the goal of genetics and tree breeding, contributed primarily by breeding inventories of forests. To date (as of 1 January 1996), in the Komi Republic 961 plus trees of pine, 473 spruce, 192 Siberian stone pine and 152 Siberian larch, occurring mainly in the middle taiga subzone, have been certified. In the same subzone, 175 ha of seed stands (spruce and pine) have been designated. There are three permanent seed orchards with a total area of about 300 ha.

Table 1. Forest area covered by principal forest-forming tree species (million ha)

Species	Year of inventory				
	1951	1961	1966	1978	1988
Scots pine	6.9	6.5	6.7	7.3	7.3
Spruce	13.9	15.2	15.5	15.8	15.8
Fir	—	—	0.03	0.2	0.2
Siberian stone pine	—	—	0.01	0.04	0.03
Larch	—	—	0.3	0.3	0.3
All conifers	—	—	22.5	23.6	23.6
Birch	3.7	4.7	4.7	4.5	4.5
Aspen	0.2	0.3	0.4	0.5	0.5
Other broadleaves	0.2	0.3	0.01	0.01	0.01
All broadleaves	4.1	5.3	5.11	5.01	5.01
Total					28.6

In the seed orchards at Sysola and Syktyvkar some clones yield an abundant crop of seeds. In the Sysola seed orchard both families (32 plus trees of pine and 191 spruce) and vegetative clones (from 183 plus trees of pine) have been used. The Syktyvkar seed orchard of pine has also been established from open-pollinated families (45 plus trees) and vegetatively propagated clones (144 plus trees). Now clones are being selected in these seed orchards in order to establish the second generation seed orchards. In 1977 provenance trials of pine were established in the Kortkerossky forest enterprise (8.7 ha) with 24 provenances while spruce provenance trials covered 16.5 ha and included 33 provenances. They are now reaching the productive age.

It should be noted that the intraspecific variation of principal forest-forming tree species occurring in the Komi Republic is still not clearly understood, though there are some data on the significant diversity of forms for both coniferous and deciduous species. Investigations into genetics and breeding were limited due to the insufficient forestry research potential and the lack of funds as well as the fact that many large forest areas are almost inaccessible. The organization of comprehensive international expeditions in collaboration with the Institute of Biology (Syktyvkar) aimed at the study of forest genetic resources of the Komi Republic would be of major importance. Research on the genetic diversity of Siberian stone pine, Siberian fir and Siberian larch occurring on the borders of their continuous ranges as well the study of natural pine, spruce and mixed forests are of greatest interest. Valuable forms to be revealed may be of obvious interest to forest genetics and tree breeding.

Biological processes behind the flowering and fructification of principal forest-forming tree species should also be studied, apart from the research on their genepools. Regional cytoembryological, morphological, physiological and karyological investigations would be of great significance.

Investigation and conservation of genetic resources of the principal forest-forming tree species in Karelia

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Intensive commercial exploitation of the Karelian forests, primarily coniferous stands, contributed greatly to the degradation of forest age structure, reduction of the area occupied by valuable pine and spruce forests, reduction of intraspecific diversity, loss of valuable genotypes, forms and parts of forest tree populations. Consequently, an urgent task is to designate and preserve valuable genepools of the principal forest-forming species in order to ensure their existence and further evolution as well as to provide them a potential for fulfilling the economic and environmental functions of forests.

Karelia is situated in the northeastern part of Russia. It borders with the Murmansk Province in the north, the Arkhangelsk Province and the White Sea in the east, the St. Petersburg and Vologda Provinces in the south and Finland in the west.

The Karelian forests are situated in the taiga zone of the European part of Russia, the forests in the northern part of the Republic forming a part of the northern subzone while the stands growing in the southern part of Karelia belonging to the middle subzone of the taiga. Main characteristics of the forest fund of the Republic of Karelia are given in Table 1. As evident from the table, the greater part of the forest area (89%) is covered by coniferous forests.

Principal forest-forming tree species are: Scots pine (*Pinus sylvestris* L.) and Finnish spruce (*Picea abies* × *fennica* Rgl.) which is a hybrid between Norway spruce and Siberian spruce. Of broadleaves the silver birch (*Betula pendula* Roth.), pubescent birch (*B. pubescens* Ehrh.), aspen (*Populus tremula* L.), grey alder (*Alnus incana* (L.) Moench.) and common alder (*A. glutinosa* (L.) Gaertn.) occur in Karelia. Particular attention should be given to 'curly birch' which is a specific variety of silver birch (*B. pendula* var. *carelica*). It is of little significance as a forest-forming tree but is distinguished for its very decorative texture. The Carelian curly birch grows locally and has a disjunct distribution. At the present time, this tree is rare in occurrence and is protected by the state.

In Karelia 64% of the forest area is covered by pine stands. Forest regions differ considerably in species composition of stands. In the northern subzone the proportion of pine is 76%, while that of broadleaves is only about 4%. In the middle subzone, 20% of the forest area is covered by broadleaves, whereas the rest of the forest area is about evenly divided between pine and spruce. Regarding the age distribution of stands, young stands constitute 32%, mature and overmature stands 38%.

The *in situ* and *ex situ* strategies are applied for the conservation of forest genetic resources. *Ex situ* conservation can be carried out in botanical gardens, through the establishment of experimental plantations, seed orchards and clonal archives as well as through tissue culture, etc.

In 1975 the Karelian researchers initiated the establishment of a permanent seed base on genetic and breeding principles (Table 2). This framework comprises the designation of plus trees and seed stands.

Table 1. Characteristics of the forest fund in the Republic of Karelia

Area of	('000 ha)	Percentage of forest covered land	Growing stock (million m ³)
Republic – total	18052.0		
Forest fund	14761.2		
Forest area	9056.4	100.0	870.8
Conifers	8061.3	89.0	775.1
Pine	5752.7	63.5	–
Spruce	2306.9	25.5	–
Broadleaves	995.0	11.0	95.8
Birch	851.3	9.4	–
Aspen	63.4	0.7	–
Alder	45.3	0.5	–

Table 2. Overview of different units within the seed base of Karelia

Type of unit	Total	Including			
		Pine	Spruce	Curly birch	Black alder
Plus trees (number)	2023.0	1408.0	486.0	100.0	–
Seed stands (ha)	581.4	394.5	181.9	2.1	2.0
Permanent seed production areas (ha)	76.3		10.0	66.3	–
Seed orchards (ha)	478.9	332.0	83.0	51.5	–

Seed orchards, which are considered the most valuable part of the permanent seed base, comprise clones and seed progeny of almost all the plus trees selected in Karelia so far. In each orchard there is a clonal archive. Experimental plantations covering 30 ha were established to conduct progeny trials for the selected plus trees.

The Tree Breeding and Seed Centre in Petrozavodsk which is responsible for the establishment of seed orchards is planning to continue an active search for plus trees and seed stands in Karelia, particularly in its northern part.

One way of *ex situ* conservation and propagation of breeding material is the use of tissue culture. Researchers of the Department of Woody Plants Cytology, Genetics and Breeding of the Forest Institute (Karelian Research Centre) achieved promising results in the field of microclonal propagation of curly birch. At present experiments on pine and spruce are being pursued.

The key problems of *ex situ* conservation are the lack of long-term financing and unfavourable changes in the genetic structure of the conserved material. It is possible to avoid these problems either totally or partially through *in situ* conservation for most of the species.

One aspect of conservation of natural forest stands is the designation of a network of protected areas (Table 3), of which nature reserves, national and nature parks occupy a highly important place. A feasibility report on the designation of protected areas is being prepared by the Institute "Karelnproekt" and the Department of Nature Protection of the Forest Institute.

At present there are two state nature reserves and two national parks in Karelia:

- State Nature Reserve Kivach, founded in 1931, the total area is 10 400 ha;
- State Nature Reserve Kostomukshsky, founded in 1983, total area is 47 600 ha;

- Vodlozersky National Park, founded in 1991, the total area is 404 700 ha, including 130 600 ha of the territory of Karelia and 274 200 ha of the territory of the Arkhangelsk Province;
- Panaiarvi National Park, founded in 1992, the total area is 103 300 ha.

Table 3. Strictly protected areas and units of the Republic of Karelia

Category of strictly protected areas and units	Number	Area (ha)
Total area	202	857 117
National parks	2	233 900
State nature protected areas	2	58 019
Botanical and forest reserves	11	2 971
Botanical and forest nature monuments	24	2 780

In 1990 scientific work leading to the designation of a network of strictly protected areas was completed, the designation of national parks in marginal areas occupying a highly important place. The Government of the Russian Federation issued a decree on the creation of five national parks in Karelia in the years 1990–2000. These are Koitaioki (Suoiarvi Area), Tulos (Muezersky Area), Ladozhskie shkhery (Northern Priladozhie), Kizhskie shkhery (Zaonezhie) and Kalevalsky (Kalevala Area).

Documents have been prepared for several additional proposed protected areas with different status. The principal drawback of the network of strictly protected areas is that they, almost without exception, do not represent in full measure the genepools of forests. In addition, restrictions imposed by management practices in nature reserves, national parks and other protected areas can hamper the gene conservation measures.

Genetic reserves are most suited to the requirements of conservation and regeneration of genepools of forest tree species. Location, size and management regime which reflect the population structure and genetic peculiarities of the preserved species should make genetic reserves different from other protected areas.

The staff of the Department of Woody Plants Cytology, Genetics and Breeding of the Forest Institute have been designating genetic reserves in Karelia since 1988. Since the genotypic and spatial population structures of principal tree species are not yet fully understood, seed zoning was taken as the starting point. From 1988 through 1989 four genetic reserves for spruce (2800 ha), four for pine (2100 ha) and one genetic reserve for aspen (1000 ha) were designated in the south Karelian seed subzone (Table 4). In accordance with the "Regulations for the designation and conservation of genepools of tree species in the forests of the USSR" (Moscow, 1982) technical documentation for these reserves (certification forms, passport data, description of stands to be conserved and working plan) was worked out. The reserves were certified by the State Committee on Forests at the technical conference held on 14 April 1989.

Table 5 lists brief characteristics of the genetic reserves proposed for designation in the northern, central and southern Karelian seed subzones in the years 1990–1994. Within these few years a total of eight reserves for pine (3350 ha) and three reserves for spruce (1260 ha) were designated. For each reserve, technical

documentation was elaborated and certification form completed. Unfortunately, it was impossible to carry out a full-scale inventory of these reserves due to the lack of financing. Hence the new reserves have not been certified yet.

The decline of the Karelian forest fund and uneven age structure of coniferous stands are the factors which restrict the possibilities for designation of adequate reserves. Selective logging performed over a long period of time contributed to decline of natural populations. Therefore, especially in the northern seed subzone, only a few stands exist which can meet the requirements of genetic reserves.

Population genetic studies provide the theoretical basis for genetic conservation measures and for breeding improvement of species. In this regard since 1990 the Department of Woody Plants Cytology, Genetics and Breeding has been making studies into intraspecific variation and population genetic structures of Scots pine and Finnish spruce occurring in the Republic. In these studies morphological traits of reproductive organs and isoenzymes were used as genetic markers.

The results of the analysis of allozyme and morphological variation in Scots pine and Finnish spruce (Table 6) suggest that the populations studied are genetically closely related. Six spruce and three pine populations were used for the population structure analysis. The division of the spruce distribution area into a great number of local populations may be a consequence of introgressive hybridization which occurs just in this part of the Norway spruce range. At the same time a decrease in the level of genetic variability can be reported for the pine and spruce populations, which is presumably due to their marginal locations and intensive exploitation of coniferous forests in this region.

Table 6. Mean values of genetic variation of the pine and spruce populations *

Species	A	H_e	$P_{99\%}$	G_{ST}	D_N
Pine	1.95	0.181	63.4	2.5	0.010
Spruce	1.72	0.147	50.0	2.2	0.013

* A = mean number of alleles per locus, H_e = expected heterozygosity, $P_{99\%}$ = percent polymorphic loci at 99% criterion, G_{ST} = proportion of genetic diversity residing among populations, D_N = Nei's genetic distance.

Researchers pursue their investigations into intraspecific variation and population structures of the principal species. This is needed for making the borders of some populations clear, introducing modifications into the current seed zoning and revealing genetic differentiation of pine and spruce stands within both the existing and proposed nature reserves and national parks. With the results obtained we shall be able to designate an adequate number of genetic reserves and establish their sizes.

It is expected that in studies on the spruce and pine population structures also monoterpenes (gas-liquid chromatography) will be used as genetic markers along with the morphological traits and isoenzymes. A variety of multivariate statistics techniques (estimation of generalized genetic distance, cluster, discriminant and principal component analyses) will be used to acquire more complete information about intraspecific variation and genetic differentiation of populations. We intend to study genetic structures of clonal progeny obtained from plus trees of the above species which is available in the Petrozavodsk seed orchard.

Table 4. Brief characteristics of the certified genetic reserves in south Karelian seed subzone

No.	Forest enterprise/		Species	Forest group	Area (ha)	Age	Site quality		Stocking density	Growing stock (m ³ /ha)
	Forest division	Forest group					Age class	Type		
1	Lakhdenpokhia/ Ikholskoe	I	Pine, spruce	I	509.2	70.3	I,6	Bilberry	0.70	246.5
2	Lakhdenpokhia/ Ladozhskoe	I	Pine, spruce	I	433.9	78.2	III, 2	Bilberry	0.59	162.4
3	Lakhdenpokhia/ Lakhdenpokhia	I, III	Spruce, pine	I, III	218.0	73.6	II,5	Bilberry	0.76	219.7
4	Lakhdenpokhia/ Lakhdenpokhia	I, III	Pine, spruce	I, III	214.0	72.5	III,0	Bilberry	0.62	180.2
5	Lakhdenpokhia/ Sortavala	III	Spruce	III	980.0	70.0	II,3	Bilberry	0.65	183.2
6	Kondopoga/ Sandalskoe	III	Spruce, pine	III	566.0	65.0	II,7	Bilberry	0.70	156.9
7	Olonets/ Obzhanskoe	I	Pine, spruce	I	952.0	77.5	III,4	Bilberry	0.74	201.9
8	Spasogubsky/ Konchezerskoe	III	Spruce, birch	III	1059.0	67.4	III,0	Bilberry	0.68	144.2
9	Lakhdenpokhia/ Spasogubskoe	III	Aspen, birch	III	1012.0	76.8	III,0	-	0.78	194.7

Table 5. Brief characteristics of the proposed genetic reserves

No.	Forest enterprise/ Forest division	Species	Forest group	Area (ha)	Age	Site quality class	Type	Stocking density	Growing stock (m ³ /ha)
North Karelian seed subzone									
1	Piaoziorski/Topozero	Pine, spruce	I	150.6	135	IV,6	Bilberry	0.53	125
2	Kestenga/Topozero (Kukat Island)	Pine	I	515.0	94	IV	Cowberry	0.59	74.8
3	Kestenga/Topozero (Kovdostrov Island)	Pine	I	109.0	90	IV	Cowberry	0.60	130
Central Karelian seed subzone									
4	Lendery/Lendery (Sulo Island)	Pine, spruce	III	733	82.9	IV,0	Bilberry	0.61	141.8
5	Muezersky/Reboly	Pine, spruce	III	854	93.7	III,9	Bilberry	0.60	130.0
6	Sukkozero/Sukkozero	Pine	III	859	68.5	III,5	Cowberry	0.69	98.8
7	Volomsky/Tumbskoe	Pine, spruce	I	841	132.7	IV,1	Bilberry	0.61	136.0
8	Valdai/Taigimiskoe	Spruce	I	159	89.3	III,1	Bilberry	0.74	143.3
9	Valdai/Vygozero	Pine	I	152.6	100.6	III,5	Cowberry Bilberry	0.60	157.6
South Karelian seed subzone									
10	Pitkianta Forest Administration/Salmi	Spruce	I	379.1	67	II,8	Bilberry	0.7	190
11	Pitkianta Forest Administration/Salmi	Spruce	I	723	69	II,8	Bilberry wood- sorrel	0.9	196

The two principal forest-forming tree species, pine and spruce, have immense distribution areas and occur across the territories of several states. This raises the question of the coordination of joint efforts regarding the study and conservation of their genetic resources (research into population structures and designation of a network of genetic reserves for these species throughout their distribution areas).

Genepools of forest tree species are being studied and conserved in many regions of Russia and in other countries. The experiences acquired may be of great value for forest geneticists not only in the respective country but also abroad. It is desirable to exchange new methods and techniques, render assistance to master them, establish an international forest genetic resources database, map out regional (with consideration of local conditions), national and international genetic resources programmes and organize relevant coordination centres. In summary, financing of research remains the hardest unsolved problem.

Forest resources of Tomsk Province; conservation and regeneration of Siberian stone pine forests

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The Tomsk Province is one of the Siberian provinces very favourably endowed with forests. According to the inventory data the total area of the forest fund of the province covers 28 334 800 ha or 90% of its total area. The greater part of forests (94.2%) is under the responsibility of the Federal Forestry Service of Russia. Large areas (5.4%) have been placed under long-term management by different agricultural enterprises and only 0.4% are in the control of other state ministries and departments.

The forest covered area of the state forest fund is 17 029 600 ha (92.3%), of which only 0.3% are covered by artificial stands. The area without forest covers 2.8% and is predominantly represented by failed afforestation (1.3%), burnt-over lands and perished stands (1.2%), stands with very low density of stocking (0.2%) as well as barren lands and glades (0.1%).

The non-forest lands cover 32.7%. Among utilized non-forest lands are arable, hay and pasture lands (0.3%). Open bogs (32.3%), sands and ravines (0.1%) make up non-utilized lands. The availability of large non-forest lands which are not utilized, opens the possibilities for the development of forest industry and calls for a rapid solving of the afforestation and forest amelioration problems.

Forests of Group I cover 8.2% of the area, including 'green zones' (0.3%), protective belts along roads (0.1%), forest plantations intended for producing nut crops (2.7%) and water protection forests along river banks (5.1%). Forests of Group II cover 3.6% of the area. Of 88.2% of the area covered by forests belonging Group III, 6.5% are covered with inaccessible forests, mainly stands of site quality classes Va and Vb.

Coniferous forests constitute 59.3% of the total forest area. The proportion of individual conifer species includes 32.5% Scots pine, 20.8% Siberian stone pine, 2.6% spruce, 3.3% fir and less than 0.1% larch. Scots pine and Siberian stone pine forests are found throughout the province. About 32% of them occur under excessive moisture conditions and are stands of site quality classes Va and Vb. Larch and spruce stands occur in the northern part of the province while fir stands occur prevalingly in its southern part.

Of the deciduous species birch (31.6%) and aspen (9%) are widely distributed. It is rare for the other deciduous species to occupy a dominant position. Poplars and arborescent willows occur in floodplains where they form mono- and polydominant intrazonal groups. Forests dominated by shrubs, mainly dumetous willows, are typical for boggy areas, dales and floodplains. Mature and overmature stands cover 59.9% of the area and contain 72% of the total growing stock.

The total growing stock is 2576.01 million m³, including 1527.01 million m³ of conifers. The total timber volume of mature stands is 1877 million m³, of which conifers amount to 1002.33 million m³. In commercial forests the growing stock of mature stands is 1729.04 million m³, including 926.3 million m³ of coniferous species. In these conditions the mean growing stock is 151 m³/ha. The average

productivity of forests in drained habitats can be higher than 250 m³/ha. However, owing to the occurrence of large boggy areas, immense open swamps, woodless and non-forested areas, the mean growing stock is 98 m³ per hectare of the forest area (forest fund) and 84 m³/ha in general – still more than in other provinces of western Siberia.

It is ecological plasticity and capacity of tree species to grow under various edaphic and hydrothermic conditions as well as economic valorization, rather than the biological potential of the forest-forming species, which determine the productivity of forests composed of different species (Table 1). The highest productivity is typical for the forest types with selective requirements for the temperature regime and soil fertility and moisture while the lowest productivity is usually typical for those which demonstrate their extended ecological amplitude.

A programme of genetic and breeding improvement of the Siberian stone pine stands in the Tomsk Province was developed under the "Concept of forestry development in the Russian Federation until 2005" (Moscow, 1989) and the long-term programme of the establishment of a permanent seed base on genetic and breeding principles.

The practical breeding programme to which the author adheres was partially published for Siberian stone pine and comprehensively for birch. On this basis the Novosibirsk branch of the Institute "Soyuzgiproleskhoz" was assigned the task to prepare a feasibility report for the creation of a permanent seed base for Siberian stone pine.

In their studies V.N. Vorobyov, A.M. Danchenko and R.N. Bagoveev (1989) reported on the breeding inventory programme for Siberian stone pine in the southern part of the Tomsk Province. Within a comprehensive programme the Institute conducted breeding inventories of the forests occurring in the territories of the Kaltai, Tomsk and Timiriachev forest enterprises using the methodology proposed by the Institute of Natural Ecology (Siberian Branch of the Russian Academy of Sciences). As a result, 42.6 ha of seed stands, 2200 ha of 'best normal' stands and 4200 ha of 'normal stands' were designated, while the remaining 8100 ha were assigned to 'minus' stands.

Objectives of the Siberian stone pine breeding

The major objectives of the Siberian stone pine breeding are:

1. Breeding evaluation of the Siberian stone pine stands occurring in each zone;
2. Selection and propagation of plus trees capable of producing high seed crops in order to create the permanent seed base and special orchards (plantations to yield commodity nut crops);
3. Selection of plus trees, their testing for growth rate and technical characteristics of timber aimed at the large-scale establishment of short-term plantations;
4. Selection and propagation of highly resinous plus trees for the establishment of artificial stands;
5. Designation of genetic reserves to conserve the genetic potential of the natural populations within each seed zone. The greatest possible amount of stands occurring under unfavourable site conditions (boggy areas and low quality forest sites) to which the genotypes have adapted in the course of the natural selection, and not just highly productive stands which are of obvious forestry interest should be among the genetic resources to be conserved.

In addition, clonal archives and seed banks should be created to conserve the breeding material.

Table 1. Parameters of productivity of different forest types according to principal forest-forming tree species

Species	Area ('000 ha)	Growing stock (million m ³)	Average			
			Age (yrs)	Stocking density	Site quality class	Growing s. (m ³ /ha)
Scots pine	5528.00	636.80	115	0.55	V.25	115
Spruce	448.50	71.78	124	0.56	IV.85	160
Fir	560.50	88.14	95	0.60	III.20	160
Larch	10.90	1.49	172	0.56	V.11	137
Siberian stone pine	3560.00	728.80	166	0.56	IV.69	205
Birch	5379.20	739.43	166	0.64	III.22	137
Aspen	1518.90	308.47	82	0.67	II.37	203
Poplar	1.60	0.19	61	0.49	II.20	119
Willow	22.00	0.91	22	0.53	IV.03	41
Total/ avg.	17029.60	2576.01	110	0.59	IV.15	151

Selection of (geographical) ecotypes is considered to be a reliable and perspective method. It allows to conserve and sustain specific polymorphisms in the first generation selected. Therefore, it is essential that selection of provenances occurring under various site conditions be supported and a programme of their testing under different site conditions be developed to reveal those which are the most productive and well adapted to the respective site conditions. In western Siberia, such experimental stands are lacking.

Lines of breeding

The main lines of Siberian stone pine breeding are as follows:

1. Selection of populations should be used to conserve and improve genepools of the natural populations which exhibit high levels of genetic variation.
2. Selection and evaluation of seed and vegetative offspring should be used for the establishment of forest plantations and strain tests.

Breeding techniques

Selection of Siberian stone pine individuals to evaluate their total combining ability. **Objective of selection** is to establish artificial populations able to produce high timber and resin yields under different site quality conditions.

Selection technique relies on progeny trials established from open pollination of individuals within a population in order to assess the total combining ability on the basis of timber characteristics as well as the estimation of nut and resin productivity in clonal orchards.

Realization of selection. The first stage is the selection of promising families of the second and third generations within a nursery of the initial selection (1991-97), the establishment of experimental trials and first-generation seed orchards (1993-98). The second stage is the subsequent estimation of half-sib families growing in the trials and clones in plantations. Selection of clones for the establishment of 1.5 and 2. generation seed orchards (2000-2005) on the basis of the results obtained and the establishment of special forest plantations.

Main stages of the regional programme

The first block of the programme (practical solution of breeding problems apparent from the previous investigations) comprises studies on the structure of the Siberian

stone pine forests to establish the permanent seed base. This stage is based on selection and testing of plus trees, forms and stands of different breeding categories, improvement of the techniques and technologies for the establishment, organization and maintenance of seed orchards and plantations as well as more precise seed zoning.

The first block of the programme relies on the preparation of a feasibility report on the foundation of a breeding centre.

The second block of the programme envisages the improvement of bare-rooted and cell-grown stock growing techniques under the greenhouse and open ground conditions.

The third block presupposes the establishment of plantations on genetic and breeding principles. It comprises questions about conditions and productivity of potential Siberian stone pine forests, to develop predictive growth models, set regional standards of technological processes of establishment, growing, tending and protection of forest plantations from diseases and forest pests as well as to elaborate regional systems of fellings and formation of stands in conformity with their ecological and economic targets.

The fourth block: as the phenotypic performance and genotypic structures of Siberian stone pine are not clearly understood, data on the contribution of genetic factors and environment into the overall variation of quantitative characters are lacking, the evidence for the quality of progeny from phenotypically selected individuals is not fully convincing and the data of the comparative analysis of genotypical structures of the populations occurring under different environmental conditions are lacking, it is presupposed to resolve fundamental theoretical problems using the results of the investigations mentioned in the previous blocks. These theoretical problems may be subdivided, as follows:

1. Revealing the levels of genetic variation on valuable commercial parameters of populations and the effects of environment on their variation;
2. Progeny trials of individuals of different breeding categories selected on the basis of the commonly accepted procedure and estimation of the improvement expected;
3. Analysis of genotypic structures of populations growing under natural and artificial conditions;
4. Analysis of the development of characters during the ontogenesis and determination of individual and family homeostatic capacity;
5. Provision of an optimum breeding technique in the context of peculiarities of genotypic structures of populations.

The fifth block envisages the determination of the components of variation as a result of controlled crossings. The main objectives of the study are as follows:

1. Revealing and evaluating the effect of pollinators on timber, resin and nut productivity;
2. Estimation of the effect of the specific combining ability on productivity;
3. Estimation of the inbreeding effect;
4. Characteristics of genetic structures of populations on the basis of their combining abilities.

To date, in the Tomsk Province 306 plus trees have been certified, including 10 plus trees selected on the basis of their seed quality, 10 on the basis of early seed crop, 210 from the seed productivity aspect and 76 according to the growth rate of trees. Seed orchards covering 55 ha have been established with vegetative progeny of 205 plus trees. Half-sib progenies of 150 plus trees grow in the breeding section

of the nursery. In the Tomsk Province forest plantations established with seeds collected from the permanent forest seed base cover 205 ha (data are as of 1 January 1996). Seed orchards cover a total area of 1432 ha, including 352 ha covered by Scots pine, 51 ha by spruce and 1029 ha by Siberian stone pine. To date, 1299 ha of seed orchards have reached productive age.

By now, in the Tomsk Province breeding inventories have been conducted in stands covering 92 600 ha. As a result of these inventories 62.6 ha of seed stands, 28 ha of 'best normal' and 'normal' stands as well as five genetic reserves covering 5300 ha were designated. To ensure a complete implementation of the genetic and breeding principles in the southern taiga zone, breeding inventories should be conducted in stands covering a total area of 133 400 ha.

Forest genetic resources of eastern Siberia

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Until recently, the vast territory of eastern Siberia (Krasnoyarsk Region, Khakassia Republic, Tyva Republic, Buryat Republic, Irkutsk Province, Chita Province and Sakhta-Yakut Republic) was covered by the scientific activities of the Laboratory of Forest Genetics and Breeding of the Institute of Forest (Tables 1 and 2). At the present time our research is limited to the forests occurring in the Krasnoyarsk Region (within its previous area covering the Khakassia Republic and the Evenk National Autonomous Region), due to mainly financial problems. Some studies are still carried out in the Buryat Republic, Irkutsk and Chita Provinces.

First and foremost we conduct traditional research into structures within and among populations, mainly of conifers, on the basis of morphological, ecological and silvicultural traits. As a result of these investigations *Larix sibirica*, *L. gmelinii*, *L. cajanderi* and *L. czekanowskii* were thoroughly studied. *Pinus sylvestris* and *P. sibirica* were also subject to investigations. Studies concerning *Picea obovata* were limited to the Yenisey basin. Population structures of numerous birch species occurring in Siberia and the Far East have been intensively studied. Of the shrub species we undertook population studies only concerning the genus *Rosa*. Among the forest-forming tree species, only *Abies sibirica* has not been studied with regard to population structures.

Extensive studies of karyological polymorphisms in all the Siberian conifers were conducted. They are covered in the report by E.N. Muratova (this volume).

Studies of genetic polymorphisms at isoenzyme loci were conducted in a number of forest-forming conifers of Siberia. Among these were *Pinus sibirica* (Sayan and Altay mountains as well as several regions of western Siberia); *P. sylvestris* (Transbaikal region and some other regions); *Larix sibirica* and *L. sukaczewii*, and *Picea obovata*. The first steps have been made in this direction and the conclusions obtained so far are only preliminary. Practical work on the conservation of forest genetic resources in the Krasnoyarsk Region and in eastern Siberia as a whole is being implemented only on a limited scale and is basically limited to selection of plus trees. To date, about 600 plus trees have been selected in the Krasnoyarsk Region, more than half of them belonging to *Pinus sibirica*. Seed orchards are established mainly as research units.

Unfortunately, among the research teams studying forest genetic resources, the V.N. Sukachev Institute of Forest is the only one which carries out permanent and systematic research in the immense territory of eastern Siberia. The research carried out by institutions such as the N.I. Vavilov Institute of General Genetics (Moscow), the Institute of Plant and Animal Ecology (Ekaterinburg) and others is rather sporadic. The Krasnoyarsk State Technological Academy, the Institute of Biology (Yakutsk), the Institute of Natural Resources (Chita) perform such studies on a limited scale. The Novosibirsk Department of the Institute of Forest Genetics and Breeding reduced the scale of its research activities.

Extensive studies are conducted at the Laboratory of Dendrology of the Central Siberian Botanical Garden (Novosibirsk) under the supervision of academician I.J.

Table 1. Forest area in Siberia (data are as of 1 January 1993)

Administrative regions	Forest area ('000 ha)	Forest area (%)
Western Siberia	73871.6	36.7
Eastern Siberia, including	200619.6	54.8
Krasnoyarsk Region, including	51276.4	35.6
Taimyr National Autonomous Region	1303.0	3.7
Evenk National Autonomous Region	33914.9	63.3
Khakassia Republic	2738.6	46.8
Tyva Republic	7864.8	48.0
Irkutsk Province	56832.8	79.1
Ust-Ordynsky Buryat National Autonomous Region	755.1	51.2
Buryat Republic	20020.9	62.1
Chita Province	26716.7	68.7
Aginsky Buryat National Autonomous Region	499.4	30.9
Sakhta-Yakut Republic	139484.7	47.5
Total	414975.9	48.8

Koropachinsky. Populations of species from the genera *Picea*, *Populus*, *Alnus*, *Caragana* and other Siberian woody plants are studied. Although these investigations are carried out mainly in the context of plant systematics, they are very useful for forest genetic resources.

Among the constraints to studies of forest genetic resources in Siberia the most urgent are financial ones. Of course, different foundations, and primarily the Russian Basic Research Foundation and the Krasnoyarsk Regional Science Foundation give great financial support to our investigations. However, this support is not sustained in the long term.

Conservation of forest genetic resources in Siberia is hampered by the lack of interest from the forestry practice. In addition, officers of local and regional forest administrations approve the documents relating to the designation of forest genetic reserves with reluctance because they are afraid of losing potential income from timber sale.

There are objective difficulties in the conservation of forest genetic resources in the Krasnoyarsk Region, too. These are mainly associated with the immense distribution areas of the forest-forming tree species which offer a broad scope for investigations by a number of research institutions. Regardless of the fact that in Siberia, and the Krasnoyarsk Region in particular, the felling volume decreased drastically, the adverse impact of other negative factors increased. For instance, in the Krasnoyarsk Region mass outbreaks of Siberian gypsy moth were observed in an area of 1 million ha during the last two years. In the Boguchan Area alone, where the most valuable *P. sylvestris* stands occur, forest fires affected 200 000 ha.

Forests growing in the northern part of Siberia are hardly influenced by the impact of industrial pollution, with the exception of the forests in the vicinity of giant factories (for example, the Norilsk Integrated Industrial Complex). At present our institute is conducting extensive studies of the forests occurring in these areas.

The only way to solve all these problems is to work in close cooperation with scientific groups abroad. At present our institute is carrying out joint research in Siberia together with scientists from USA, Germany, Switzerland, Italy, Japan and other countries. Such cooperation is also foreseen in the area of forest genetic resources.

Table 2. Distribution of forest area (in '000 ha) of Siberia and growing stock (million m³) of the main forest-forming species (% of total shown in parentheses)

Administrative regions	<i>P. sylvestris</i>	<i>Picea</i>	<i>Larix</i>	<i>P. sibirica</i>	<i>Abies sibirica</i>	<i>Betula</i>	<i>Populus tremula</i>
Western Siberia	28510.50 (37)	5287.3 (7)	6726.80 (9)	11682.90 (15)	3453.00 (4)	17198.50 (22)	4727.90 (6)
Stock	2904.80 (30)	570.23 (6)	622.31 (7)	2062.36 (22)	503.67 (5)	2059.89 (22)	778.14 (8)
Eastern Siberia	33821.60 (17)	10941.40 (6)	89556.50 (45)	24076.00 (12)	8297.50 (4)	26524.90 (13)	5676.30 (3)
Stock	5699.51 (22)	1445.75 (6)	9596.72 (37)	4689.15 (18)	1508.49 (6)	2165.83 (8)	741.41 (3)
Krasnoyarsk Territory	9744.20 (19)	6367.90 (12)	7916.80 (15)	8455.50 (17)	5889.70 (12)	10579.30 (21)	2166.10 (4)
Stock	1706.25 (22)	834.60 (11)	1126.85 (15)	1586.60 (21)	1043.09 (14)	989.75 (13)	347.59 (4)
Taimir Region	0	187.50 (11)	1464.60 (86)	0	0	52.80 (3)	0
Stock	0	12.69 (15)	71.29 (83)	0	0	2.32 (2)	0
Evenk Region	3195.20 (7)	1055.20 (3)	34761.50 (81)	1463.60 (4)	17.80 (0.04)	2241.10 (5)	48.20 (0.1)
Stock	495.50 (14)	117.71 (3)	2588.79 (71)	303.95 (8)	2.36 (0.06)	133.12 (4)	4.02 (0.1)
Khakass Republic	215.80 (8)	406.00 (10)	413.60 (15)	869.10 (31)	523.10 (19)	647.40 (23)	73.60 (3)
Stock	129.12 (7)	5.50 (1)	59.92 (14)	190.44 (44)	84.51 (19)	56.54 (13)	9.88 (2)
Tuva Republic	101.60 (1)	61.30 (1)	3701.10 (49)	3516.90 (46)	0.70 (0.01)	239.00 (3)	6.70 (0.01)
Stock	16.85 (2)	7.91 (1)	565.24 (52)	470.21 (43)	0.13 (0.01)	25.03 (2)	0.50 (0.05)
Irkutsk Province	14806.20 (28)	3225.00 (6)	17240.10 (32)	6914.40 (13)	1582.00 (3)	7010.10 (13)	2419.70 (5)
Stock	2741.04 (32)	456.40 (5)	2576.52 (30)	1639.20 (19)	329.83 (4)	607.94 (7)	296.92 (3)
Ust-Ordynsky Region	259.20 (35)	21.70 (2.9)	191.10 (26)	13.00 (2)	1.30 (0.1)	214.40 (29)	39.40 (5)
Stock	59.92 (45)	2.84 (2)	34.91 (26)	2.42 (2)	0.23 (0.2)	24.96 (19)	7.25 (5.8)
Buryat Republic	3036.20 (18)	157.30 (1)	8845.00 (59)	1858.20 (11)	277.50 (2)	1123.90 (7)	457.30 (2)
Stock	360.31 (19)	19.41 (1)	987.94 (54)	304.64 (16)	47.35 (3)	71.80 (4)	50.55 (3)
Chita Province	2401.90 (10)	12.40 (0.5)	15240.30 (65)	984.00 (4)	5.40 (0.02)	4309.10 (19)	444.80 (2)
Stock	283.10 (12)	1.38 (0.6)	1616.89 (69)	191.44 (8)	0.99 (0.04)	244.65 (10)	23.47 (1)
Aginsky Region	61.30 (13)	0	247.00 (50)	1.30 (0.3)	0	160.60 (33)	20.50 (4)
Stock	7.42 (12)	0	39.66 (66)	0.25 (0.4)	0	12.04 (20)	1.23 (2)
Yakut Republic	10052.20 (7)	380.10 (0.3)	116879.80 (91)	396.50 (0.3)	21.00 (0.02)	1817.20 (1.4)	94.90 (0.07)
Stock	1043.79 (12)	48.02 (0.5)	7881.55 (86)	74.26 (0.8)	3.84 (0.04)	64.67 (0.7)	11.77 (0.1)
Total in Siberia	72582.20 (18)	16630.50 (4)	213219.00 (52)	36167.10 (9)	11772.80 (3)	45594.40 (11)	10518.00 (3)
Area	9700.60 (22)	2066.84 (5)	18105.33 (41)	6827.94 (15)	2016.23 (4)	4303.31 (9)	1537.34 (4)
Stock							

Karyotype pools of conifers in Siberia and the Far East and their protection

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Conservation of gene pools of main forest-forming tree species should be based on detailed studies of natural populations. One approach is to study the natural mechanisms of chromosome set transformation both in the normal state and after different external actions. Populations of tree species differ in karyological features. In this regard karyological data can be used for developing protection measures of the natural plants gene pool.

Conifers are characterized by stable chromosome number and similar chromosome morphology (Metre 1968, Kozubov and Muratova 1986). However, studies carried out for the recent two decades have revealed karyotypical diversity of the species of the *Pinaceae* family and the wide spectrum of chromosomal anomalies.

This paper presents the results of the karyological and cytogenetical study of 24 species of the genera *Larix*, *Pinus*, *Picea* and *Abies* from Siberia, the Far East of Russia. Our results extend the notion of coniferous karyotype structure in normal state and anomaly.

The larch species studied fall into two related groups. The first group is represented by *Larix sibirica* Ledeb. and *L. sukaczewii* Dylis. Siberian larch (*L. sibirica*) belongs to series *Eurasiaticae* of section *Pauciseriales*. The consideration of *L. sukaczewii* as a distinct species is debatable (Milyutin et al. 1993). The second group consists of *L. gmelinii* (Rupr.) Rupr., *L. cajanderi* Mayr, and *L. ochotensis* Kolesn. *Larix gmelinii* and *L. cajanderi* belong to series *Paucisquamatae* of section *Pauciseriales*. Many botanists do not consider *L. ochotensis* as a distinct species.

The diploid set of larch species consists of 24 chromosomes ($2n=24$). Karyotypes include 6 pairs of symmetric (metacentric) and 6 pairs of asymmetric (submeta- and intercentric) chromosomes (Figure 1). Larch species differ in number and localization of secondary constrictions (Muratova and Chubukina 1985, Muratova 1991a, 1993, 1994).

The pine species studied belong to two subgenera of the genus *Pinus*. These are subgenus *Strobus* (section *Strobi*, subsection *Cembrae*) and subgenus *Pinus* (section *Pinus*, subsection *Sylvestres*). Of the subsection *Cembrae* three species – *P. sibirica* Du Tour, *P. pumila* (Pall.) Regel and *P. koraiensis* Siebold et Zucc. – were analyzed in sufficient detail while *P. cembra* L. was analyzed using insufficient experimental material. Five pine species belong to subsection *Sylvestres*. *Pinus sylvestris* L. is the most important species for Siberia. This species was studied thoroughly. In addition, *P. densiflora* Siebold et Zucc., *P. thunbergii* Parl., *P. funebris* Kom. and *P. eldarica* Medw. were also studied.

Karyotypes of pines contain 24 chromosomes. Pines of the subsection *Cembrae* (Figure 2) have 11 pairs of symmetric (metacentric) and 1 pair of asymmetric chromosomes – submetacentric or similar in configuration (Muratova 1980). Pines of the subsection *Sylvestres* (Figure 3) have 10 pairs of symmetric chromosomes and

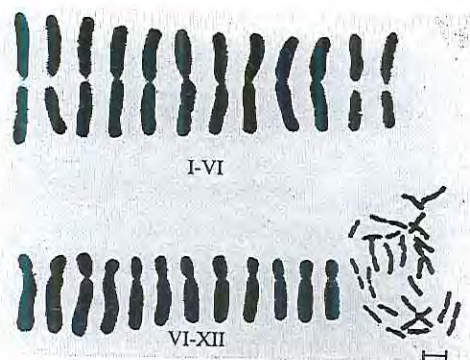


Fig. 1. Karyotype of *Larix cajanderi* Mayr. I-VI, VII-XII are the chromosome numbers. Bar = 10 mm.

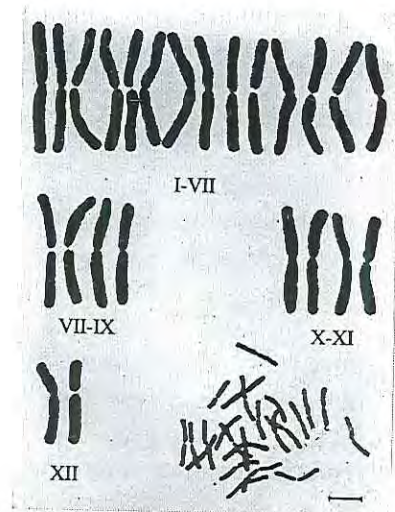


Fig. 2. Karyotype of *Pinus koraiensis* Siebold et Zucc. I-VII, VIII-IX, X-XI, XII are the chromosome numbers. Bar = 10 mm.

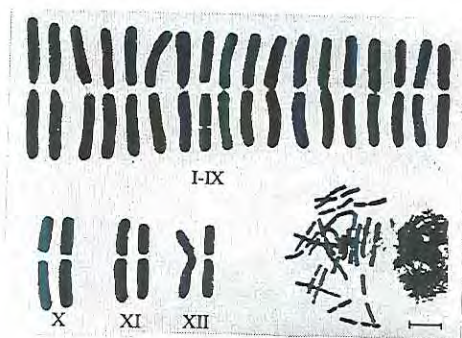


Fig. 3. Karyotype of *Pinus densiflora* Siebold et Zucc. I-IX, X, XI, XII are the chromosome numbers. Bar = 10 mm.



Fig. 4. Karyotype of *Picea ajanensis* (Lindl. et Gord.) Fisch. ex Carr. I-VIII, IX, X-XI, XII are the chromosome numbers. Bar = 10 mm.

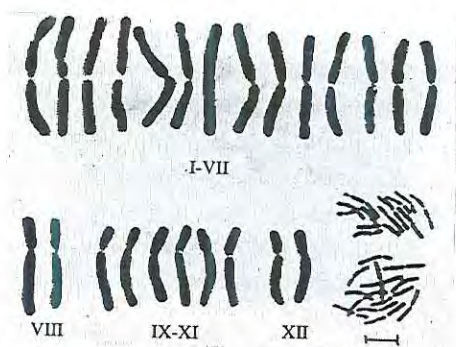


Fig. 5. Karyotype of *Abies sibirica* Ledeb. I-VII, VIII, IX-XI, XII are the chromosome numbers. Bar = 10 mm.

2 pairs of asymmetric ones (Muratova 1985, 1991b, 1995a, Muratova and Suntsov 1988, Muratova and Sedelnikova 1993).

Five species of the genus *Picea* were studied: *Picea obovata* Ledeb. and *P. schrenkiana* Fisch. et Mey. of series *Obovatae* of section *Eupicea*, *P. glehnii* (Fr. Schmidt) Mast., series *Glehnianae*, the same section, *P. ajanensis* (Lindl. et Gord.) Fisch. ex Carr. and Japanese species *P. jezoensis* (Siebold et Zucc.) Carr. of series *Ajanenses*, section *Casicta*. The species belonging to the genus *Picea* (Figure 4) have 8 pairs of long metacentric and 4 pairs of shorter meta- and submetacentric chromosomes (Medvedeva and Muratova 1987, Muratova and Frolov 1995).

Systematically, *A. sibirica* Ledeb. belongs to series *Sibiricae* of section *Piceaster*; *A. alba* Mill. belongs to series *Albae* of section *Abies*, *A. sachalinensis* Fr. Schmidt belongs to series *Nephrolepides* of section *Elatae*, *A. lasiocarpa* (Hook.) Nutt. belongs to series *Lowianae* of section *Piceaster*, *A. holophylla* Maxim. belongs to series *Homolepides* of the same section. Karyotypes of the *Abies* species studied (Figure 5) include 7 pairs of metacentric and five pairs of submeta- and subacrocentric chromosomes (Muratova and Matveeva 1996).

Many populations of these species were studied. Some of them occupy central parts of distribution ranges and occur in optimum growth conditions. Other populations are located in marginal parts of their distribution ranges and grow under extreme conditions. In addition, some populations that are on ecological verge of the occurrence of species (for example, in marsh areas), were also studied.

The results obtained show that in conifers growing in optimum conditions chromosome anomalies rarely occur. Contrary to them marginal populations, growing in extreme conditions, exhibit disturbances in the chromosome number and morphology as well as an increase in secondary constriction number and chromosome mutations (Muratova and Suntsov 1988, Muratova 1991b, 1992, Muratova and Sedelnikova 1993). In the cytogenetic analysis of Scots pine individuals growing at the southern and northern margins of the distribution range, many chromosome anomalies became evident. Ring and polycentric chromosomes could often be observed. These trees demonstrated disturbances of mitosis. The study of meiosis (Muratova 1995b) revealed anomalies of the generative development.

Chromosome mutations were found in *Larix sibirica* from Kazakstan and Mongolia, *L. sukaczewii* from the South Urals, the northern populations of *L. gmelinii*, *Pinus pumila*, *Picea obovata* and *Abies sibirica* from the Chamar-Daban mountains (Muratova and Chubukina 1985, Medvedeva and Muratova 1987, Muratova 1991a, 1994, Muratova and Matveeva 1996). *Larix gmelinii* occurring in the Eastern Zabaikalye region was the first among conifers in which pericentric inversion was found (Muratova 1994). Genome mutations, resulting in aneuploids, mixoploids and in specific cases polyploids were observed for the pine, larch, spruce and fir species studied.

Karyotypes of plants and animals usually consist of A-chromosomes which are permanent chromosomes of the set. Some species also include B-chromosomes. More than 20 coniferous species with B-chromosomes have been discovered, and more than half of them belong to the genus *Picea*.

Our research shows the presence of B-chromosomes in two populations of *Picea obovata* from Yakutia and *P. ajanensis* from the Far East of Russia (Medvedeva and Muratova 1987, Muratova and Frolov 1995). In the analysis of the literature data it became obvious that B-chromosomes were available in 9 of the 25 *P. obovata* populations studied. The highest frequency of B-chromosomes was revealed in

Siberia. B-chromosome was found in *L. gmelinii* from eastern Siberia. This is still the only one for the genus *Larix* (Muratova 1991c).

In conclusion it is noted that the populations studied have many rare karyotype forms. They differ in the chromosome number, presence of B-chromosomes and chromosome mutations. Such populations require conservation measures and should be included in reserves. Special attention should be paid to individual trees, mutant and anomalous forms. Valuable individuals should be conserved under natural conditions *in situ* and in clonal archives established *ex situ*. They should also be used for the creation of seed, meristem and pollen banks.

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Investigation and conservation of forest genetic resources of the North Caucasus

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The North Caucasus is a part of the Great Caucasus. The northern frontier follows the Kuma-Manych cavity and the southern one follows the Great Caucasus main ridge. The western border skirts on the Sea of Azov coast and the eastern border – the Caspian Sea coast up to the Samur river. The North Caucasus also covers the western part of the Black Sea coast which is the territory of the Russian Federation as far as the administrative border with Abkhazia, Georgia (the river Psou). The distribution of the forest land by dominant species and administrative units is shown in Table 1.

The proportion of forests in the region is uneven. It varies from 22% in the Krasnodar Region and the Republic of North Ossetia-Alania to 7% in the Stavropol Region.

Oak forests occupy about 35% of the total forest area in the region (Table 1) and are unmerchantable: the mean site quality class is III,5 and the mean growing stock is 113 m³/ha. Almost two thirds of the oak forests are low. They consist of *Quercus robur* L., *Q. petraea* Liebl., *Q. pubescens* Willd. and *Q. hartwissiana* Stev. which occupy different ecological niches and call for individual approaches.

Beech forests consisting of *Fagus orientalis* Lipsky cover 637 400 ha. Here, the mean growing stock is 225 m³/ha.

Unique relict chestnut forests (*Castanea sativa* Mill.) occur only in the Krasnodar Region.

Table 1. Distribution of the forest area in the North Caucasus forest fund by dominant species ('000 ha)

Species	Administrative unit [†]							Total
	1	2	3	4	5	6	7	
Pine	51.9	21.6	68.3	7.4	7.0	7.0	55.8	219.4
Fir and spruce		41.4	29.2	–	–	–	–	70.6
Oak	68.4	703.0	62.0	9.5	7.6	31.7	101.5	984.2
Beech		247.8	67.0	46.3	96.0	146.6	33.8	637.4
Hornbeam	96.9	23.3	11.9	13.1	40.2	40.2	43.7	229.1
Chestnut		38.9	–	–	–	–	–	38.9
Other hardwoods	33.9	34.5	39.6	2.9	7.4	18.8	8.6	145.7
Softwoods	23.0	24.5	100.3	28.0	17.9	45.2	67.5	306.4
Wild fruit and nut trees	3.1	24.2	1.5	1.3	1.6	2.6	1.8	36.1
Other species	0.3	54.4	36.6	13.3	7.8	19.7	11.6	143.8
Shrubs	10.4	3.8	0.5	2.1	3.0	6.4	3.9	30.1
Total	191.0	1291.7	428.3	122.4	161.5	318.9	327.9	2841.7

[†] 1 = Rostov Province, 2 = Krasnodar Region and Adigei, 3 = Stavropol Region, 4 = Kabardino-Balkarsk Republic, 5 = Republic of North Ossetia-Alania; 6 = Checheno-Ingush Republic, 7 = Dagestan Republic.

Caucasian fir (*Abies nordmanniana* Spach.) usually grows in mixed stands with *Picea orientalis* Link. and *Fagus orientalis*. The fir and spruce trees reach the biggest dimensions found in the North Caucasus. They can be as high as 75 m and as thick as 2 m. Fir stands cover only 2.5% of the total forest area. Their proportion from the total growing stock is 21.5%.

Pine forests are composed of Caucasian pine (*Pinus kochiana* Klothsch.), Crimean pine (*P. pallasiana* D. Don.) and Pitsunda pine (*Pinus pithyusa* Stev.).

Softwood forests include birch (*Betula litvinowii* Doluch.), alder (*Alnus glutinosa* Gaertn.) and aspen (*Populus tremula* L.).

Wild fruit forests, of which 85% occur in the Krasnodar Region, consist of 20 species, the principal ones being *Pyrus caucasica* (Fed.), *Malus orientalis* (Uglitzk.), *Prunus divaricata* (Ledeb.), *Cornus mas* (L.), etc.

At the present time all the forests of the region are assigned to the Group I. In more than 90% of the stands logging has been carried out and many of them lost their environmental functions. In large areas, undesirable species such as alder, aspen and willow displaced more valuable species.

Investigations and conservation of genetic resources of the North Caucasus forests are carried out by different methods. Good experience has been gained with the conservation of rare and vanishing species in botanical gardens and arboreta, in which at the present time more than 2000 taxa and the most complete in Europe collections of pines (82 species), oaks (68 species) and other genera can be found. The established system of nature protected areas, reserves, national parks and genetic reserves is of greatest importance. In the North Caucasus these are the Caucasus Biospheric Reserve founded in 1926 (263 000 ha), the Teberda Reserve founded in 1936 (85 000 ha), the Kabardino-Balkarsk Reserve founded in 1986 (74 000 ha) and the North Ossetian Reserve founded in 1976 (29 000 ha).

The largest national park is the Sochi National Park which was founded in 1986. Its area is 190 000 ha. It is one of the natural units where tertiary Colchis flora is conserved. The State Nature Park "Prielbrusie" founded in 1986 (100 000 ha) plays an important role in the conservation of natural ecosystems occurring on the northern slopes of the Great Caucasus Range.

In addition to nature reserves and national parks, a wide network of conservation units has been designated for preserving gene-pools of forests. These are special state, regional and local conservation units and nature monuments as well as genetic reserves which came into being in recent years.

To date, genetic reserves for all the principal forest-forming tree species were designated (the total area is about 5000 ha) and 1500 plus trees were selected. On this basis clonal and seedling seed orchards as well as experimental plantations for progeny trials are being established. But this work still remains unfinished because breeders put forward a concept of the establishment of a complete permanent seed base in all seed zones, whose greater part is located in the mountains and not in flat land. Due to the data suggesting that phenotypic selection is not efficient, it becomes evident that supplementary selection of plus trees is needed. In order to do this work properly, the "Programme of organization of a permanent seed base of principal forest-forming species on the genetic and breeding basis" was drawn up. In accordance with this programme further breeding work is planned.

At the present time investigations are pursued within two projects:

1. Research and practical work on the establishment of the permanent seed base of principal forest-forming species of the North Caucasus (research director is V.K. Kireenko PhD (Biol.), 3 collaborators).

2. Increasing the resource potential of the North Caucasus mountain forests by means of breeding and introduction of promising exotic species in artificial stands (research director is V.G. Kartelev (Dr Sci. Agric.), 3 collaborators).

In the North Caucasus great attention is also paid to selection and conservation of valuable genepools at the intraspecific level. A clonal archive was established with 64 best performing varieties of European walnut from different geographical zones. They are complemented with new subtropical varieties resistant to marsonina. A clonal archive with 120 varieties of filbert from all over the world as well as a plantation with eight Vavilov varieties of pecan and 10 spontaneous intervariety hybrids were established. In our opinion the main restriction to this work is little awareness of the importance of establishment of clonal archives as living genebanks and the inadequate protection of the the conservation units. The trend has been toward the establishment of clonal seed orchards because of the problems associated with heterovegetative propagation, especially in oaks. At the same time population breeding has been supported. Genetic maps were constructed for populations of oaks, beech and Caucasian fir selected on the basis of their phenotypic traits. In the immediate future we plan to carry out progeny tests.

Nowadays the main tasks of forest genetics are to accelerate investigations into genetic diversity of populations of principal tree species and to verify the fast methods for evaluation of genotypes early in the development (devised by professor G.G. Gonchrenko). It is extremely desirable to extend the range of genetic and breeding work not only for the purpose of gene conservation of principal forest-forming tree species, but attention should be paid to rare and vanishing species as well. We believe it is reasonable to conduct our investigations in the framework of an international programme.

Forest genetic resources of Abkhazia: a long-term programme for their conservation

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Abkhazia is situated in the northwestern part of the Black Sea coast of the Caucasus region. Abkhazia is bordered by the Great Caucasus in the north, by the river Ingur in the east, Psou in the west and by the Black Sea in the south. The territory stretches from 0 to 400 m asl and the total area represents 870 000 ha. The total area of the state forest fund covers 527 700 hectares, including 493 600 ha of forest area (57% of the total area of Abkhazia). The distribution of the forests by principal forest-forming tree species is shown in Table 1.

The forests are situated prevalingly in mountains (98%) where they fulfil important water and soil protection functions. Total growing stock represents about 100 million m³ (mean growing stock is 202 m³/ha). Lowland forests are characteristic with the occurrence of deciduous species: alder (40%), oak-hornbeam (30%), chestnut (15%) and beech (15%). These forests are depleted mainly due to the uncontrolled logging and grazing. The mean growing stock is low (45 m³/ha). Until 1967 the mean annual volume of fellings was 280 000–407 000 m³. Subsequent decrease in the annual volume of fellings to 98 500 m³ enabled the preservation of forests in their ecological balance.

The Abkhazian forests were investigated by such prominent scientists as N.M. Albov, J.N. Voronov, A.A. Kolakovsky, A.G. Dolukhanov, V.Z. Gulisashvili and A.A. Grossheim as well as K.L. Tugushi, S.M. Bebia, A.Z. Kobakhia, Z.M. Adzinba and B.T. Todua. They described locations of valuable stands of relict and endemic species in the different zones.

As a result of the recent military operations in the years 1992–1993 forestry activities were interrupted. To date, the structure of forest management has been restored. All the forests are owned by the state. At present the felling volume is 18 000 m³ a year. Genetic resources of tree species are protected in units such as the Ritza National Park, Pitsunda-Miusera Reserve, Pskhu-Gumista Reserve and Skurchin Reserve. The total area of these nature protected units is 60 900 ha. Particular attention has been paid to the conservation of vanishing flora with its relict and endemic species.

The Abkhazian Forest Research Experimental Station is located in the northwestern part of the Colchis lowland while its stationary units are located in different zones from lowlands to alpine meadows. The Colchis lowland oak, chestnut, beech and fir forests have been studied since 1957 when the Station was founded. The characteristics of these stands were studied and conservation stands were designated. The researchers selected 200 plus trees of oak, beech and fir and established clonal archives. Karyotypes of principal forest-forming native tree species and perspective introduced species were studied.

Progress has been made towards the remote hybridization of European chestnut and Caucasian fir.

Table 1. Distribution of the Abkhazian forests by principal forest-forming tree species (data are as of 1989)

Species	Area		Growing stock		
	('000 ha)	%	million m ³	%	m ³ /ha
Beech (<i>Fagus orientalis</i>)	230.5	59.5	53.6	55	233
Fir (<i>Abies nordmanniana</i>)	74.0	19.0	33.2	34	448
Chestnut (<i>Castanea sativa</i>)	17.4	4.5	3.4	3.5	197
Hornbeam (<i>Carpinus caucasica</i>)	14.9	3.8	2.1	2.1	138
Oak (<i>Quercus iberica</i>)	14.5	3.7	1.8	1.9	126
Alder (<i>Alnus glutinosa</i>)	14.1	3.6	1.4	1.4	97
Box (<i>Buxus colchica</i>)	5.7	1.5	0.7	0.7	60
Spruce (<i>Picea orientalis</i>)	2.9	0.7	0.6	0.6	222
Lime (<i>Tilia caucasica</i>)	1.9	0.5	0.3	0.3	181
Pines (<i>Pinus kochiana</i>), (<i>Pinus pithyusa</i>)	1.7 0.3	0.4	0.2 0.1	0.2	123 310

In 1961 at the elevations of 20, 500 and 900 m asl an arboretum was established. It involves 1000 native and introduced species and has a total area of 40 ha. This is considered a unique collection in the Caucasus. Of the taxa occurring in the arboretum more than 350 have reached productive age. Forestry and bioecological studies carried out for many years described economically valuable species which can be used to increase the resource potential of the mountain forests.

Study and conservation of forest genetic resources in the Republic of Bashkortostan

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The Republic of Bashkortostan is situated at the interfaces between Europe and Asia and includes the eastern part of the East European Plain (Cis-Urals), the mountainous South Urals and the Trans-Urals. It extends from 51°31' to 56°25'N latitude and from 53°10' to 60°00'E longitude. The area of the Republic is 143 600 km². The total forest fund is 6 310 800 ha or about 40% of the total area of the Republic, including 5 553 800 ha covered by forests. Table 1 gives the distribution of the forest area by principal forest-forming tree species.

The forests are distributed unevenly. Most of the forest areas, especially those covered by coniferous forests, are located in the mountain forest zone. Mature and overmature forests prevail.

In the analysis of the present forest condition in the region some negative tendencies were revealed: change in species composition of stands, loss of the most productive stands, increase in the percentage of artificial forests, decline of some tree species due to drought, extinction of tolerant clones, etc.

Breeding work carried out in the last few decades was aimed mainly at the designation of plus trees and seed stands, establishment of seed orchards and designation of seed production units.

The data given in Table 2 show that breeding was limited to designating plus trees and seed stands. Seed orchards were established for Scots pine. To date, larch hybrid seed orchards were established for the production of seeds which result from interspecific and interpopulation crossings. In addition, on the population basis seven larch genetic reserves were designated (Putenikhin 1993). Forest genetic resources are also conserved, with certain limitations, in national parks, nature protected areas, reserves and nature monuments.

The studies of genepools of forest tree populations are conducted in four scientific laboratories of the Botanical Garden and Institute, Ufa Scientific Centre of the Russian Academy of Sciences. Phenotypic traits are studied, caryological analyses and studies at isoenzyme genetic markers are carried out to describe population structures of tree species. At present the South Urals populations of *Pinus sylvestris*, *Picea obovata* and *Larix sukaczewii* are being investigated with the use of these methods. In addition, in recent years investigations into genetic structures of *Quercus robur*, *Acer platanoides*, *Betula pendula* and other species have been pursued using isoenzyme genetic markers.

A number of particular features in the region generates interest in research into the genepools of forest trees which includes population genetics and gene conservation. A high variability of geomorphological, hydrogeological and environmental conditions as well as historical heterogeneity of the plant cover in the South Urals allowed to reveal very heterogeneous population structures. Changes in the genetic structures of the stands occurring in the zones of industrial pollution in the South Urals were also studied. Boundaries of distribution areas of some species follow the territory of the Republic, and this fact allows for the

investigation of population genetic processes in marginal populations as well as in stands located in the zones of introgressive hybridization.

Table 1. Distribution of forest area by principal forest tree species

Species	'000 ha	% of the total forest area
<i>Pinus sylvestris</i>	716.2	12.9
<i>Picea obovata</i>	251.0	4.5
<i>Abies sibirica</i>	84.8	1.5
<i>Larix sukaczewii</i>	39.3	0.7
<i>Quercus robur</i>	341.9	6.2
<i>Acer platanoides</i>	173.3	3.1
<i>Ulmus</i> spp.	35.0	0.6
<i>Betula</i> spp.	1292.3	23.3
<i>Populus tremula</i>	780.4	14.1
<i>Alnus</i> spp.	171.1	3.1
<i>Tilia cordata</i>	1021.1	18.4
<i>Populus</i> spp.	16.8	0.3

Table 2. Overview of the breeding and conservation measures relating to forest genetic resources in the Republic of Bashkortostan *

Species	Plus trees	Seed stands (ha)	Seed orchards (ha)
<i>Pinus sylvestris</i>	735	909.5	73.2
<i>Larix sukaczewii</i>	117	110.2	—
<i>Picea obovata</i>	9	—	—
<i>Abies sibirica</i>	1	—	—
<i>Betula pendula</i>	70	51.6	—
<i>Tilia cordata</i>	130	108.5	—

^{*)} Only the certified units for native species in accordance with the data of the Bashkir zonal seed station.

Progress toward solution of the problems related to the conservation of gene pools of principal forest-forming tree species in Bashkortostan is associated with integration of our investigations into the international structures and projects that are being drawn up and carried out.

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Status and conservation of forest genetic resources in the south-eastern part of Kazakstan

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Conservation and rational use of natural biological resources is a global priority. On the one hand, this is caused by the great value of the genetic potential of plants for the further development of the mankind and on the other hand by the drastic reduction of plant genepools.

Kazakstan is a sparsely wooded country. The proportion of forests is only 3.8% (the total forest area is 10.5 million ha).

In the forests of Kazakstan about 240 tree and shrub species are found. Stands with dominant representation of conifers cover 19.2% of the area, stands with dominant deciduous species cover 65.7% and those with shrub species dominating cover 15.1% of the area.

Principal forest-forming tree species of the southeastern part of Kazakstan (which is the area of activity of the Almaty Forest Seed and Tree Breeding Centre) are *Picea schrenkiana* Fisch. et Mey., *Abies sibirica* Ledeb., *Malus sieversii* and *Haloxylon aphyllum*.

The Provinces of Almaty, Taldy-Kurgan, Jambul and South Kazakstan belong to the southeastern part of the country. Its total area is 485 000 km². The proportion of forest ranges from 3.3% in the Taldy-Kurgan Province to 10.6–12.8% in the other provinces and averages 9.5%.

Two major forest types are found all through the region, namely, mountain forests formed principally by *P. schrenkiana* stands and desert forests of *H. aphyllum*.

Wild fruit forests grow in the lower part of the forest-meadow zone of the mountains. They rise to elevations of 800 up to 1200 m asl. The dominant species is *M. sieversii*.

Mountain forests cover an area of 144 500 ha. They grow on the northern slopes of the Tian Shan mountain range (the Zailiy, Kungey and Ketmensk populations) as well as on the slopes of the Djungar Ala Tau mountain range (the Djungar population). These forests occur at an elevation of 1400–2800 m asl. Besides *P. schrenkiana* also *Abies sibirica* grows in the Djungar Ala Tau mountains.

The conservation of the genepool of *P. schrenkiana* is being carried out not only under natural conditions, by designating genetic reserves and reserves aimed at seed production (seed stands *in situ*), but through the establishment of clonal archives, seed orchards, permanent seed production areas, provenance experiments and other plantations (*ex situ*) as well.

In the mountain forests of the northern Tian Shan and Djungar Ala Tau two *P. schrenkiana* genetic reserves were designated. Their total area is 826 ha. One of them (468 ha) is located in the range of the Kungey population (the Zhalanash forest division of the Kegen forest enterprise). The other *P. schrenkiana* and *Abies sibirica* genetic reserve (358 ha) is located on the northern slope of the Djungar Ala Tau mountains (Karin forest division, Kopal forest amelioration station).

At present the permanent seed base of *P. schrenkiana* comprises 29 ha of seed production areas, 5 ha of reserves aimed at seed production (seed stands), 40 plus trees and 3.5 ha of experimental plantations including provenance trials.

A large area of the southeastern part of Kazakhstan (56%) is covered by saxaul stands which are scattered across the vast deserts of the Balkhash-Alakul depression as well as Jambul and South Kazakhstan Provinces. Three saxaul species occur, namely, *Haloxylon aphyllum*, *H. persicum* and *H. ammodendron*.

In desert forests five *H. aphyllum* genetic reserves were designated. Their total area is 14 800 ha. Two of them are located in the territory of the Karoy forest division of the Bakanas forest enterprise, one in the Iliy forest division of the Pribalkhash forest enterprise, one in the territory of the Koktal forest division of the Panphilov forest enterprise and one in the Koskuduk forest division of the Koskuduk forest enterprise. A permanent seed production area is being established, which will occupy a total area of 20 ha.

Kazakhstan is a unique centre of origin for a great number of wild fruit trees. In mountain forests more than 130 wild fruit species belonging to 30 genera (apple, pear, rowan, hawthorn, apricot, sea-buckthorn, pistachio, walnut, almond, Russian olive, etc.) can be found. Nineteen species are endemic.

On the basis of the results of breeding inventories conducted in the wild fruit forests of the Djungar Ala Tau mountains professor A.D. Djangaliev designated four *Malus sieversii* genetic reserves. One hundred and sixty varieties and forms of this species are now represented in clonal archives which provide the richest gene pool for breeding new apple varieties.

The establishment of nature reserves and national nature parks is a keystone in the system of measures aimed at the preservation of biological diversity. At the present time there are two nature reserves and one state nature park in Kazakhstan.

- Almaty State Nature Reserve (Almaty Province, Talgar, established in 1964, 73 400 ha) – flora and fauna of the Tian Shan mountains (Zailiy Ala Tau), spruce and deciduous forests (*Picea schrenkiana*, *Betula tianshanica*, *Malus sieversii* and *Armeniaca vulgaris*).
- Aksu-Djabaglin State Nature Reserve (South Kazakhstan Province, Tiulkubas, established in 1926, 74 400 ha) – flora and fauna of the Western Tian Shan. More than 40 species of rare plants are protected. The area occupied by tree species is 3700 ha and shrub species cover 17 390 ha.
- Ile-Ala Tau State Nature Park (Almaty Province, 1966, 164 000 ha).

Kazakhstan is one of the 150 states which signed the Convention on Biodiversity (in Rio de Janeiro, 1992) and thus made a commitment to contribute to preserving and increasing vegetation at a global level.

In August 1994 the Council of Ministers of the Republic of Kazakhstan issued a decree on the development of the "National Programme of Sustainable Conservation of Biodiversity". Scientists of the research institutes of the National Academy of Sciences of the Republic of Kazakhstan, the Academy of Agricultural Sciences and institutions of higher education engaged in biological research took an active part in the development of the Programme.

In 1995 the Ministry for Science approved a programme of international scientific and technical cooperation. It should be implemented during several stages and under agreements with foreign partners.

A "Programme on the Conservation of Biodiversity of Forest Resources in Kazakhstan" is a part of the above mentioned National Programme. The necessity of establishing a separate strategy devoted to the problems of forest tree species derives from the fact that forests preserve most valuable species as well as a rich intraspecific diversity. In this regard not only conservation but rational use of the

genepools of the forest ecosystems in southeastern Kazakstan are of great significance.

Since 1995 the National Programme is being implemented by the research and production centre "Plant Gene Pool", interdisciplinary laboratory "Gene Pool Preservation" of the Institute of Botany, Forest Seed and Tree Breeding Centres, "Kazlesproekt" and "Kazgiproleskhoz" project planning organizations and other forestry institutions.

Study and conservation of forest genetic resources in Uzbekistan

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The Republic of Uzbekistan occupies 4 474 000 km². It extends from the west to the east over 1400 km and from the north to the south over 925 km. A larger part of the territory is flat. One of the largest Central Asian deserts, Kyzylkum, is located in this area. A smaller part is occupied by mountains and foothills. These are mainly part of the Western Tian Shan and the Pamirs and Altay mountain ranges.

The total area of the forest fund is 8 583 900 ha or about 19% of the territory of the Republic (data are as of 1 January 1993). The forest area covers 2 521 000 ha, including more than 268 000 ha covered by shrubs. The forest covered area represents 29.4% of the total area of the forest fund. Uzbekistan ranks last among the CIS (Commonwealth of Independent States) in the proportion of forests (only 5.1%). It was estimated that for each inhabitant of the Republic there was less than 0.1 ha of forest area.

The forest fund is prevalingly located in the desert (6 546 200 ha) and mountain (1 238 400 ha) zones whereas in the alluvial zone it covers only 35 900 ha and in valleys 41 700 ha. In recent years the area of the forest fund has been reduced drastically. This occurred because a definite portion of the forest area had been converted to agriculture. At the same time 500 000 ha of the area previously covered by the waters of the Aral Sea as well as 2 353 400 ha of the Ustyurt Plateau were allotted to forestry and should be afforested. The degradation of the forest conditions has been noted recently. This is particularly evident in areas of long-term land use (30.5% of the total area of the forest fund) as well as those belonging to cooperative agricultural farms. No reforestation and protection measures are taken in such areas, resulting in negative changes of the ecosystems.

Forests are distributed unevenly throughout the territory of the Republic. A larger portion (more than 60%) is found in the desert Bukhara and Navoi Provinces while in the Samarkand and Ferghana Provinces forest areas take less than 1%. The greatest proportion (7.8%) is in the Khorosm Province where mainly psammophytic shrubs are distributed. They strengthen the sand layer and provide additional source of feeding on desert pastures. The Jizzak and Tashkent Provinces are fairly favourably endowed with forests. Here, the juniper and Persian walnut forests occur.

All the forests growing in the territory of Uzbekistan fall under the Group I of forests, water protection forests prevailing. Main fellings are carried out only as part of reforestation programmes and are restricted to small areas of stands growing on sandy and alluvial soils.

In the mountain zone the arborescent junipers, Persian walnut, pistachio, almond and maple are the principal forest-forming tree species while the sea-buckthorn, dog-rose and barberry are the main forest-forming shrubs. Juniper stands covering 190 900 ha constitute the major component of mountain forests. These stands are typically composed of three juniper species, namely, zeravshan juniper (*Juniperus seravsehanica* Kom.), hemispherical juniper (*J. semiglobosa* Rgl.) and Turkestan juniper (*J. turkestanica* Kom.). In the mountains the forests with Persian walnut (*Juglans regia* L.) predominating cover 2200 ha. Mixed stands in which Kirghiz apple tree and Turkestan maple grow are quite common. Pistachio

(*Pistacia vera* L.) stands are mainly concentrated within the Babatag Range. They cover 24 600 ha of the total 27 000 ha covered by this species. Some small pistachio forests can also be found in the Tashkent and some other provinces. On the slopes of mountains pistachio usually forms pure stands, with low stocking density. Wild almond stands (these are basically *Amygdalus spinosissima* and *A. bucharica*) occur universally in the dry conditions of low and moderate mountain elevations. They are of great soil protection importance. Almond trees with sweet kernels grow in artificial stands.

The principal forest-forming species in the desert zone is the saxaul. It occupies 1 229 000 ha, including 976 000 ha covered by white saxaul (*Haloxylon persicum* Bge.) and 253 000 ha covered by black saxaul (*H. aphyllum*). The arborescent thistles (*Salsola richteri* and *S. paletziana*), calligonum (*Calligonum* L.) and other shrubs occupy 126 400 ha. Tamarix species (*Tamarix* L.) occupy 64 500 ha. The desert forests provide valuable pastures and prevent sand movements.

The alluvial stands still persist in Uzbekistan. They cover only 35 900 ha, including 24 900 ha of the forest area. The main representative of the alluvial species is "turanga" (*Populus pruinosa* × *P. diversifolia*). This tree usually grows in association with oleaster species (*Elaeagnus* L.) and willows (*Salix* L.). The alluvial forests fulfill important water regulation and protection functions.

As early as 1945 systematic work on the breeding and genetics of forest trees was started in Uzbekistan. To date, more than 20 species have been dealt with. Willows, poplars, elms, walnut, pistachio, almond, oleaster and other trees and shrubs have been studied in greater detail. The research was carried out by the Forestry Research Institute, the Scientific and Production Association of Horticulture and Viniculture and the Tashkent University of Agriculture (now Agrarian University).

Comparative trials including more than 190 willow species and clones were conducted in the early stages of research. Altogether 23 species were recommended for use in the forestry practice. They are distributed over main climatic zones of Uzbekistan.

The possibility of the introduction of Chinese gutta-percha (*Eucommia ulmoides*) which is a valuable technical and medicinal plant was carefully studied. Growing techniques were developed and industrial plantations were established.

The results of research, breeding and introduction of poplars permitted selection of a group of species, their clones and hybrids which is of prime practical interest for the establishment of artificial stands in the conditions of Uzbekistan and other republics of Central Asia. It was recommended that such poplar varieties as 'Bolley', 'First-born of Uzbekistan', 'Headlong', 'Bolley's poplar renovated', 'Bolley's poplar improved' and 'Late poplar' be established because they show high growth rates and very high productivity. At present Uzbekistan has no timber supplies from its own sources. As a consequence of the sharp rise in the cost of the imported timber the Republic is now facing an acute problem of the establishment of artificial stands for timber production (it is planned to establish 10 000 ha of plantations per year). It is necessary to establish mother tree archives of native poplar species.

Considerable advances have been made by the Institute in the area of selection of elms (*Ulmus* L.) for resistance to the Dutch elm disease, growth rate and decorative timber properties. This work was carried out through both selection and artificial inoculation of *graphiosis* into the offspring of the selected forms. The

varieties produced are characterized by their decorative timber properties, high growth rate and resistance to the Dutch elm disease.

15 plus trees of oleaster, distinguished by the quality and sizes of their fruits, as well as fructification, were selected.

Important work on the breeding of nut trees (Persian walnut, pistachio and almond) has been carried out. Several generations of breeders have been involved in the selection of best fruit bearing trees. With selection made in natural stands and orchards as well as hybridization, numerous varieties of Persian walnut were obtained. Among them are 'Bostanlyksky', 'Kazakhstansky', 'Panfilovetz', 'Rodina', 'Yubileyny', 'Ideal', 'Gvardeisky' by the Scientific and Production Association of Horticulture and Viniculture; 'Durmensky desertny 1', 'Durmensky 2' and 'Grozdevidny' by the Forestry Research Institute. A great number of plus trees have been selected and a comparative analysis has been made. Over the past 10–15 years 16 forms of Persian walnut and 11 forms of pistachio have been recommended for the establishment of plantations and for strain tests. In the Gallya-Aral experimental collection more than 28 native and introduced forms and varieties of pistachio are grown. An industrial plantation was then established, covering 20 ha. Mother tree archives of economically valuable forms of Persian walnut were established in the territories of eight forest enterprises. The total area of the archives is more than 26 ha. Mother tree archives of pistachio were established in two forest enterprises (the total area is 80 ha).

The breeding of almond also has an extended history. Breeding and genetic parameters were used to assess the stands and orchards occurring in the Western Tian Shan. Several tens of plus trees were selected, of which varieties such as 'Paper-Shelly', 'Kolkhozny', 'Konsaysky', 'First-born' and others were selected and are being used for the establishment of industrial plantations. Research in the area of hybridization plays an important role in the breeding of almond carried out by the Scientific and Production Association of Horticulture and Viniculture, intraspecific and distant crossing methods having been employed. More than 350 hybrids were obtained. Economically valuable varieties were bred. Among them are 'Bostanlyksky', 'Pozdnetsvetuchshy', 'Vostok', 'Tien Shansky' and others. A number of varieties collected in the Crimea, Turkmenistan, some west European countries and the USA were introduced and are being studied. Some of them appeared to be very promising for Uzbekistan and are considered desirable for propagation in the mountain regions of the country.

Systematic work was started on the breeding and genetic assessment of the main forest-forming species of Uzbekistan – the juniper and saxaul species – not long ago, in the early 1980s. As a result of the study of the juniper stands occurring in different forest regions of Uzbekistan the best performing stands were selected (the total area is 550 ha) and a reserve with zeravshan juniper (1260 ha) was designated. The researchers selected 232 plus trees of the three species and made a comparative analysis. It was recommended that some of them be used for the establishment of seed orchards in order to collect seeds with improved qualities. Research on the inheritance of properties from plus trees is being performed in experimental plantations. New methods of vegetative propagation are being devised. They will allow for the establishment of clonal archives of plus trees.

In the saxaul stands phenotypic traits of 263 plus trees were studied. The first seed orchard in the Republic was established using seed progenies of the selected trees (16.5 ha). Genotypic traits of plus trees are being evaluated in the field tests. Sixteen black saxaul plus trees were placed into the category of elite trees and were

accepted as promising. The devised method of vegetative propagation by lateral stalk cuttings is applied for the establishment of clonal archives for the saxaul plus trees. On the basis of the results of the study of the offspring of different saxaul provenances the 'Jondor' form (black saxaul) was recognized. For afforestations in the Bukhara Province this form holds much promise. It is noted for a high growth rate, high disease and pest resistance and high quality of seeds.

Other forest-forming species of Uzbekistan such as the arborescent Russian thistle (*Salsola richteri* and *S. paletziana*), calligonum, turanga, ash, maple and others remain to be explored by breeding methods. Numerous shrubs among which are species of the barberry (*Berberis*), dog-rose (*Rosa*), sea buckthorn (*Hippophaë rhamnoides*) are of prime importance but are yet to be studied. So far, the study of the introduced species, Crimean pine (*Pinus pallasiana*), Scots pine (*P. sylvestris*), Eastern red cedar (*Juniperus virginiana*), pedunculate oak (*Quercus robur*) and others, has not received support.

In Uzbekistan work on the breeding of plant genepools, their study and conservation should be continued and intensified. This is feasible in the Republic characterized by a diversity of geographical conditions and forest-forming species.

Forest genetic reserves is the main way of conservation of forest genetic resources in populations. Work on the designation of forest genetic reserves in Uzbekistan has not begun yet. With the exception of the mentioned reserve for juniper there are no forest genetic reserves in the Republic. Strictly protected forests are concentrated into nine nature protected areas and two national parks located in the mountain, desert and alluvial zones. Their total area is 331 600 ha. The juniper and nut tree stands as well as forests occurring on sandy and alluvial soils are protected areas. In addition, seven reserves, 400 nature monuments, protected forest areas and valuable arboreta were designated in the Republic. Most of the legally protected areas and reserves are insufficiently provided with qualified scientific staff. Research activities should be improved.

The long-term programme for the designation, investigation and conservation of genetic resources in the forests of Uzbekistan can be summarized as follows:

- To develop methods for the designation, investigation and conservation of the genetic resources of trees and shrubs in the forests of Uzbekistan;
- To develop methods for the selection of stands and designation of genetic reserves with emphasis on the character of the species and environments;
- To perform a field survey of the mountain, desert and alluvial forests, primarily aimed at protective zones within legally protected areas and reserves and to prepare a feasibility report on the designation of genetic reserves for the principal forest-forming species;
- To carry out a review of the tree and shrub species in order to identify new species, unique phenotypes as well as rare and vanishing species and populations. To develop guidelines for the establishment of clonal archives (and arboreta) for conservation and breeding purposes;
- To continue the evaluation of native and promising introduced species on a genetic basis. To develop techniques for early recognition of inherited traits and features. To establish clonal archives of the valuable breeding material and to endorse recommendations on their conservation and use;
- To develop methods for the long-term storage of seeds (and other reproductive material as appropriate) and to establish a seed bank in order to conserve valuable genotypes of forest tree species.

Genetic resources of pine, spruce and fir species in the former Soviet Union: analysis of their genepools, phylogenetic relationships and genome organization

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Introduction

The major part of Eurasian boreal forests is located on the territory of the former Soviet Union (eastern part of Europe and Siberia). One of the principal forest-forming trees of these stands are pines, spruces and firs which cover about 220 million ha and are distributed from the Baltic Sea to the Pacific Ocean (Vorobyev *et al.* 1985). Regardless of the important economic and ecological role of the pine, spruce and fir stands, studies concerning their genetic resources were only started not long ago. This was mainly because of the lack of methods to carry out population genetic investigations. At present one of the most accurate and suitable method for the study of genepools remains isoenzyme electrophoresis which allows researchers not only to evaluate genetic resources, but also to recommend their management in certain respects.

By the early 1990s in different countries of the world data on the condition of the genetic resources of more than 50 coniferous species, including genotype frequencies, allelic diversity, genetic variability and other parameters had been obtained by isoenzyme electrophoresis (Yeh and El-Kassaby 1980, Conkle 1981, Guries and Ledig 1982, King *et al.* 1984, Gullberg *et al.* 1985, Mejnartowicz and Bergmann 1985, Ledig 1986, Müller-Starck and Gregorius 1986, Schiller *et al.* 1986, Cheliak *et al.* 1988, Millar *et al.* 1988, Moran *et al.* 1988, Paule *et al.* 1990, Kuittinen *et al.* 1991, Boscherini *et al.* 1994, Hawley and DeHayes 1994, Edwards and Hamrick 1995, etc.). However, in the former Soviet Union similar investigations of the species from the *Pinus*, *Picea* and *Abies* genera were rarely performed.

The objective of our research was to assess the genetic resources and to determine phylogenetic relationships among all the pine, spruce and fir species occurring in the former Soviet Union.

Isoenzyme methods for the analysis of conifers

In the first stage we developed methods of isoenzyme electrophoresis for 11–16 enzyme systems in the species studied (Goncharenko *et al.* 1987, 1989, 1990, 1992a, 1992b, 1993b, 1994, 1995a, 1995b, Goncharenko and Potenko 1991, 1992, Goncharenko and Padutov 1995, Silin and Goncharenko 1996). In the genetic analysis it was revealed that the enzyme systems assayed were encoded by 21–25 different genes. Acid phosphatase (ACPH, E.C. 3.1.3.2.), alcohol dehydrogenase (ADH, E.C. 1.1.1.1), aspartate aminotransferase (AAT, E.C. 2.6.1.1.), diaphorase (DIA, E.C. 1.6.4.3.), fluorescent esterase (FL-EST, E.C. 3.1.1.2.), glutamate dehydrogenase (GDH, E.C. 1.4.1.2.), glutamate-pyruvate transaminase (GPT, E.C. 2.6.1.2.), glucose phosphate isomerase (GPI, E.C. 5.3.1.9.), glucose-6-phosphate dehydrogenase (G-6-PDH, E.C. 1.1.1.49.), hexokinase (HK, E.C. 2.7.1.1.), isocitrate dehydrogenase (IDH, E.C. 1.1.1.42.), leucine aminopeptidase (LAP, E.C. 3.4.11.1.), malate dehydrogenase (MDH, E.C. 1.1.1.37.), malic enzyme (ME, E.C. 1.1.1.40.),

phosphoenolpyruvate carboxylase (PC, E.C. 4.1.1.31.), phosphoglucomutase (PGM, E.C. 2.7.5.1.), 6-phosphogluconate dehydrogenase (6-PGDH, E.C. 1.1.1.44.), shikimate dehydrogenase (SKDH, E.C. 1.1.1.25.) and sorbitol dehydrogenase (SDH, E.C. 1.1.1.14.) were scored on 13 to 14% starch gel. For electrophoresis, three buffer systems were used: (i) tris-EDTA-borate, pH 8.6, (ii) tris-citrate, pH 6.2, (iii) tris-citrate, pH 6.2 (electrode buffer)/tris-HCl, pH 8.0 (Goncharenko *et al.* 1989, 1992b).

The number of trees sampled from populations ranged from 10 to 60 and averaged 26. Within each population, trees were sampled randomly along transects, the minimum distance between individuals being greater than 50 m. Individual trees were genotyped using 8–20 megagametophytes plus some embryos for every gene locus. The megagametophytes and embryos were sampled randomly from a set of no less than 50 seeds extracted from 2 to 30 cones of each tree.

The current study reports the results of research carried out for many years at the Laboratory of Molecular Genetics and Forest Tree Breeding of the Forest Institute (Gomel) in accordance with the programmes developed there for the former State Committee on Forests of the USSR and the Academy of Sciences of Belarus.

Methods of assessment of genetic resources in natural populations

For a long time only phenotypic traits of trees were analyzed. However, these traits are greatly influenced by the environment and have a low coefficient of heritability. Thus it was impossible to determine the genotypic structure and the levels of genetic variation in populations and species. The situation changed drastically once isoenzyme electrophoresis became widely used in population genetic studies. Lewontin (1974) and Ayala (1982) pointed out that analyses of natural populations using 18–20 and more loci randomly sampled from the genome yielded quite accurate results. In the course of development of population genetics by the mid-1970s, scientists essentially of Dobzhansky's school (Lewontin and Hubby 1966, Prakash *et al.* 1969, Richmond 1972, Ayala and Powell 1972, Ayala *et al.* 1972, Lewontin 1974, Prakash 1977) succeeded in elaborating a precise set of population genetic parameters. These parameters enable researchers not only to describe adequately genetic structures of the populations investigated, but also to estimate levels of genetic diversity and evaluate condition of the genetic resources of populations and species without any excessive financial and time expenditures. This provides a way for purposeful re-establishing of populations in the course of reforestation. Among principal genetic parameters are percent polymorphic loci (P), mean number of alleles per locus (A), expected heterozygosity (H_e) and observed heterozygosity (H_o). To estimate the genetic differentiation among populations Nei's genetic distance (D_N) is most frequently used (Nei 1972).

Percent polymorphic loci (P) is calculated by dividing the number of polymorphic loci (having two and more various alleles) by the overall number of the loci surveyed. This parameter is normally computed in accordance with two criteria of reliability estimated at the 99% level (the frequency of the most common allele is not greater than 99% – P_{99}) and at the 95% level (P_{95}).

Mean number of alleles per locus (A) is computed by dividing the number of alleles revealed by the overall number of the loci analyzed. In individual cases the mean number of non-rare alleles per locus ($A_{1\%}$) is used. To calculate this parameter only the alleles whose frequencies are greater than 1% (i.e. non-rare alleles) are used.

Expected and observed heterozygosities permit the estimation of the level of genetic variation within populations most accurately. The observed heterozygosity (H_o) is calculated for a particular locus by dividing the number of heterozygous trees with the overall number of the individuals surveyed. The expected heterozygosity (H_e), which depends on the population sample to a lesser extent than the other parameters, is calculated for a particular locus using allelic frequencies as follows:

$$H_e = 1 - \sum x_i^2$$

where x_i is the frequency of the i -th allele.

Both expected and observed mean heterozygosities are estimated as mean arithmetic of the H values for all the loci:

$$\bar{H} = (1/L) \sum H_j$$

where H_j is heterozygosity for the j -th locus and L is the number of the loci assayed.

Genetic distance (D_N) among the populations is calculated according to the formula by Nei (1972).

To visualize genetic differentiation in the populations studied dendrograms are constructed using most often an unweighted pair-group method (UPGMA).

The parameters considered in this paper and calculated in our studies on the basis of allelic frequencies of 21–25 loci enabled us to estimate the levels of genetic variation in pine, spruce and fir species occurring in the territory of the former Soviet Union.

Genetic resources of conifers

Pines

The investigation was based on the seed material collected from more than 1500 individual trees of 10 pine species. Six species and two subspecies belong to two-needle pines of the *Sylvestres* subsection and the other four species belong to five-needle pines of the *Cembrae* subsection. More than 60 natural populations from Latvia, Belarus, Ukraine, Georgia, Kazakstan and Russia including North Caucasus, Siberia and the Far East, were assayed (Figures 1 and 2).

Table 1 lists the basic parameters characterizing genetic resources. It is obvious that in the *Sylvestres* subsection *Pinus sylvestris* var. *sylvestris*, *P. sylvestris* var. *hamata*, *P. mugo*, *P. funebris* and *P. nigra* have the highest values. The percent polymorphic loci parameter varies from 73 to 90% and the mean heterozygosity ranges from 25 to 28%. Of the five-needle pines such a high variability was obvious only in *Pinus pumila*. It is also observed that *P. sylvestris* possesses the highest level of variability, the mean number of alleles per locus being 4.5 (Table 1).

Figure 3 presents the levels of heterozygosity in the pine species studied. It is significant that the majority of the pine species growing in boreal forests show higher levels of variability in comparison with the average values obtained for all the pine species analyzed at 20 and more loci (Figure 3). At the same time pines occurring on the Black Sea coast of the Crimea and the Caucasus – *P. pithyusa* and *P. stankewiczii* – show much lower levels of genetic variability.

It should be noted that the pine species which were analyzed using 20 and more loci demonstrate a very wide heterozygosity distribution that ranges from 0% in *P. torreyana* (Ledig and Conkle 1983) to 28.3% in *P. sylvestris* (see Table 1).

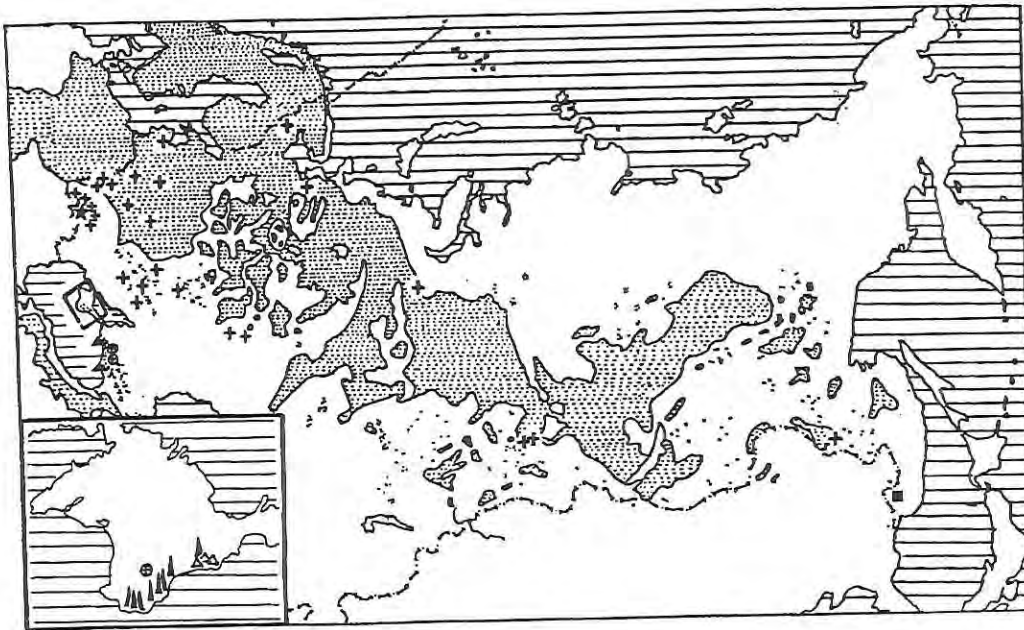


Fig. 1. Locations of 45 investigated natural populations of two-needle pines in the territory of the former USSR: + *P. sylvestris* var. *sylvestris*, ⊕ *P. sylvestris* var. *hamata*, ★ *P. mugo*, ▲ *P. nigra*, △ *P. stankewiczii*, ▲ *P. pithyusa*, ■ *P. funebris*. Natural distribution area of Scots pine (dotted area) follows Pravdin (1964); Critchfield and Little (1966).

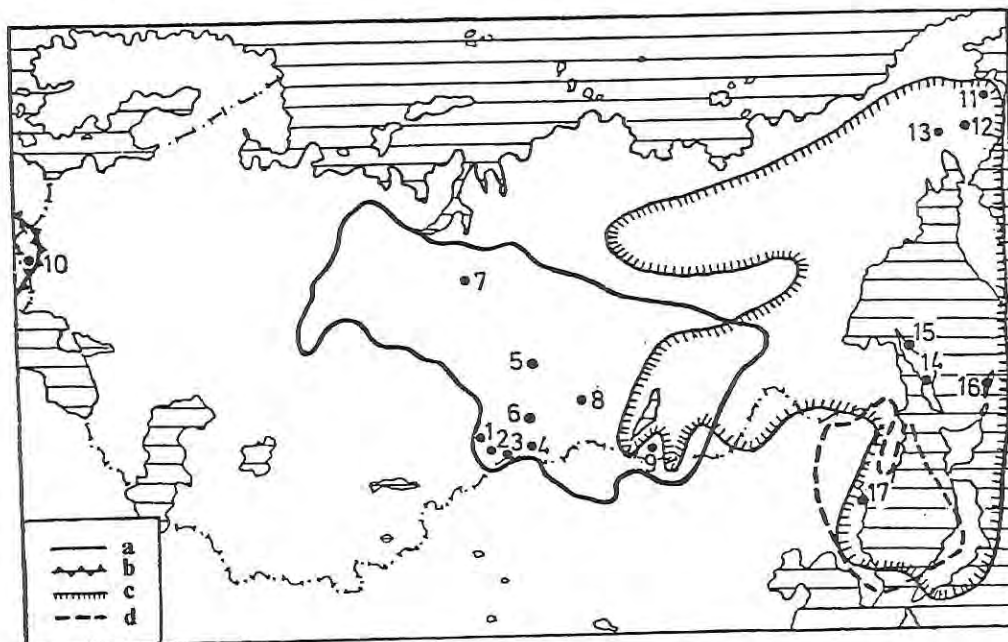


Fig. 2. Locations of 17 studied natural populations of five-needle pines: 1-9 - *P. sibirica* (a); 10 - *P. cembra* (b); 11-16 - *P. pumila* (c); 17 - *P. koraiensis* (d). Natural distribution areas follow Critchfield and Little (1966).

Table 1. Parameters of genetic variation observed in pine species occurring in the territory of the former USSR

<i>Pinus</i> species	P_{95}	P_{99}	A	H_e	H_o
<i>sylvestris</i> var. <i>sylvestris</i>	0.714	0.857	4.476	0.283	0.274
<i>sylvestris</i> var. <i>hamata</i>	0.762	0.905	3.000	0.265	0.264
<i>mugo</i>	0.652	0.826	2.609	0.267	0.254
<i>funnebris</i>	0.739	0.739	2.043	0.263	0.309
<i>nigra</i>	0.609	0.783	3.000	0.259	0.252
<i>pithyusa</i>	0.304	0.348	1.522	0.091	0.086
<i>stankewiczii</i>	0.435	0.435	1.522	0.125	0.124
<i>koraiensis</i>	0.500	0.500	1.800	0.212	0.233
<i>pumila</i>	0.682	0.773	2.727	0.263	0.271
<i>sibirica</i>	0.450	0.500	1.900	0.174	0.171
<i>cembra</i>	0.400	0.400	1.450	0.116	0.158

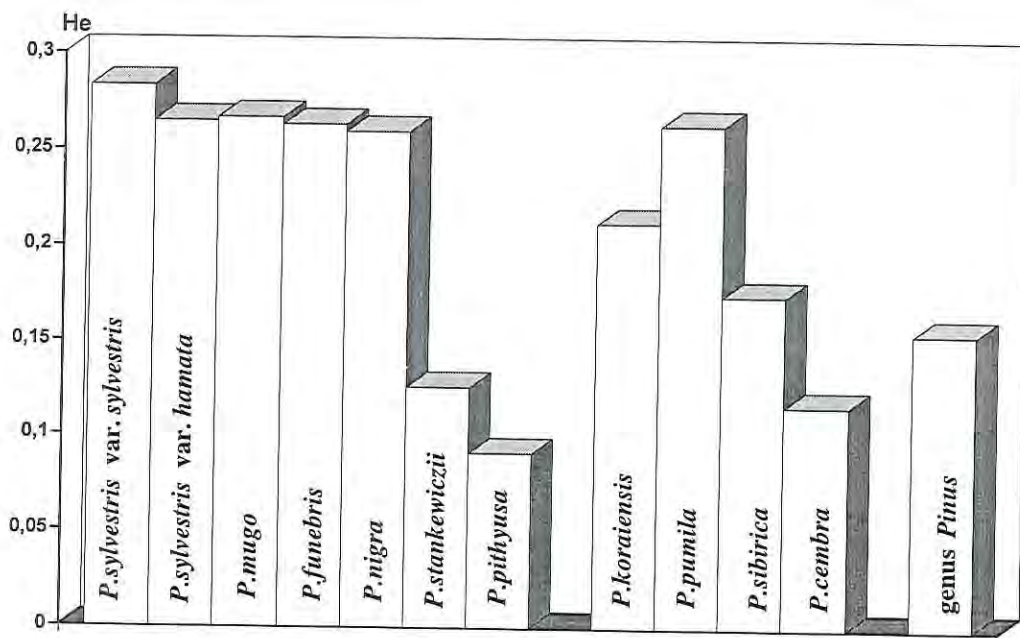


Fig. 3. Levels of genetic variability based on expected heterozygosity (H_e) values in pine species occurring in the territory of the former USSR. The average data on the genus *Pinus* are taken from the current study, from Goncharenko *et al.* (1993c) as well as from studies of Gibson and Hamrick 1991, Mosseler *et al.* 1991, Boscherini *et al.* 1994, Goncharenko *et al.* 1994, Kim *et al.* 1994, Edwards and Hamrick 1995.

The data presented enable to assume that Scots pine is the most polymorphic species among all the members of the genus *Pinus* analyzed at 20 and more loci.

Interestingly, in the *P. sylvestris* populations (Fig. 1) 13 unique alleles were found, that is, alleles which are characteristic of only one particular population. Such alleles were revealed in both isolated populations and those from the continuous distribution area from Latvia, Belarus, Ukraine and Russia. The availability of a great number of unique and rare alleles (more than 30) indicates that the evolutionary processes in *P. sylvestris* populations are presently intensive. This provides an explanation for the great plasticity of this species and its capacity to grow under extreme ecological conditions, from tundra to mountains. It should be noted that in particular populations the frequency of some unique alleles is 3–

-5%. If the objective is to preserve the genetic resources of a species in full measure, the presence of the unique alleles in local populations should necessarily be taken into account in breeding programmes aimed at effective afforestation of a certain region.

It must be emphasized that even in isolated *P. sylvestris* populations from eastern Europe practically the entire level of genetic variation is preserved and they were not subject to the influence of inbreeding. Thus each *P. sylvestris* population analyzed, including isolated ones, possesses a rich genepool and is a source of valuable genetic material.

The great variability in *P. sylvestris* indicates that it is very promising for breeding. In order to achieve success in breeding it is necessary that the broad genetic resources in Scots pine be preserved. However, this may not be achieved easily.

We compared natural stands, seed orchards and cultivated stands of *P. sylvestris* located in the south of Belarus (Figure 4). The heterozygosity level for the trees growing within seed orchards and cultivated stands was lower than that within the natural stands. Besides allelic diversity in the seed orchards also appeared to be sufficiently lower. This is quite natural that the use of seeds from such seed orchards for reforestations will lead to impoverishment of future forests.

At the same time, the knowledge of the genetic structure and level of genetic variability allows to solve the problems of reforestation without damaging the genetic resources.

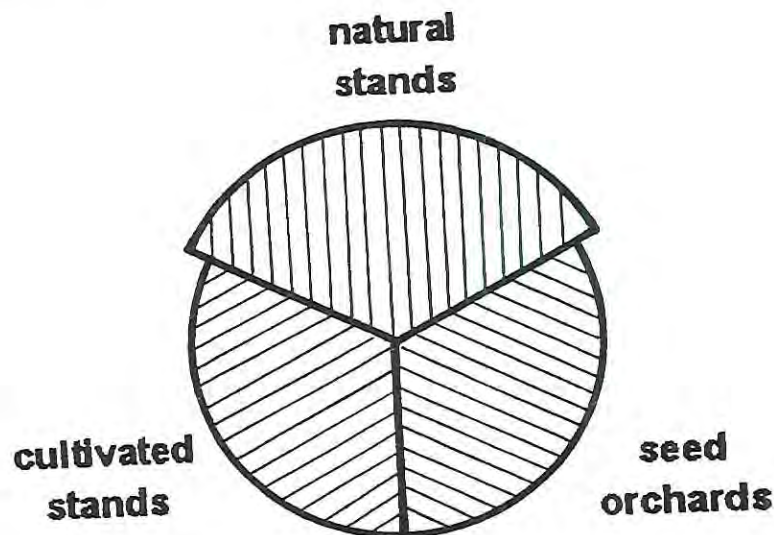


Fig. 4. Comparison of the levels of genetic variation based on the values of expected heterozygosity in *Pinus sylvestris* natural stands, artificial stands and seed orchards.

Spruce

The investigation was based on the seed material collected from more than 1000 individual trees in seven spruce. Thirty seven natural populations from Latvia, Belarus, Ukraine, Kyrgyzstan, Kazakstan and Russia including North Caucasus, Siberia and the Far East, were analyzed (Figure 5).

In Table 2 the basic parameters are listed. The species belonging to the *abies-obovata* complex (*P. abies*, *P. fennica*, *P. obovata*), which has an immense distribution in Eurasia, show the greatest values of genetic variability. Lower values are characteristic for mountain species such as *P. orientalis* and *P. schrenkiana* having small ranges in the Caucasus and Central Asia.

Figure 6 presents the levels of heterozygosity. The species typically occurring in mountains show a lower level of variability than the lowland spruce species.

When analyzing *Picea abies* occurring in the territory of Belarus, we estimated levels of genetic variation in both natural populations and seed orchards. Contrary to Scots pine, the values of most of the genetic parameters, including A and H_e , were higher in seed orchards than in the natural populations. This suggests that in some seed orchards the genetic material typical for natural populations may be collected and used as a basis for breeding and reforestations.

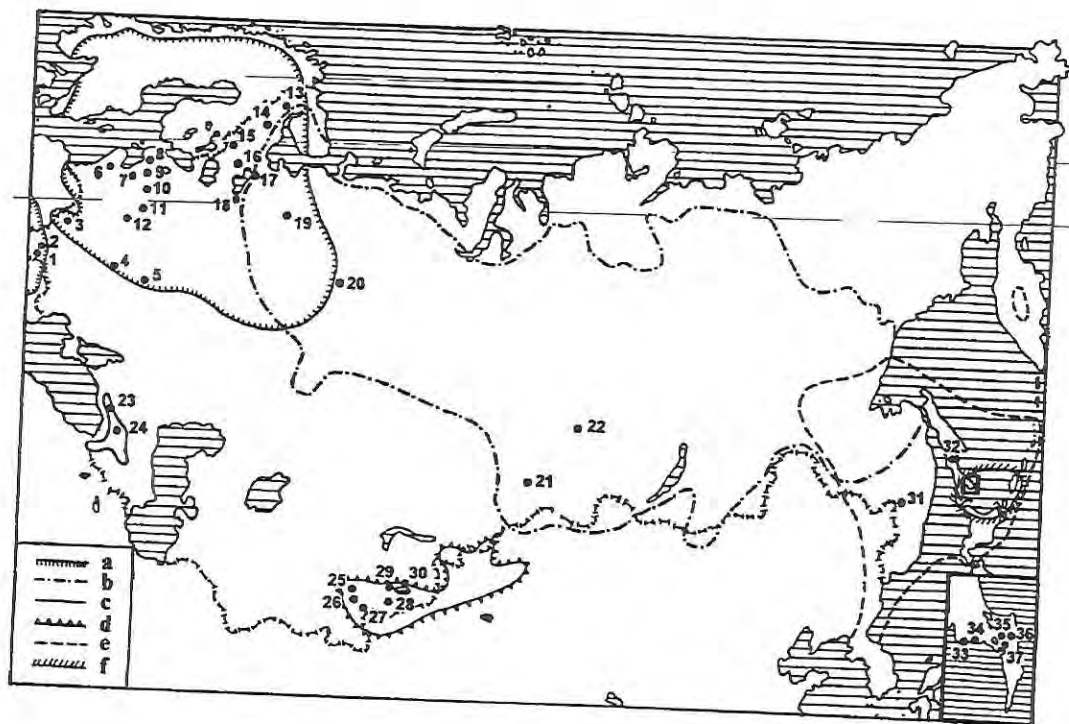


Fig. 5. Locations of 37 studied natural populations of spruce occurring in the territory of the former USSR: 1–12 – *P. abies* (a); 13–20 – *P. fennica*; 21–22 – *P. obovata* (b); 23–24 – *P. orientalis* (c); 25–30 – *P. schrenkiana* (d); 31–34 – *P. ajanensis* (e); 35–37 – *P. glehnii* (f). Natural distribution areas follow Shimaniuk (1974), Pravdin (1975).

Table 2. Parameters of genetic variation in the spruce species occurring in the territory of the former USSR

<i>Picea</i> species	P_{95}	P_{99}	A	H_e	H_o
<i>abies</i>	0.500	0.846	3.654	0.193	0.195
<i>fennica</i>	0.577	0.731	3.000	0.209	0.222
<i>obovata</i>	0.577	0.731	2.308	0.198	0.223
<i>orientalis</i>	0.417	0.625	2.000	0.159	0.159
<i>schrenkiana</i>	0.458	0.458	1.875	0.140	0.114
<i>ajanensis</i>	0.573	0.752	2.092	0.186	0.201
<i>glehnii</i>	0.520	0.582	1.732	0.185	0.195

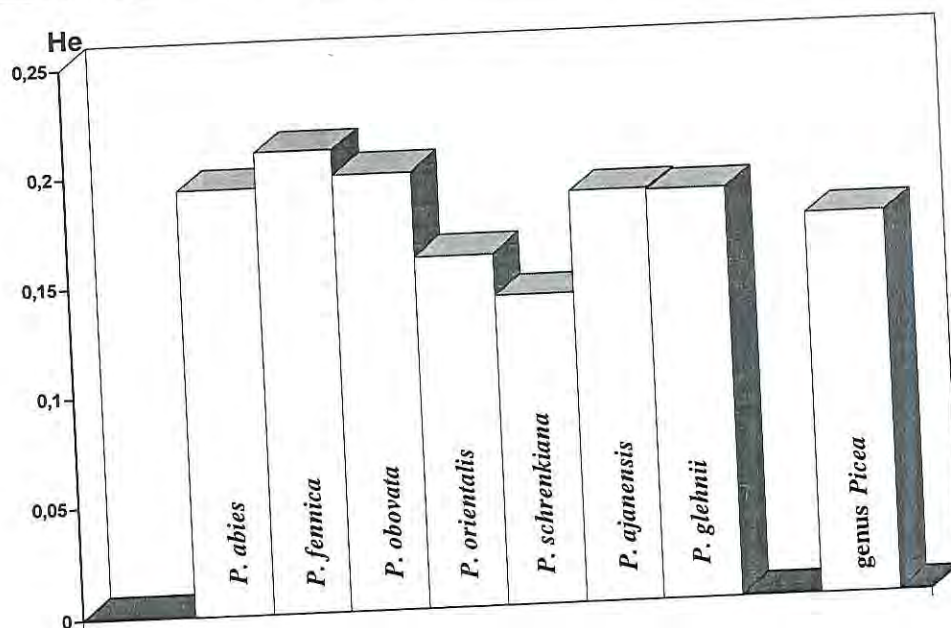


Fig. 6. Levels of genetic variability based on expected heterozygosity in the spruce species occurring in the territory of the former USSR. The average data on the genus *Picea* are taken from the current study as well as from the studies of Yeh and El-Kassaby (1980), King *et al.* (1984), Yeh *et al.* (1986), Tremblay and Simon (1989), Giannini *et al.* (1991), Hawley and DeHayes (1994).

Fir

The investigation was based on the seed material collected from six fir species occurring in the territory of the former USSR. Twenty two natural populations from Belarus, Ukraine, Kyrgyzstan, Kazakstan and Russia including North Caucasus, Siberia and the Far East, were analyzed (Figure 7).

From Table 3 presenting the basic parameters of genetic variation it is obvious that *Abies sachalinensis* revealed the richest gene pools. In this species more than 80% of loci is polymorphic and every tree is heterozygous for 20% of its genes. At the same time, the fir species assayed show lower levels of genetic variation than the pine and spruce species (Figure 8).

It should be emphasized that among the fir species there is one in which the level of genetic variation is the least among all the conifers of the former USSR (Tables 1, 2 and 3). This is *Abies semenovii* which is distributed in an extremely limited area in the Tian Shan mountains and is composed of a very small number of trees.

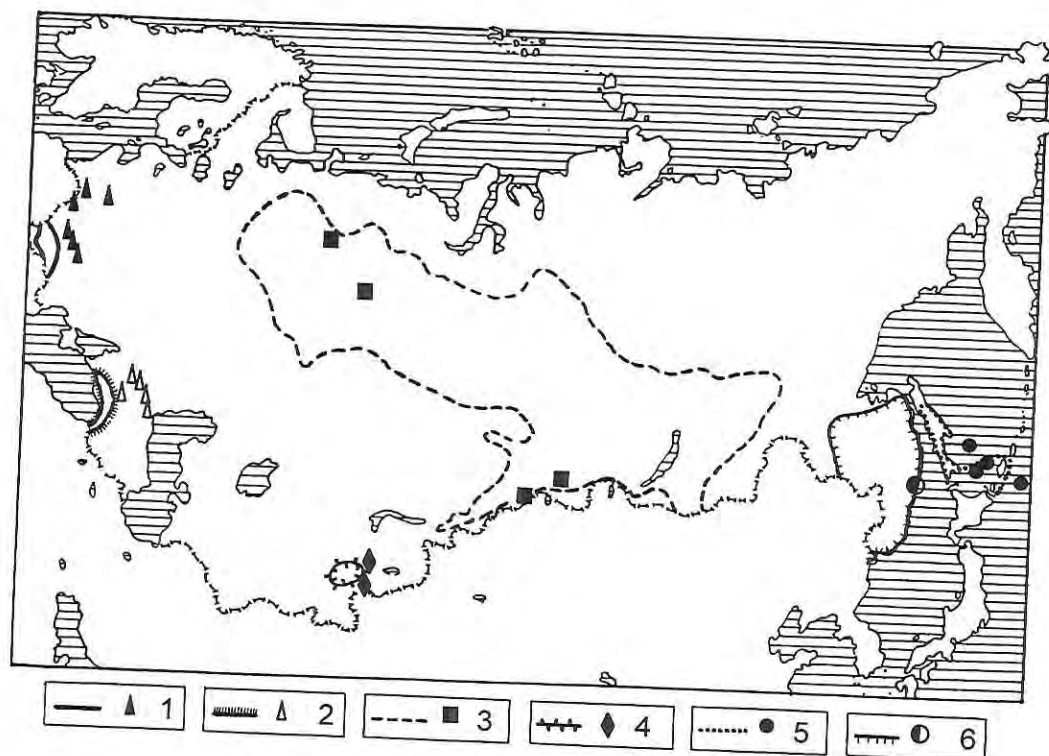


Fig. 7. Locations of 22 investigated fir natural populations in the territory of the former USSR: 1 - *Abies alba*; 2 - *A. nordmanniana*; 3 - *A. sibirica*; 4 - *A. semenovii*; 5 - *A. sachalinensis*; 6 - *A. nephrolepis*.

Table 2. Parameters of genetic variation in the fir species occurring in the territory of the former USSR

Species	P_{95}	P_{99}	A	H_e	H_o
<i>A. alba</i>	0.381	0.524	1.905	0.123	0.118
<i>A. nordmanniana</i>	0.429	0.619	2.476	0.111	0.106
<i>A. sachalinensis</i>	0.619	0.810	2.190	0.207	0.200
<i>A. nephrolepis</i>	0.143	0.143	1.143	0.071	0.143
<i>A. sibirica</i>	0.429	0.571	1.857	0.145	0.131
<i>A. semenovii</i>	0.048	0.095	1.143	0.015	0.017

According to our data *A. semenovii* was subject to strong inbreeding of the 'bottle-neck' type and is presently endangered due to its small size. This species had been entered in the Red Data Book of the USSR. This is a bright example of the correlation between the structure of genetic resources and the parameters such as viability, number of individuals per population, etc.

Thus on the basis of the parameters of genetic variation it was determined that among the species of the *Pinus* genus *Pinus sylvestris* possess the richest genetic resources. In *P. cembra*, *P. pithyusa* and *P. stankewiczii*, whose distribution ranges are limited, genepools have the lowest levels. In the genus *Picea* the species of the *abies-obovata* complex have the highest values of genetic variation. Low values are typical for the mountain species *Picea orientalis* and *P. schrenkiana*, whose ranges in the Caucasus and Central Asia are small. Among the species of the genus *Abies* the highest level of genetic variation is characteristic for *Abies sachalinensis*.

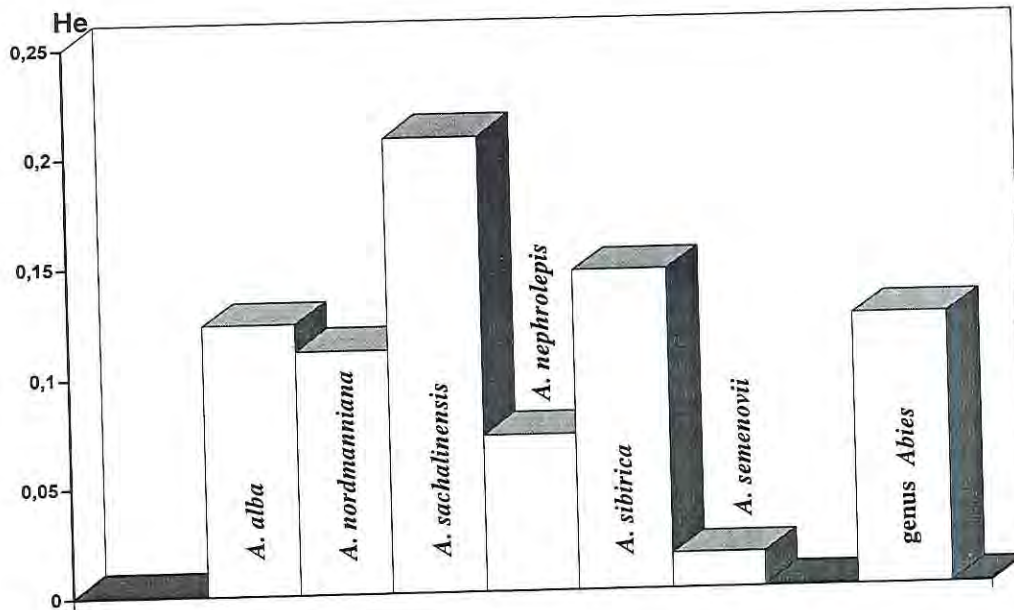


Fig. 8. Levels of genetic variability based on expected heterozygosity values in the fir species occurring in the former USSR.

The poorest genepool not only among firs but also among all the coniferous species assayed was shown for endemic *A. semenovii*. On the whole, the data obtained support the conclusions drawn in the studies of Nevo *et al.* (1984) and Hamrick *et al.* (1992). They inferred that species having a high level of genetic variation usually have a broad distribution range and possess ecological plasticity while in a local species the values of polymorphic genetic parameters are low. With due regard to the data obtained on genetic resources of the coniferous species occurring in the former USSR it will be possible to carry out future reforestation programmes on the genetic basis.

Evolutionary and phylogenetic relationships among conifers

An advantage of isoenzyme electrophoresis is that it permits to ascertain phylogenetic and evolutionary relationships between related and distant species without the need for making special crossings and determining the degree of reproductive isolation. Despite the availability of the methods of the direct DNA investigation, isoenzyme analysis is still the most suitable and accurate method to solve evolutionary and taxonomic problems.

Nei's genetic distance (D_N) was used to estimate genetic differentiation among all the coniferous species studied. On the basis of the results of the analysis of the seed material collected from the studied populations (Figures 1, 2, 5 and 7) and using the unweighted pair-group method (UPGMA), we constructed dendrograms visualizing the phylogenetic relationships among all the taxa assayed. The data presented in the current study have been partly reported in the journals published in both Russian and English (Goncharenko *et al.* 1990, 1991, 1992a, 1992b, 1993a, 1994, 1995a; Goncharenko and Padutov 1995).

Scots pine in the territory of the former Soviet Union is represented by numerous geographical races and ecotypes, many of which have been given different

been given different taxonomic rankings (Pravdin 1964; Bobrov 1978; Vidaković 1991). The results of our investigations of the Scots pine forms as '*sylvestris*', '*carpatica*', '*rigensis*', '*lapponica*', '*cretacea*', '*sibirica*' and '*hamata*' show that regarding the Caucasian form, '*hamata*', alone as a distinct intraspecific taxon is genetically justified (D_N is 0.024) (Goncharenko *et al.* 1995a).

As seen from Figure 9a, among the two-needle pines occurring on the territory of the former USSR *P. mugo* appeared to be the most closely related to *P. sylvestris*. The genetic distance between them is 0.141, indicating differences for more than 14% of structural genes. *P. funebris* ($D_N = 0.171$) and *P. nigra* ($D_N = 0.187$) subsequently joined them (Fig. 9a). Southern pines, *P. stankewiczii* and *P. pithyusa*, were very close to each other ($D_N = 0.010$) and the most divergent from other two-needle pines. In all instances the genetic distance between them exceeded 0.54 (Fig. 9a).

Besides the above two-needle pines, we studied phylogenetic relationships among four five-needle pines constituting subsection *Cembrae* – *P. cembra*, *P. sibirica*, *P. pumila* and *P. koraiensis*. Of the above pines, *P. sibirica* and *P. cembra* appeared to be the closest to each other (Fig. 9b). The genetic distance between them was only 0.036, indicating that to regard Siberian stone pine and European stone pine as distinct species is not genetically justified (Goncharenko *et al.* 1992b).

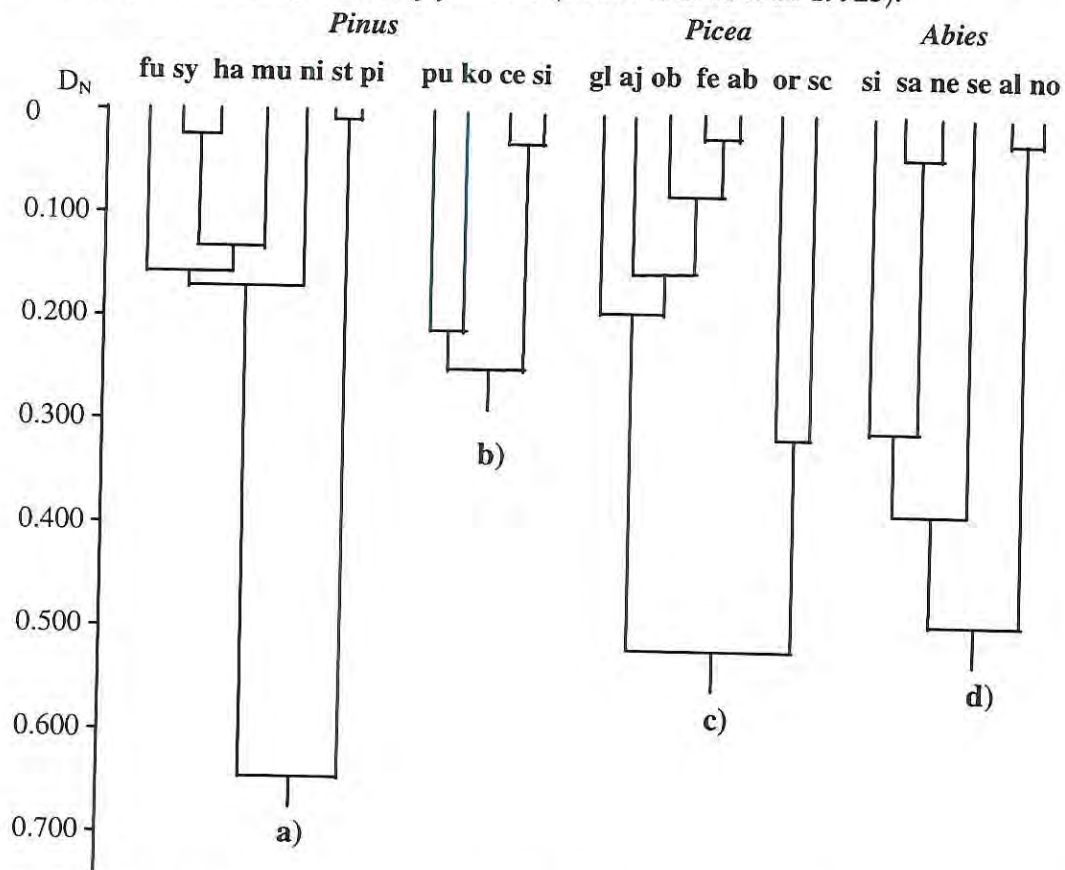


Fig. 9. Dendrograms constructed on the basis of Nei's distance coefficients (D_N) showing genetic differentiation levels for the taxa assayed. The genus *Pinus*: fu - *P. funebris*, sy - *P. sylvestris* var. *sylvestris*, ha - *P. sylvestris* var. *hamata*, mu - *P. mugo*, ni - *P. nigra*, st - *P. stankewiczii*, pi - *P. pithyusa*, pu - *P. pumila*, ko - *P. koraiensis*, ce - *P. cembra*, si - *P. sibirica*. The genus *Picea*: gl - *P. glehnii*, aj - *P. ajanensis*, ob - *P. obovata*, fe - *P. fennica*, ab - *P. abies*, or - *P. orientalis*, sc - *P. schrenkiana*. The genus *Abies*: si - *A. sibirica*, sa - *A. sachalinensis*, ne - *A. nephrolepis*, se - *A. semenovii*, al - *A. alba*, no - *A. nordmanniana*.

Interestingly, *P. pumila* forms one cluster with *P. koraiensis* rather than with *P. sibirica* and *P. cembra* (in both cases D_N values exceeded 0.2). The genetic distance between *P. pumila* and *P. koraiensis* was 0.219. Both clusters united at the D_N value of 0.261 (Fig. 9b).

Within the genus *Picea* the species assayed were divided into two clusters. Species from the lowland formed one cluster while mountain species formed the other one (Fig. 9c). The basis of the first cluster were the taxa of the *abies-obovata* complex. At first *P. abies* and *P. fennica* united at the D_N value of 0.033 and then *P. obovata* joined the above cluster. The genetic distance coefficient between *P. abies* and *P. obovata* was 0.083. The D_N value close to 0.1 is typical for the related coniferous species between which there is a zone of hybridization or whose specific rankings are not universally recognized (Dancik and Yeh 1983, Wheeler *et al.* 1983, Jacobs *et al.* 1984, Yeh and Arnott 1986, Wheeler and Guries 1987, Millar *et al.* 1988, Wang *et al.* 1990).

Picea schrenkiana and *P. orientalis* formed the second cluster. The genetic distance between them was 0.314 (Fig. 9c) suggesting that these species differ significantly from one another (for more than 30% of structural genes).

The most complicated situation is for taxonomy in the genus *Abies*. Different authors believe that 6–10 fir species occur in the territory of the former Soviet Union (Matzenko 1964, Liu 1971, Bobrov 1978, Kriussman 1986, Krylov *et al.* 1986, Vidakovic 1991). Phylogenetic relationships among the firs of the former USSR are not uniquely determined either.

From the dendrogram constructed on the basis of the results of our investigations (Fig. 9d) it is obvious that *A. alba* and *A. nordmanniana* appeared to be the most closely related taxa, the genetic distance between them being only 0.024. In regard to the Far Eastern firs, *A. sachalinensis* and *A. nephrolepis*, the situation is similar. Although Nei's genetic coefficient is somewhat higher in this case (0.042), it also indicates that the above firs are closely related and can be regarded as a single species.

A different situation is for the *sibirica-semenovii* pair. Some researchers do not consider *Abies semenovii* to be a distinct species. They regard it as either *A. sibirica* growing in isolated populations or a variety, *A. sibirica* var. *semenovii*. The data obtained enable us to regard *A. semenovii* as a distinct species because it differs greatly from *A. sibirica* for 7 genes and Nei's genetic distance coefficient ranged up to 0.406. In addition, from the dendrogram (Fig. 9d) it is obvious that *A. sibirica* is closer to the *sachalinensis-nephrolepis* complex than to *A. semenovii* (D_N values were 0.308 and 0.406, respectively). At the present time *A. semenovii* forms only two small isolated populations and, as mentioned in the previous section, its genepool declined greatly. All the above factors may have a profound effect on the strategy of gene conservation of this species. If *A. semenovii* is nothing but *A. sibirica* growing in isolated populations, their loss will not have a severe impact on the species. These populations can be re-established using the seed material from the nearest stands of the continuous range of *A. sibirica* (for instance, from those occurring in the Altay). But being sure that *A. semenovii* is a distinct species which differs notably from *A. sibirica* we should make every effort to conserve and strengthen it because the loss of both populations of this fir will inflict irreparable losses on the whole of the species.

Hence the analysis of phylogenetic relationships not only permits us to settle fundamental problems but in some cases it also determines the strategy of concrete gene conservation.

Localization of the allozyme genes used in conifers

A number of specialists consider that isoenzyme loci do not reflect adequately the structural and functional genome of plants and thus can not be used in the analysis of the genepools of forest tree populations and species. Some of them believe that the allozyme genes used comprise a close gene complex and are localized on either a single chromosome or even in its specific segment.

In this connection we mapped the isoenzyme loci in *Pinus sylvestris*, *P. mugo*, *P. nigra*, *P. brutia* (two-needle pine) and *P. pumila* (five-needle pine) as well as in *Picea abies* which are commonly used in investigations of forest tree populations and species of conifers.

Genes were localized on the basis of the analysis of haploid megagametophytes which are immediate meiosis products in conifers. With the availability of trees heterozygous for two and more loci this permits to analyze linkage without making special crossings. The genetic distances between loci were calculated in centiMorgans (cM) by the formula of Kosambi (1944). The linear order of genes was determined from analysis of trees heterozygous for three or more loci.

The results of genetic mapping of the loci used in the studies are illustrated in Figure 10 by the example of *Pinus mugo*. It is obvious that of the 23 loci analyzed, 13 were localized in four linkage groups. As evident from our investigations the remaining 10 loci are linked with neither the genes of the above four linkage groups nor each other. This indicates that the remaining genes are distributed among the other 8 chromosomes. In other words, 23 genes in *P. mugo* are dispersed over the whole of the genome.

It is significant that in all the pine and spruce species investigated the order and the localization of homologous genes in the linkage groups assayed were similar. This corroborates the conclusion that the structural arrangement of the genomes of the genera *Pinus* and *Picea* is conservative.

Hence the data obtained indicate that the set of the isoenzyme loci used in this population genetic study is distributed over all chromosomes, is a representative sample from the structural and functional genome and permits to reflect adequately the overall polymorphism typical for conifers. In addition, this gene set encodes isoenzymes from different biochemical cycles (glycolysis, pentose cycle, tricarboxylic acid cycle, amino acid and vitamin synthesis, etc.) which participate in different stages of metabolism.

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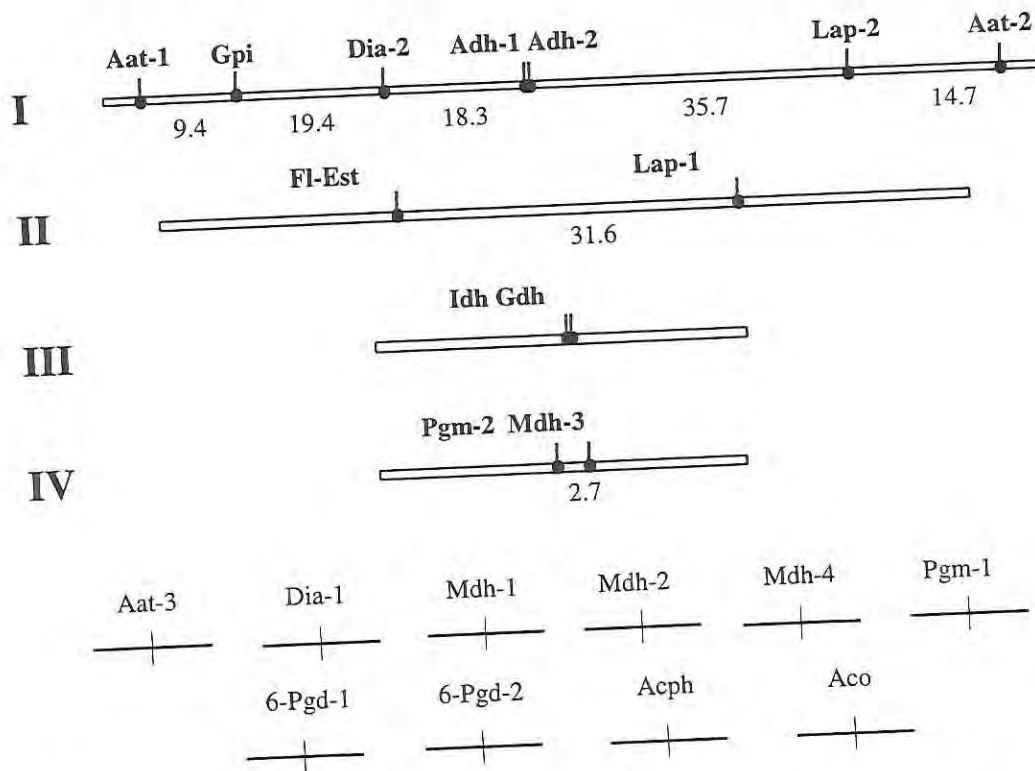


Fig. 10. Genetic map of *Pinus mugo* constructed on the basis of the results of isoenzyme electrophoresis. Distance in centiMorgans (cM).

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Resolution of the Workshop participants

The Workshop "Sustainable Forest Genetic Resources Programmes in the Independent States of the Former Soviet Union" was held from 23 to 27 September 1996 in Belovezhskaya Pushcha, Belarus. 33 participants attended from 9 independent states of the former Soviet Union as well as observers from three further European countries and from the International Plant Genetic Resources Institute.

Coordinated national programmes

The participants recognized that coordination of activities on forest genetic resources should be established or strengthened. It was agreed that the basic building block should be well coordinated national programmes with defined objectives and structure. It is recommended that each country will nominate a coordinating institute or set up a coordinating committee in charge of the national programme.

Such committees should ideally include representatives of all relevant ministries and organizations. In view of the Convention on Biodiversity and other international agreements (such as the Strasbourg Ministerial Resolution on the "Conservation on forest genetic resources"), it is recommended that the coordinating committees develop close contacts with all related fields dealing with biological diversity and its conservation. National programmes should be developed in countries that have not yet done so.

Moldova:

Institute of Botany will continue to play the coordinating role and maintain close cooperation with the Ukraine.

Ukraine:

A framework for comprehensive national programme was created and national coordinating centre composed of forest research institutes established. It will closely cooperate with the national programme of Moldova, in relation to many common tasks.

Belarus:

It was suggested that the Institute of Forest carries on coordinating activities related to the conservation of forest genetic resources.

Russian Federation:

It is proposed that the already existing Scientific Board for Forest Genetics, Seed Science, Tree Breeding and Introduction (under the Federal Forestry Service) be the coordinating agency. The Board will include a strong component of institutes representing the Federation's regions. It was felt that the representation of the Siberian and Far East regions should be strengthened.

Baltic States:

National coordination mechanisms are in place complemented by regional Baltic cooperation.

Central Asia (Kazakhstan and Uzbekistan):

The national forest services together with boards on genetic resources will serve as a framework for activities related to forest genetic resources and their conservation.

The participants recommended that action should be taken to raise awareness about the need to conserve forest genetic resources. This should be done at a national level with policy makers, forestry authorities and the general public. The international community should support these efforts wherever possible. International organizations (IPGRI, FAO, and others) should contribute to raise awareness about the importance of forest genetic resources conservation in the independent states of the former USSR.

Training was seen as an essential element in support of national conservation programmes. Main target groups for training are young scientists and forest officers that can be expected to take responsibility for forest gene conservation in the medium term. Special courses and curricula about forest genetic resources should be included into study programmes for forestry faculties and forestry schools.

Support should be given to the national programmes and their coordinating institutes or committees through the provision of basic communication facilities and infrastructure (e.g., computers and basic laboratory equipment).

International collaboration

Information flow among national programmes should be strengthened through active international collaboration. Participants expressed their wish to join the existing European networks on forest genetic resources.

Sub-regional collaboration was also considered very important and should be promoted, e.g. in the Caucasus and Central Asia.

Examples of collaborative projects proposed by the Workshop participants:

- Genetic conservation of endemic, rare and threatened tree species on the whole territory of the former Soviet Union, with priority being given to Central Asia and the Caucasus;
- Ecogeographic surveys of forest genetic resources in the independent states of the former Soviet Union;
- Genetic inventories of principal broadleaved species (oaks and beech species) in the independent states of the former Soviet Union;
- Coordinated population genetic studies and further development of the existing databases containing results of inventories carried out so far mainly on conifers;
- Surveying of *in situ* gene conservation areas through establishment and analysis of permanent sample plots;
- Re-activation of currently abandoned field experiments;
- Development of databases on *in situ* gene conservation units and areas (stands, gene reserves) using compatible international descriptor lists.

Workshop Programme

23 September 1996

Arrival of participants and registration

24 September 1996

- 09.00–09.15 Welcome remarks (G.G. Goncharenko)
 09.15–09.30 Welcome remarks (T. Gass, IPGRI)
 09.30–10.00 Workshop objectives and format (J. Turok, IPGRI)
 10.00–11.00 Reports:
 L.I. Milyutin (Krasnoyarsk, Russian Federation)
 E.N. Muratova (Krasnoyarsk, Russian Fed.)
 A.M. Danchenko (Tomsk, Russian Fed.)
 11.00–11.20 Coffee break
 11.20–13.00 Reports:
 N.A. Vorobyeva (Tomsk, Russian Fed.)
 P.V. Korobko (Almaty, Kazakstan)
 V.I. Mosin (Schuchinsk, Kazakstan)
 E.S. Alexandrovsky (Tashkent, Uzbekistan)
 V.A. Olisaev (Vladikavkaz, Alania, Russian Fed.)
 V.G. Kartelev (Sochi, Russian Fed.)
 13.00–14.20 Lunch
 14.20–16.40 Reports:
 V.D. Lejba (Ochamchira, Abkhazia, Georgia)
 J.A. Yanbaev (Ufa, Bashkortostan, Russian Fed.)
 G.M. Kozubov (Syktyvkar, Komi, Russian Fed.)
 A.A. Ilyinov (Petrozavodsk, Karelia, Russian Fed.)
 A.E. Prokazin (Pushkino (Moscow), Russian Fed.)
 16.40–17.00 Coffee break
 17.00–19.00 Reports:
 A.I. Iroshnikov (Voronezh, Russian Fed.)
 I.I. Kamalova (Voronezh, Russian Fed.)
 Ü. Tamm (Tartu, Estonia)
 R. Gabrilavicius (Girionys, Lithuania)
 I.N. Patlay (Kharkiv, Ukraine)
 R.M. Yatsyk (Ivano-Frankivsk, Ukraine)
 19.30 Dinner

25 September 1996

- 08.40–10.00 Reports:
 I.N. Shvadchak (Lviv, Ukraine)
 A.F. Khromov (Yalta, Ukraine)
 Gh. Postolache (Chisinau, Moldova)
 A.E. Padutov (Gomel, Belarus)

- 10.00–10.40 State of genetic resources of principal coniferous forest tree species in the independent states of the former USSR—an overview (G.G.Goncharenko)
- 10.40–11.00 Coffee break
- 11.00–12.00 Experience in the development of national strategies on forest genetic resources in European countries (Cs. Mátyás, H. Muhs and L. Paule)
- 12.00–14.00 Lunch
- 14.00–14.15 Rapporteur summary of the presentations
- 14.15–16.30 Regional discussion groups (session I)
- 16.30–17.00 Coffee break
- 17.00–19.00 Regional discussion groups (session II)
- 19.30 Social dinner

26 September 1996

- 08.45–11.00 Thematic discussion groups
- 11.00–14.00 Excursion in the National Park Belovezhskaya Pushcha (Lunch)
- 18.00–19.00 Conclusions of the Workshop
- 20.00 Dinner

27 September 1996

Departure of participants

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