GENETIC RESOURCES OF BEECH (*FAGUS SYLVATICA*) IN THE REPUBLIC OF MOLDOVA

Gheorghe Postolache – Dragos Postolache

Botanical Garden (Institute), Academy of Sciences, Department of Geobotany and Forestry, Padurii 18, MD-2002 Chisinau, Republic of Moldova

ABSTRACT

This paper presents data about the natural distribution, establishment of natural distribution maps, diversity analysis, forest regeneration applications, inventory of genetic resources, *in situ* conservation and rational use of forest genetic resources of beech (*Fagus sylvatica*) in the Republic of Moldova.

Key words: European beech (*Fagus sylvatica*), fag (in Moldavian), beech diversity, plant associations, natural species composition, natural distribution, maps of natural distribution, inventories of genetic resources, *in situ* conservation

GENERAL CHARACTERISTICS

Forests are the most inestimable, renewable natural resources and all forests belong to the first functional group, which means that the function of these forests is a protective one, according to Art. 14 of the Forest Code.

The National Forest Fund of the Republic of Moldova covers 400,900 ha (11.0% of the country territory) including 362,700 ha covered by forests (10.7%) (Galupa et al. 2006). State forests are subject to forest management plans that provide the description of the state of forest biodiversity parameters: typological diversity of forests, species composition of forest sub-compartments, state of grassy cover, regeneration, etc. Deciduous species cover 97.8% and conifers 2.2%.

The natural forests in Moldova consist of broadleaved formations of the Central European type. The main species components of the forest are pedunculate oak (*Quercus robur*), sessile oak (*Q. petraea*), pubescent oak (*Q. pubescens*) and beech (*Fagus sylvatica*). Their distribution depends on the altitudinal levels, on the exposure level and the degree of slope inclination, on the soil and other conditions. These and other factors determined the formation of different types of forests and associations (Postolache 1995).

NATURAL DISTRIBUTION

Beech is found in the northwestern part of the Codrii Reserve from the central part of Moldova and considered at the eastern border of the natural range in Europe (Borza 1937, Soceava, Lipatova 1952, Gheideman 1969, Tishkevici 1984, Postolache 1995). From the climatic, pedologic and geomorphologic point of view this part of Moldova is different from the rest of the country. Many

researchers (Andreev 1957, Gheideman et al. 1964, Postolache 1995) consider this part of Moldova as a particular subregion. Hydrothermic coefficient is 1.0 – 1.1.

Beech forests cover 2,062.8 ha. Most of beech forests, 1,441.9 ha, are present in protected areas (Plaiul Fagului/The Beech Region, Codrii, Căbăieşti – Pârjolteni, Cazimir – Milesti, Cabac, Bogus, Harjauca – Sipoteni, Sadova (Fig. 1, 2). The rest of the beech forests, 620.9 ha, are situated in the forest districts Harjauca, Calarasi, Ciorăşti and Păruceni.

Fig. 1: Beech forests from the "Plaiul Fagului"/The Beech Region reserve

Fig. 2: The protected area of “Cabac”

ESTABLISHMENT OF MAPS OF NATURAL DISTRIBUTION OF BEECH (*FAGUS SYLVATICA*)

The distribution maps of the natural range of beech forests have been developed based on floristic and phytocenological investigations and forest planning information (Andreev 1957). The herbarium illustrated the distribution of pedunculate oak, sessile oak and beech in Moldova. Gheideman (1969, 1986) presents general data about the distribution of these species in geobotanic districts. Data about the distribution of beech are included in the works of Soceava et Lipatova (1952), Postolache (1976, 1995) etc.

In 1975, 1995, 1992 – 1996, the forest fund planning in Moldova was completed. These materials contain data about the forest stand composition. In 1966 – 1972 the forest types and forest associations

with beech from the forest farms in the centre of Moldova were mapped and classified. Turok et al. (2000) published a distribution map of the beech forests in southeastern Europe, comprising also the beech in the Republic of Moldova. Postolache (2002) published the vegetation map of Republic of Moldova, where the distribution of beech forests was presented.

From these maps it can be observed that the largest surface area of beech (*Fagus sylvatica*) was recorded in the central part of Moldova (scientific reserves "Codri", "Plaiul Fagului"/The Beech Region, the forest farms Calarasi, Nisporeni. All the beech areas in Moldova can be attributed to the category of the marginal ones, as they are located at the easternmost border of the beech distribution range in Europe.

PLANT COMMUNITIES DIVERSITY

Beech communities are distributed at an altitude of 200 – 400 m, more often on the upper part of slopes with an inclination of 10 – 40, with north and north-east exposures. These communities are represented by small areas, often in the form of narrow strips near the breaks caused by landslides, or along valleys and small rivers where in many places they go down below 200 m of altitude. Beech communities are growing on brown forest soils.

Pure forest stands and mixed beech forests stands were distinguished according to their composition and structure. The coverage of tree canopy is around 0.8 – 0.9. Beech (*Fagus sylvatica*) dominates the upper part of the tree layer. Beech as the main species of these forests attains the height of 30 – 35 m, diameter of the trunk 50 – 70 cm. It is characterized by a forest stand with a diverse composition and structure. Forest stands are composed of a range of 15 different tree species. Besides *Fagus sylvatica* and *Quercus petraea* also *Tilia tomentosa*, *T. cordata*, *Fraxinus excelsior* have been recorded. Hornbeam (*Carpinus betulus*) dominates at the lower tree layer. Also scattered broadleaves species like *Cerasus avium*, *Acer platanoides*, *A. pseudoplatanus*, *A. campestre*, *Sorbus torminalis*, *Ulmus glabra*, *Populus tremula*, *Malus sylvestris*, *Pyrus pyraster* are present. The shrub layer is poorly developed and is represented by solitary species like *Sambucus nigra*, *Swida sanguinea*, *Crataegus monogyna*, *C. curvisepala*, *Corylus avellana*, *Staphylea pinnata*, *Viburnum lantana*, *Cornus mas*, *Euonymus europaea*, *E. verrucosa*. The herb layer is sometimes as poorly developed as the shrub layer. Therefore the coverage of herb layer varies from 4% to 50%. However, in the spring when ephemeral plants flourish (*Scilla bifolia*, *Corydalis solida*, *C. marschaliana*, *Dentaria bulbifera*, *D. glandulosa*, *Allium ursinum*, *Anemone ranunculoides*, *Ficaria verna*, *Gagea lutea*, *G. pusilla*, *Isopyrum thalictroides*), herb layer may reach a coverage of 60 – 90% in some places. During the summer period the herbs are represented by species such as: *Galium odoratum*, *Carex pilosa*, *C. brevicollis*, *C. digitata*, *C. sylvatica*, *Asarum europaeum*, *Hedera helix*, *Aegopodium podagraria*, *Galeobdolon luteum*, *Sanicula europaea*, *Polygonatum latifolium*, *P. multiflorum*, *Pulmonaria obscura*, *Alliaria petiolata*, *Circea lutetiana*, *Mercurialis perennis*, *Geranium robertianum*, *G. phaeum*, *Viola reichenbachiana*, *V. mirabilis*, *Dryopteris filix-mas*, *Epipactis heleborine*, *Stachys sylvatica*, *Actaea spicata*, *Convallaria majalis*, *Poa nemoralis*, *Mycelis muralis*, *Neottia nidus-avis*, *Salvia glutinosa*, *Scrophularia nodosa*, *Arum orientale*, *Athyrium filix-femina*, *Cephalanthera damasonium*, *Cephalanthera longifolia*, *Dactylis glomerata,* *Stellaria holostea*, *Urtica dioica*, *Euphorbia amygdaloides*, *Geum urbanum*, *Lamium maculatum*, *Lunaria rediviva*, *Melica uniflora*, *Milium effusum*, *Platanthera bifolia*, *Astragalus glycyphyllos*, *Cardamine impatiens*, *Equisetum telmateia*, *Glechoma hirsuta*, *Lamium purpureum*, *Lathyrus niger*, *Parietaria erecta*, *Ranunculus auricomus*, *Scutellaria altissima*, *Tussilago farfara*, *Vicia dumetorum*,

Monotropa hypopitis. Most of these species are characterized by a very low abundance, and some of them can be found only in a few exemplars. In beech forests 25 species of rare plants have been recorded, most of them are listed in the Red Book of Moldova: *Daphne mezereum*, *Dryopteris dilatata*, *D. carthusiana*, *D. caucasica*, *D. filix-mas*, *Polystichum aculeatum*, *Thelypteris palustris*, *Athyrium filix-femina*, *Cystopteris fragilis*, *Gymnocarpium dryopteris*, *Cephalanthera damasonium*, *C. longifolia*, *C. rubra*, *Cypripedium calceolus*, *Lunaria rediviva*, *Telekia speciosa*, *Dentaria quinquefolia*, *D. glandulosa*, *Ortilia secunda*, *Pyrola rotundifolia*, *Majanthemum bifolium*, *Platanthera bifolia*, *P. chlorantha* (Gheideman 1969, Postolache 1995, Postolache, Chirtoaca 2005).

According to the phytocenologist Gheideman (1969), there are seven associations of beech forests in the country. According to the authors Postolache and Chirtoaca (2005) from the central European school, the beech forests comprised in the scientific reserve "Plaiul Fagului"/The Beech Region were classified as association *Carpino-Fagetum silvaticae* Pauca 1941.

In these communities, the dominant plant species are mesophilic – 47.7%, followed by mesohygrophilic – 32.6% and xeromesophilic – 17.5%. The mesoxerophilic and hygrophilic species are presented in 1% each. The life forms spectra are dominated by hemicryptophyte species (33%) and geophyte species (30%) followed by phanerophyte species (25%). The floristic elements analysis reveals the dominance of Eurasian element (Euras. – 35.2%), European element (Eur. – 20.5%) and Central-European element (Eur. centr. – 11.4%). Relatively well represented are circumpolar elements (Circ. – 10.2%).

BEECH DIVERSITY

Many researchers have studied beech populations, but up to the present there has not been a consensus regarding the systematics of Moldovian beech. Savulescu et Rayss (1926) indicated two forms of beech in the beech forests in Basarabia: (a) f. *cuneifolia* Beck and (b) f. *rotundifolia* Beck. Borza (1937) considered that there are two varieties of beech in Basarabia: (a) *Fagus sylvatica* var. *podolica* spread in the North of Basarabia and (b) *Fagus sylvatica* var. *moesiaca* Czecz. spread in the Centre of Basarabia. Soceava et Lipatova (1952) attributed the beech from Moldova to the var. *moesiaca* Czecz.

Istrati (1975, 1980), after studying the vegetative and generative organs of beech populations, concluded that according to the leaf form the beech belongs to the *Fagus sylvatica* species and differs from *F. orientalis* Lipsky and *F. taurica* Popl. A special peculiarity of the beech population is the asymmetry of the leaf blade.

On the basis of the investigations on the vegetative and reproductive organs of beech populations Tishkevici (1984) made similar conclusion, that the Moldovian beech has some specific peculiarities but is the closest to *Fagus sylvatica.*

Thus the problem of the beech population structure is not resolved. It is possible that one of the principles is the phylogenetic problem of the beech. Mattfeld (1936) quoted by Borza (1937) presumed that long ago during the preglacial period the differentiation of beech (*Fagus sylvatica*) took place from a tertiary species into two species. After the glacial period the environment became more favourable for beech (*Fagus sylvatica*). According to Wulff (1931) *Fagus sylvatica* developed after the glacial epoch from *Fagus orientalis*.

Following this short characteristic of the beech populations it may be concluded that the beech population has a complex structure and it is necessary to protect all these areas as they are both of scientific and practical interest.

As the beech in Moldova is situated at the eastern border of its distribution area, it has been attributed to the category of marginal forest genetic resources.

FOREST REGENERATION APPLICATION

Between 1975 and 1984 some experiments on the establishment of beech plantations were performed (Tishkevici 1984). During the years 1997 – 2005 other experiments regarding beech regeneration, by the method of successive cuttings, were carried out in the scientific reserve "Plaiul Fagului"/The Beech Region on an area of 294.9 ha. The purpose of this work was to optimize the forests structure where hornbeam is abundant.

Nowadays the developed successive cuttings are applied in several forest districts in order to optimize the composition and structure of beech forests.

INVENTORY OF *FAGUS SYLVATICA* GENETIC RESOURCES

Resulting from analysis of forest plans, 236 sub-compartments with beech with a total area of 2,062.8 ha were delineated in the state forest fund. According to the abundance of beech in forests stands 65 sub-compartments (274.3 ha) have been distinguished in natural forest stands, where the beech represents more than 50%. The rest of beech sub-compartments 152 (1,737.0 ha) are located in derivative forest stands with a beech proportion of 10 – 49% and the other 19 sub-compartments are planted forests with an area of 51.5 ha. The areas protected by the state (Plaiul Fagului/The Beech Region, Codrii, Căbăieşti – Pârjolteni, Cazimir – Milesti, Codrii, Cabac, Bogus, Harjauca – Sipoteni, Sadova) contain 1,441.9 ha of beech forests or forests with beech (Fig. 1, 2). Outside the protected areas there are 620.9 ha of beech forests managed by the forestry institutions from Harjauca, Calarasi, Ciorăşti, Păruceni.

Taking into consideration that the beech in Moldova is situated at the eastern border of the distribution area in Europe it should be stressed that it is necessary to extend the state protected areas within the beech forests. The forest genetic resources in these areas have been sampled based on the quality of the forest stands.

Three categories of forest genetic resources have been established:

- Optimal forest genetic resources of beech (*Fagus sylvatica*) include the most valuable genetic resources. The volume of the wood is 340 – 460 $m^3 \cdot ha^{-1}$. The height of the tree range is 26 – 38 m and the diameter of the stems is 32 – 56 cm. Ten forest genetic resources of beech have been attributed to this category.
- Forest genetic resources seed stands include forest stands which are less productive than the optimal ones (230 – 308 $m^3 \cdot ha^{-1}$). Three forest genetic resources seed stands have been established.
- The forest genetic resources from the reserves are a separate category. In the reserves 11 forest genetic resources have been established with a total area of 1,441.9 ha (Tab. 1).

CONSERVATION AND RATIONAL UTILIZATION OF THE FOREST GENETIC RESOURCES

There are nine state protected areas of beech of which two of them: "Plaiul Fagului"/The Beech Region, and "Codrii", are scientific reserves. One beech forest "Hîrjauca – Sipoteni" was attributed to the category of protected areas being considered a monument of nature. Four protected areas such as "Cabac", "Sadova", "Bogus" and "Leordoaia" were attributed to the category of nature reserves, while two protected areas "Cazimir – Milești" and "Căbăiești – Pârjolteni" were assigned to the category of landscape reserves.

Nowadays within these nine protected areas only 1,441.9 ha of beech forests and forests with beech are under the protection of the state, representing a total of 70% of the existing beech forests. These 204.1 ha include natural-fundamental forests in which the beech represents more than 50%. Also registered is an area of 1,193.6 ha of derivative beech forests where the participation of the beech tree varies between 10 to 40%. In the scientific reserve Plaiul Fagului/The Beech Region and in nature reserve Căbăiești – Pârjolteni, 14 areas were planted with beech trees, an area of 44.2 ha (Tab. 1).

Tab. 1: Area (ha) occupied by different categories of beech forests within the protected areas

Protected areas	Natural-fundamental forest stands	Derivative forest stands	Planted forest stands	Total
Plaiul Fagului	130.9	691.0	26.7	848.6
Căbăieşti – Pârjolteni	5.0	256.0	17.5	278.5
Cazimir – Milesti	18.5	166.8	–	185.3
Codrii	38.0	28.2	–	66.2
Cabac	7.3	39.7	–	47.0
Bogus	1.8	7.8	–	9.6
Harjauca – Sipoteni	1.3	4.1	–	5.4
Sadova	0.8	–	–	0.8
Leordoaia – Palanca	0.5	–	–	0.5
Total	204.1	1,193.6	44.2	1,441.9

CURRENT LEGISLATION

Based on the research undertaken by Borza (1937), eight compartments were identified within the forest vegetation classification, among which there were two with beech forests (Pârjolteni – 10 ha and Hârjauca – Palanca – 7 ha). In conformation with a decision of the Romanian Council of Ministers taken in July 19, 1937, these areas along with others were declared Monuments of Nature in Basarabia. Based on the decision of Moldova S. S. R. taken on January 8, 1975, No. 2 "Regarding the settlement of natural areas and complexes from the territory of Moldova S. S. R. under the protection of the state" several areas with beech forests of nine protected areas (Plaiul Fagului/The Beech Region, Căbăieşti – Pârjolteni, Cazimir – Milesti, Codrii, Cabac, Bogus, Harjauca – Sipoteni, Sadova, Leordoaia – Palanca) were put under the protection of the state.

In agreement with the Law on Natural State Protected Areas Fund adopted by the Parliament of the Republic of Moldova No. 1538 – XIII in February 25, 1998, these protected areas were reconfirmed and attributed to several categories of protected area status. Thus were established: two scientific reserves (Plaiul Fagului/The Beech Region, Codrii), one monument of nature (Harjauca – Sipoteni), two landscape reserves (Căbăieşti – Pârjolteni, Cazimir – Milesti) and four nature reserves (Cabac, Bogus, Sadova, Leordoaia - Palanca).

FOREST RESEARCH

The beech forests were studied by several groups of researchers. During 1949 – 1951 one group of researchers from Sankt-Petersburg guided by B. Soceava investigated the spread of beech forests in Moldova. The results of this research were published in a number of articles by Soceava et Lipatova (1952).

The researchers from the Agriculture University of Chisinau under the guidance of G. Tishkevici investigated the biological, ecological and physiological properties, systematic position, natural regeneration and productivity of beech during the period 1970 – 1980. These results were published in the monograph "Okhrana i vosstanovleniye bukovikh lesov" [Conservation and reconstruction of beech forests] (Tishkevici 1984) and in a number of articles.

Other research activities regarding different aspects of the beech tree and beech forests were performed within the Botanical Garden (Institute) from the Academy of Sciences of Moldova.

During 1966 – 1969, T. Gheideman investigated the plant associations, microclimatic conditions, hydric regime of beech trees and other components of beech forests. The results of these investigations were published in the monograph "Bukovaya dubrava Moldavskoi S. S. R. [Beech forests of Moldova S. S. R.] (Gheideman 1969).

Later, during 1997 – 2000, a group of researchers under the guidance of Professor Gh. Postolache, performed important research studies on the identification of beech genetic resources (*Fagus sylvatica*) within the collaborative project with Bulgaria, Moldova and Romania "Genetic resources of broadleaved forest tree species in southeastern Europe" initiated by IPGRI (International Plant Genetic Resources Institute). The selection of beech forest genetic resources was performed by means of a methodical selection of forest areas which included exploration, sampling and classification. Based on this research the monograph of "Genetic resources of *Fagus* spp. in southeastern Europe" was prepared and published by Turok et al. (2000).

Postolache (2004) in his work "State of Forest and Tree Genetic Resources in the Republic of Moldova" presented information regarding the forest genetic resources of beech. Postolache and Chirtoaca (2005) investigated beech forests in the scientific reserve "Plaiul Fagului"/The Beech Region that was attributed to the association *Carpino-Fagetum sylvaticae* Pauca 1941. They show the floristic and phytocenological composition of beech forest communities.

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Reviewed

Contacts:

Dr. habil. Gheorghe Postolache
Botanical Garden (Institute), Academy of Sciences, Department of Geobotany and Forestry
Padurii 18, MD-2002 Chisinau, Republic of Moldova
e-mail: ghpost@asm.md, ghpost@mail.ru

CURRENT STATE OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) GENE-POOL IN ROMANIA

Lucia Ioniță – Gheorghe Pârnuță

Forest Research and Management Institute Department of Genetics and Tree Breeding
Bd-ul Eroilor nr. 128, Code 077190 Voluntari- Ilfov, Romania

ABSTRACT

The paper outlines the state of European beech (*Fagus sylvatica* L.) in Romania. The information included deals with the distribution, ecology, taxonomy, phenotypic and genetic variability of European beech. Information about characteristics and forest management, as well as methods for preservation of European beech genetic resources, are also included.

Key words: European beech (*Fagus sylvatica* L.), fag (in Romanian), Romania, distribution, phenotypic and genetic variability, genetic resource, forest research

DISTRIBUTION AND ECOLOGY OF EUROPEAN BEECH IN ROMANIA

In Romania, European beech is the dominant species, covering 32.3% of the forest land (about 2,041,000 hectares, INS 2008) and amounting for 37% of standing wood volume. Romania has 11.7% of Euro-Asian beech stands, thus ranking third in the world. The map of natural distribution range of *Fagus sylvatica* was elaborated by Blada et al. (2002) and is presented in Figure 1.

European beech is a hill and mountain tree growing in both pure and mixed stands with silver fir, Norway spruce and sessile oak. The sub-zone of European beech covers a great deal of Banat, Transylvania, Maramureş, the two slopes of the Carpathians and the central plain of Moldavia. As for the beech extension in altitude, it is very variable depending on the geographical location: 150 m in Banat (seldom 60 m along the Danube Valley and 100 m in Cerna Valley), 800 m in the Transylvanian Alps. The upper limit of closed beech stands lies between 1,200 and 1,400 m but can reach even 1,500 m in the Transylvanian Alps and 1,700 m in the Western Carpathians on the northern slopes.

The optimum range is characterized by a range of precipitation of 650 – 1,250 mm depending on the geographical region and a mean annual temperature of 5.2 – 8.7 °C. European beech stands of high productivity can be found only on deep and rich soils, with a high availability of water and nutrients. Such kind of stands exists in the Western Carpathians (Banat and Crişana regions).

Ecological researches regarding Romanian beech forests were performed by Pauca-Comănescu (1989).

Fig. 1: Map of natural distribution range of *Fagus sylvatica* (Blada et al. 2002)

PHENOTYPIC AND GENETIC VARIABILITY OF EUROPEAN BEECH IN ROMANIA

Phenotypic variability of European beech population in Romania area was described by Milescu et al. (1967) who classified the systematic subunits of *Fagus sylvatica* as follows: *F. sylvatica* ssp. *europaea* (ssp. *sylvatica*), *F.* var. *moesiaca sylvatica* ssp. *orientalis*, var. *grandifolia* and *F. sylvatica* ssp. *taurica*, var. *grandifolia*.

The ecological units of European beech were defined based on the natural types of beech forests. After Ienciu (2005) other subunits of European beech had been described, by many authors, based on the form and structure of the crown, characteristics of leaves, bark and wood and also other traits as follows:

– *F. s.* var. *pendula* Lodd. Catal. (Florescu, Dumitriu-Tătăranu 1960), in Banat Mountains at 800 m, Aleşd, Black Forest (Bihor) (Beldie 1952) and Jerălău Valley (Banat);
– *F. s.* f. *dentata* Dalla Torre et Sarnth, in Transylvania at Braşov, in Muntenia at Schitu Goleşti-Grădiştea Forest (Muscel), (Beldie 1952);
– *F. s.* var. *vulgaris* (Dom.) Beldie Syn., the most common in Romania, the most interesting population from genetic, ecological and productivity points of view being the ones from Beliu,

Dumitreşti, Dobra, Voineşti, Bârzava, Sudrigiu, Radna, Mihăieşti, Fântânele, Soveja and Făget (Chiriţă et al. 1981);

- *F. s.* var. *typica* C. K. Schneider f. *crenata* Kárp., at Băile Herculane (Banat) (Karpati 1937);
- *F. s.* f. *beckii* Dom., in Parâng (Beldie 1952);
- *F. s.* var. *moesiaca* (Maly) Hayek Emend. Dom., in Transylvania, Banat, Oltenia, Moldovia and Dobrogea (Beldie 1952), the most valuable populations being Berzasca, Orşova, Bozovici, Anina, Mehadia and Tismana (Dumitriu-Tătăranu, Ocskay 1953);
- *F. s.* var. (Maly) Dom. *moesiaca* f. *czeczottae* Paşcovschi, in Neva Valley, at Svinița (540 m) and in Little Mountain at Sebeş (1,200 m) (Paşcovschi 1945);
- *F. s.* f. *roseo-marginata* Henry. Syn. in Timiş Park (Braşov) (Beldie 1952) and in Arinilor Park at Sibiu (Ţopa 1956);
- *F. s.* f. *leucodermis* Georgescu et Dumitriu-Tătăranu in Cheia, Bistrița, Argeş Region, Bistricioarei and Zănoaga (Dumitriu-Tătăranu 1959), in Brădiştea (Milescu et al. 1967), in Mehedinţi and Vulcan Mountains, at Săcărâmb, and in Apuseni, at Suharău (Enescu 1975);
- *F. s.* f. *quercoides* Pers., Ciucaş Mountain (1,060 m) and Red Mountain (1,240 m) (Băile Herculane) (Dumitriu-Tătăranu, Ocskay 1953);
- *F. s.* var. *borzae* Dom., in Banat (Domogled Mountain), in Moldova at Grăjdeni, Feredeu-Deleni, Repedea (Iaşi) (Beldie 1952);
- *F. s.* f. (var.) *microcarpa* Aschers-Graebn., in Cheile Bicazului (1,000 – 1,120 m) (Ţopa 1956), in Neteda Plai Mountain (1,500 m) (Georgescu 1958) and in Hurcu Mountain (Banat) (1,200 m) (Florescu, Dumitriu-Tătăranu 1960).

Fagus orientalis Lipsky was found in Banat at Moldova Nouă and Orşova (900 – 1,100 m), Cerna Mountain (1,160 m), in Moldavia at Buhuşi, Huşi, Piatra Neamţ Regions, Măgura Odobeşti, Berneşti and Iaşi, and in Snagov Forest, Dobrogea and Lucovița. Three forms – f. *major* Dom. (Fata lui Matis, Herculane), f. *minor* Dom. and f. *fallax* Dom. (Duhova, V. Gratca, Orşova at 70 m, Snagov Forest) – were identified.

One hybrid – *Fagus orientalis* × *Fagus sylvatica* – was also identified in the plains of the south-west and east of the country.

CHARACTERISTICS AND FOREST MANAGEMENT

In the past European beech wood was not used very much for industrial purposes. Nowadays it is widely used for lumber, parquetry fillet, veneer, plywood, lumber-core plywood, particle boards, rural buildings, fuel wood, etc. Recently, it has been used even for pulp and paper production.

European beech stands in Romania are almost all (95%) naturally regenerated, the national policy in this field being to increase the share up to 100%.

Wood production is the main destination of European beech forests in Romania. The total wood production at 100 years old in pure European beech stands varies between 453 $m^3.ha^{-1}$ in the lowest (Vth) site class and 1,155.5 $m^3.ha^{-1}$ in the highest (Ist) site class. At 80 years of age, the mean growth of pure European beech stands in the Ist site class is 11.9 $m^3.ha^{-1}.yr^{-1}$ and decreases down to 4.3 in the

(lowest) Vth class. At 100 years of age, in the Ist site class, the proportion of industrial wood is 72%, of which 65% is sawnwood (Enescu 1993).

The amount of European beech wood harvested in the forests (state and private) of Romania in the past 10 years is shown in table 1.

Tab. 1: Amount of beech wood harvested in Romania in the past 10 years (Romanian Statistic Yearbook 2008)

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Harvested volume (million m^3)	3.963	4.505	4.956	4.480	4.439	4.748	5.412	4.794	4.997	5.182

FOREST RESEARCH

In Romania, because of only natural regeneration (by seed), European beech has not been the topic of a breeding programme. For that reason its phenotypic and genetic variability was barely searched in-depth.

A biosystematic research in 60 natural populations has investigated traits of pulp production interest (Ciocnitu et al. 1975). Populations with high pulp value were found in the north of the Eastern Carpathians, Suceava Plateau, south Eastern Carpathians, Mehedinți Plateau and in Western Carpathians (Apuseni Mountains).

Another study (Urecheatu 1992) using 77 natural populations took into consideration 42 morphological and anatomical parameters and showed a very large inter- and intrapopulation variability. The research carried out by Stănescu and Şofletea in 1990 – 1992 in European beech populations from a relevant proportion of its natural range in Romania showed a large variation of some leaves' morphology and bark colour.

The first study regarding phenotypic and genotypic variation of European beech in Romania was initiated by Enescu et Muhs (1988). The first step was the study of phenotypic variation of some evolutionary traits in natural populations of European beech from Romania. The biosystematic research of 21 natural populations selected after 5 altitudinal profiles containing the main parts of European beech natural range had included the measurement and observation of 29 traits of forest interest. The first results showed the existence of a large variation of those traits. The second step was the establishment of international provenance trials in Romania in 1995 and 1998 (Wuehlisch von 2007). These trials were the object of other research projects performed by Ioniță in 2005 – 2008 (Mihai et al. 2008).

Researches on differentiation in European beech at allozyme loci were performed by Gömöry et al. (2003). The Romanian Carpathians are unambiguously the centre of the allelic richness, both at the regional and population level. On the other hand, allelic richness exhibits very distinct trends. Despite local variations, centres of high as well as low allelic multiplicity can easily be identified. Extremely low values occur at the northeastern limit of the distribution range – Baltic coast and

centre of Poland. The highest values were found in the Romanian Carpathians, mainly in the Apuseni Mts. and at the southeastern edge of the Carpathians (regions Ploieşti and Braşov).

European beech continues to be the most resilient species among the most important Romanian forest species. Its defoliation proportion was 15.6% in 2004, 11% in 2005 and 11.5% in 2006 (Badea et al. 2005 – 2007). In some particular areas (NE and Central Romania) beech decline has been recorded, due to a complex mixture of abiotic factors (water fluctuation, frost, etc.), favouring (agedness, compact soil, low drainage, etc.) and aggravating (bark and wood insects, diseases – *Phytophthora* spp., *Nectria* spp., etc.) (Chira et al. 2005, Chira, Chira 2007). As a new phenomenon, *Lymantria dispar* defoliations have been recorded in beech stands in the last years (Tăut, Neţoiu 2007). Also beech canker is widely spread in hilly and low mountain areas (Chira, Chira 1998).

CONSERVATION OF EUROPEAN BEECH GENETIC RESOURCES

In Romania, the beech genetic resources are conserved only *in situ*, with the exception of 4 populations that are included in the international field trials of European beech established in our country.

A first method of conservation is the seed stand, which amounts for 7,665 ha spread all over the phytogeographic subzones of our country (Seed Stands Catalogue 2001). Other virgin stands, with garden-like patterns, are preserved under total non-intervention regime in old forests legally dedicated as nature monuments. Eight virgin forests – Văliug Forest District, compartment 37, Mehadaia Forest District, compartments 214 and 94, Bozovici Forest District, sub-compartment 110 C and compartment 47, Nera Forest District, compartments 38 A and 64, and Făget Forest District, sub-compartment 110 A – were identified. Among these forests, Nera and Făget are protected areas.

A second method of conservation is the selection of genetic resources of European beech which are included in the National Catalogue of Forest Genetic Resources (Pârnuţă et al. 2008). The genetic resources of European beech consist in 123 conservation units, with 11,803 ha total surface, of which 3,106.4 ha as core zone and 8,696.6 ha as buffer area.

The map of *Fagus sylvatica* genetic resources distribution on regions of provenances is presented in Figure 2.

Scattered stands of European beech located outside of the natural range such as Bucovăţ-Craiova, Bucoviciorul-Dolj, Luncaviţa-Măcin, Mănăstirea Câlnic-Tulcea, are also preserved. To the same group belong the scattered individuals or small groups of European beech trees located in the Transylvania Plateau (Sivaşul de Câmpie-Mureş) and in the Muntenia Plains (Ţigăneşti-Snagov, Curcubeul-Gherghiţa).

An important proportion of European beech forests are subject of NATURA 2000 programme in Romania (273 of SCI, which amounts for 2,023,601 ha, including beech forests also) (Stoiculescu 2007).

The Romanian legislation regarding the forest genetic resources consists of the Governmental Ordinance no. 11/2004 on the production, marketing and utilization of forest reproductive material, approved by Law no. 161/2004 and Law no 46/2008–Forest Code.

Fig. 2: *Fagus sylvatica* (L.) genetic resources distribution on regions of provenances

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Reviewed

Contacts

Dr. Lucia Ioniță, Prof. Dr. Gheorghe Pârnuță
Forest Research and Management Institute Department of Genetics and Tree Breeding
Bd-ul Eroilor nr. 128, Code 077190 Voluntari- Ilfov, Romania
tel.: +4021 350 3238; +4021 350 3245
e-mail: luciaionita1@yahoo.com, gh_parnuta@icas.ro

CURRENT STATE OF BALKAN BEECH (*FAGUS SYLVATICA* SSP. *SYLVATICA*) GENE POOL IN THE REPUBLIC OF SERBIA

Mirjana Šijačić-Nikolić[1] – Saša Orlović[2] – Andrej Pilipović[2]

[1] Faculty of Forestry, University of Belgrade, Kneza Višeslava 1, 11030 Belgrade, Republic of Serbia
[2] University of Novi Sad, Institute of Lowland Forestry and Environment, Antona Čehova 13, 21000 Novi Sad, Republic of Serbia

ABSTRACT

Total forest area of Serbia is 2,412,940 ha. The dominant species in the forest growing stock is beech (50.4% by volume) with a wide range of vertical distribution, occurring in a great number of forest types, in different structural forms, in pure or mixed stands, of different origin, at different sites. The main characteristic of the beech gene pool in Serbia is high individual and group variability in many morphological and genetic-physiological traits, which results in numerous intraspecific taxa described in this region.

Key words: Balkan beech, bukva (in Serbian), taxonomy, morphology, variability, range, forest community, environmental conditions, state, forest management system, fungi, insects, gene pool

TAXONOMY

In Serbia, in addition to European beech (*Fagus sylvatica* L.) and oriental beech (*Fagus orientalis* Lipsky), according to Jovanović (2000), there is also Balkan beech which is the most represented species. This author considers Balkan beech (*Fagus moesiaca* Domin, Maly/Czeczott.), as a separate species in the region of the Balkan Peninsula and Serbia.

Balkan beech was first described as a separate taxon by Josef Karel Malý in 1911. The description of this taxon was later completed by Czeczott (1933). Opinions regarding the taxonomical status of this taxon varied. Frequently, it is described as a separate unit (Czeczott 1933, Fukarek 1954). Mišić (1957) considers it a phylogenetical link between *F. sylvatica* and *F. orientalis*. Sometimes it is considered a hybrid between both species morphologically closer to *F. sylvatica* (Becker 1981), a mixture of *F. sylvatica* and *F. orientalis* with the occurrence of transition forms dominated by characters of one of the two species (Stoyanoff 1932), an ecotype (Staňescu 1979) or identical with the Crimean beech *Fagus taurica* Popl. (Didukh 1992).

The morphological description of "*F. moesiaca*" is rather vague. There is no agreement among different authors about the morphological traits discriminating between the Balkan and European

and/or Eastern beech. For most characters, the mean values are different but the ranges of variation overlap considerably. In comparison with pure *F. sylvatica*, *"F. moesiaca"* has larger leaves with more lateral veins, larger beechnuts and longer cupule peduncle (Czeczott 1933, Mišić 1957, Staňescu 1979). In addition to the morphology, *"F. moesiaca"* differs from *F. sylvatica* by a high sprouting capacity and a considerably higher frequency of seed years, as well as ecological requirements (Mišić 1957).

Furthermore, the description of the distribution range of Balkan beech is not unequivocal. The main part of the range seems to be the former Yugoslavia (Bosnia, Serbia, Montenegro, Macedonia), Albania, Bulgaria and Greece (Fukarek 1954, Mišić 1957), but isolated occurrences have been reported from south-eastern Rumania, Hungary and even Poland and the former Czechoslovakia (Karpáti ex Fukarek 1954, Staňescu 1979). Croatian and Slovenian populations are generally considered *F. sylvatica*. European beech belongs to those forest tree species whose genetic variation has been very thoroughly documented within the majority of its range employing isozyme markers. However, the data for Balkan beech are scarce, especially for our main area of interest, i. e. the southern Balkans, and for Eastern beech they are practically missing. Comps et al. (1991) investigated beechwoods from the continental and Mediterranean parts of Croatia, and reported the presence of differences between these two regions. Data from Balkan countries were also included in a wide study of beechwoods in Central Europe (Comps et al. 1990), but the data from Serbia, Bulgaria and the Romanian Carpathians were pooled, so that no differentiation patterns within this large area could be identified. Recently, a study focusing on this region was published by Hazler et al. (1997). Although there is a gap in their material between Macedonia and Croatia, a north-west to south-east cline can be identified in their presentation of PCA results. In all these reports, beech in this region was denoted as *Fagus sylvatica* L.

The final question to be solved is the taxonomical status of Balkan beech. Unfortunately, the criteria for distinguishing species in the plant kingdom are very vague. The populations in this region can be distinguished from the remaining common beech by morphology, and they are genetically differentiated, so that they can be considered a separate taxon. Nevertheless, the rank of a separate species seems to be too high. There are other beechwoods, e. g. in Calabria, which are even more differentiated, but they are denoted as *F. sylvatica*. Therefore, the rank of a subspecies appears to be more appropriate for Balkan beech (Gömöry et al. 1999).

MORPHOLOGY

Balkan beech is a deciduous tree capable of reaching a height up to 30 (45) m, a diameter of 2 m, and a lifespan up to 300 years. It has a dense crown, which is spherical in isolation, and reduced in stand conditions. Its root system is variable, shallow to medium deep, with well-developed lateral roots. Its bark is whitish-grey and smooth.

It has thin twigs and long shoots with alternately arranged buds and leaves in two rows. The buds are long, spindle-shaped, prominently long, pointed. Bud scales are brown, naked and glossy. Balkan beech leaves grown in sunlight (resembling *F. sylvatica* leaves) differ from the leaves grown in the shade (which are similar to the leaves of *F. orientalis*). Sun leaves are smaller, thicker, ovate (elliptic), and shade leaves are larger, thinner, obovate with a wedge shaped base (elongated) with 5 – 12, most often 9 pairs of veins. The leaves are entire, sometimes crenate, sparsely toothed, with bristles.

Flowers are unisexual. Staminate flowers appear on the shoots hanging on peduncles in globular inflorescences. Perigon parts are shorter and broader than in *Fagus sylvatica* L. Female flowers, two per cupule, are on the upper end of strong shoots. Male and female flowers occur in two-flowered dichasia. The flowers appear simultaneous with the leaves in April or May. Beechnuts, 1.3 – 1.8 cm long, are borne in pairs in each cupule. Cupules are formed by fusing numerous scaly stipules (bracts), 13 – 35 mm long, split in the upper part, with four valves. Stipules are variable, leaflike-wide (as in *F. orientalis*) or thread-like narrow (as in *F. sylvatica*). Beech nuts are brown, triangular, containing usually one, rarely two seeds. They mature in the autumn from September through November, when they fall (Jovanović, Cvjetićanin 2005).

VARIABILITY

In Serbia, Balkan beech has three ecological races, four varieties and two forms. Near the lake Vlasinsko Jezero (altitude about 1,300 m) there is a beech tree with golden-yellow leaves, which is designated as a special variety *Fagus moesiaca* (Maly) Czecz. var. *aurea* Obrad. 1892 Em Jov. It was used for the cultivar 'Zlatia' which is cultivated in parks and botanical gardens in Europe.

In the study of beech variability and ecology of the former Yugoslavia, in the area of Serbia, Mišić (1957) describes Balkan beech as a separate species and distinguishes three ecological races:

1. *Fagus moesiaca* (Domin, Maly) *brevipedunculata*;
2. *Fagus moesiaca* (Domin, Maly) *macrocarpa*;
3. *Fagus moesiaca* (Domin, Maly) *longipedunculata*.

He further reports that "... three separate races occupy predominantly three altitudinal belts of our mountains, forming specific altitudinal regional associations. On some lower mountains, there is only one race – *macrocarpa*, because the boundaries of some vegetation belts are moved downwards, due to specific climate effects. At the particular sites there are individual trees or small groups of trees, which by some characteristics resemble one race, and by other characteristics – another race. They are transitory or hybrid forms. All three beech races have approximately equal alternation of seed years. The statistically determined differences are not equal in all the studied characteristics of the three races. The two oldest taxonomic forms of beech in Serbia are *macrocarpa* and *brevipedunculata*, and they exhibit the slightest differences. There is a series of transitory populations among the three altitudinal races regardless of the substantial differences in the majority of morphological characteristics among individual races. All the above shows that the races are not completely differentiated, formed and stabilised.

Within the race *brevipedunculata* Mišić (1957) distinguishes the variety *rotundicarpa* in the ravines, and the variety *microcarpa* on the prominent ridges. Beech with quercoid bark (*Fagus moesiaca* var. *quercoides*) was described in Serbia by Tucović et Jovanović (1964). On the mountain Golija, there is a beech stand on acid siliceous bedrock, in which bark colour is very similar to that of white-bark pine. The new form of beech was named *Fagus moesiaca* (D. M.) Cz. *leucodermis* by Korać (1974). The Balkan beech form with pendulous branches (*Fagus moesiaca* /Domin, Maly/ Czecz. f. *pendula* /Dum-Cour./ Lodd.) on Šar Planina was described by Ostojić et Dimović (1999).

DISTRIBUTION, FOREST COMMUNITIES AND ECOLOGICAL CONDITIONS

Total area under forests in Serbia is 2,412,940 ha. Beech is the dominant species (50.4% by volume) with a wide range of vertical distribution, occurring in a great number of forest types, in different structural forms, in pure or mixed stands, of different origin, on different sites.

Although the question of the ranges of European beech (*Fagus sylvatica* L.), Balkan beech (*Fagus moesiaca* Domin, Maly/Czeczott.) and Oriental beech (*Fagus orientalis* Lipsky) in Serbia has not been completely resolved, as they are often mixed and occur together in this area, all beech stands in Serbia are treated as Balkan beech forests and are studied and described as such.

Beech forests in Serbia occur in the form of special altitudinal belts, at the altitudes between 40 m in the Đerdap area and 2,100 m on Mt. Prokletije. The beech altitudinal zone is divided into four beech altitudinal belts: submontane beech forests (*Fagenion moesiacae submontanum*), montane beech forests (*Fagenion moesiacae montanum*), beech and fir forests (*Abieti-Fagetum*) and subalpine beech forests (*Fagenion moesiacae subalpinum*). Submontane beech forests grow in oak altitudinal belt, and above it beech forms a climate-regional vegetation belt. The characteristic of beech forest belt (altitudinal range) in Serbia is the migration to the higher altitudes going from the north to the south, both of the lower and the upper boundaries of distribution. The lower boundary in the north part is at the altitude of about (40) 250 m (Northeast Serbia), and in the south, about 600 – 800 m (Suva Planina, Kopaonik). The identical phenomenon also occurs on the upper boundary of this belt, which is in Northeast Serbia about 1,100 m, and on Kopaonik and Suva Planina about (1,300) 1,800 m (Krstić 2005).

Syntaxonomically, beech forests in Serbia belong to the class of Eurosiberian deciduous forests (*Querco-Fagetea* Br.-Bl. et Vlieg 1973), order – beech forest (*Fagetalia sylvaticae* Pawl. 1928), suborder – forest of Balkan beech (*Fagenalia moesiacae* B. Jov. 1986), and to the alliance of Balkan beech forests (*Fagion moesiacae* Bleč. et Lak. 1970). This alliance is divided into seven suballiances, four of which are designated by altitudes, and three are based on the edaphic differences (Jovanović, Cvjetićanin 2005).

The dominant soil types characterize not only the edaphically conditioned coenoses of beech forests, but also the orographically conditioned coenoses. Based on the criteria of Soil Classification (Škorić, Filipovski, Čirić 1985), the 10 main soil types in beech forests are divided into four classes: undeveloped (diluvium), humus-accumulating (rendzina, black earth on limestone and ranker), cambic (acid brown soil, eutric brown soil and brown soil on limestone) and eluvial-illuvial soils (illimerized, brown podzolic, and podzol). The soils are formed on different parent rocks, such as all types of eruptive and metamorphic rocks and several types of sedimentary rocks (Knežević, Košanin 2005).

The range of beech forests in Serbia is characterized by two types of regional climate: the drier continental climate and the colder, more humid mountainous climate. The elements of regional climate are under a strong local impact. Regarding air temperature, beech belongs to the ecological group of mesothermal plants, which grow best on the sites with moderate temperatures, and the extreme temperatures can be harmful and can lead to tree damage or death. Regarding mean annual relative humidity, Balkan beech has a wider ecological range (65 – 80%) than European beech (75 – 85%) and Oriental beech (70 – 80%) (Krstić 2005).

THE STATE AND FOREST MANAGEMENT SYSTEM

Beech is the dominant species in the growing stock in Serbia (50.4% per volume). The percentage of beech forests in the total area of state forests in central Serbia is 47.11%, the percentage of mixed forests of beech and fir, and beech, fir and spruce is 4.03%. Regarding the origin, high forests occupy 69.3%, coppice forests 29.8%, brushland 0.7%, and degraded forests used for fodder 0.2%. The area of degraded and destroyed forests in beech forests is 28,279 ha (7.6%) (Medarević et al. 2005).

The average volume in beech forests is 217 $m^3.ha^{-1}$, average current volume increment is 4.55 $m^3.ha^{-1}$; the average volume in mixed forests of beech and fir is 308 $m^3.ha^{-1}$, volume increment is 6.95 $m^3.ha^{-1}$; the volume in mixed forests of beech, fir and spruce is 353 $m^3.ha^{-1}$, volume increment 8.24 $m^3.ha^{-1}$. The average volume in high forests is 255 $m^3.ha^{-1}$, volume increment 5.04 $m^3.ha^{-1}$; the average volume in coppice forests is 166 $m^3.ha^{-1}$, average volume increment 4.30 $m^3.ha^{-1}$. Regarding the average volume and volume increment in high forests, only about 85% of the total production potential are used, and in coppice forests, about 65% of the production potential are used (Medarević et al. 2005).

Beech forests are classified into 35 specific purpose entities, in which 18 special objectives of management have been defined. Production forests occupy 277,315 ha or 74.40% of the total area of beech growing stock. Protection forests cover 18.48% and national parks 7.12% (Medarević et al. 2005).

The main characteristics of forest management systems applied in beech forests, according to Milin (1988), can be defined as: shelterwood management system characterized by seed tree felling or shelterwood felling with three cuts (preparatory, regeneration and removal cut) which are performed during the regeneration period; selection management system characterized by selection cutting, in which the trees which reached the target diameter are cut, and of the smaller diameter trees only those that should be removed because of silvicultural reasons; and group selection management system characterized by silvicultural groups which are not defined by the size of the area, but by the homogeneity of stand conditions, the basic silvicultural requirement and the respective basic silvicultural operation.

THE MOST FREQUENT PHYTOPATHOLOGICAL AND INSECT DAMAGES

In the research of parasitic and saprophytic mycoflora in beech high and coppice forests in Serbia, 147 species of fungi have been identified on beech trees, of which 33 species occur on cupules, fruits and seedlings, 56 species on foliage and bark of branches and stems, and 58 species are wood rotting and sap stain fungi. The most harmful disease agents are *Nectria* species (*coccinea, ditissima, galligena*), and somewhat less harmful are the fungi *Phytophthora cactorum* (Leb. et Cohn) Schr., *Apiognomonia errabunda* (Rob. ex Desm.) Hohnel, *Cytospora* spp., *Diatrypella verruciformis* (Her. ex Fr.) Nits., *Melanconium stromaticum* Corda and *Stilbospora angustata* Pers. The fungus *Nectria coccinea*, together with the insect from fam. Eriococcidae *Cryptococcus fagisuga* Lind., causes the so-called beech bark disease. Of the 58 fungi species which infest wood, 48 species destroy beech wood (i. e. cause wood decay), four species cause sap stain, and six species are secondary pests and therefore they have not a practical significance. Among wood rotting fungi, the greatest economic damage is caused by fam. Polyporaceae *Fomes fomentarius* (L. ex Fr.) Fr. and *Hypoxylon deustum* (Hoffm. ex Fr.) Grev. and, somewhat less, by *Armillaria mellea* s. l. (Vahl. ex Fr.) Karst., *Bjerkandera adusta*

(Willd. ex Fr.) Karst., *Fomitopsis pinicola* (Sov. ex Fr.) Karst., *Ganoderma applanatum* (Pers. ex Wallr.) Pat., *Pholiota adipose* (Fr.) Kumm., *Pleurotus ostreatus* (Jacq. ex Fr.) Kumm., *Polyporus squamosus* (Huds.) Fr. and *Trametes hirsuta* (Wulf. ex Fr.) Pil. These fungi infest live trees, and continue the destruction of wood after tree felling (i. e. on the dead wood) (Karadžić, Milijašević 2005).

In beech stands in Serbia, a total of 142 phytophagous insect species have been identified to date. Of the total number of insect pest species, 93 species or 65.5% are primary pests, nine species or 6.4% are secondary pests, 17 or 11.9% are tertiary, and five species or 3.5% are quaternary pests. Six species or 4.2% are very significant pests of beech, of which three (*Phyllaphis fagi* L. from Aphidae, *Cryptococcus fagisuga* Lind. from Eriococcidae, and *Rhynchaenus fagi* L. from Curculionidae) are oligophagous and specific for beech, and the other three butterflies (*Lymantria dispar* L. from *Lymantridae, Operophtera brumata* Hbn. and *Erannis defoliaria* L. from Geometridae) are wide polyphages and during mass outbreaks they also cause damage to beech stands (Mihajlović 2005).

GENE POOL CONSERVATION

The main characteristic of beech gene pool in Serbia is the high individual and group variability of numerous morphological and genetic-physiological traits, which resulted in numerous intraspecific taxa recorded in this area. Taking into account the beech domination in the growing stock of Serbia, its wide range of horizontal and vertical distribution, its presence in a great number of types of forest communities, the conservation of its gene pool should be performed on the original sites (*in situ* conservation), aiming at the conservation of the adaptable potential of the species (dynamic gene conservation). This means the selection of the superior natural populations, the revision of the existing ones and the designation of the new seed forests, groups or individual trees. Also, conservation can be done in artificially established *ex situ* sites, such as provenance tests, archives, clonal or seedling seed orchards.

To enhance the production of good-quality reproductive material, and as a form of gene pool conservation, 19 seed stands have been designated to date in Serbia, total area 137.57 ha. The spatial distribution of the designated seed stands covers almost completely its coenological, ecological and population diversity.

The Law on Reproductive Material of Forest Trees adopted in 2005 defined clearly the production of reproductive material at the level of provenance regions, which resulted in the designation of five beech provenance regions in Serbia.

The degree of variability and the potential of different beech provenances in the juvenile stage of development were assessed in the framework of the project "Conservation and directed utilisation of beech gene pool in Serbia" which was financed by the Ministry of Agriculture, Forestry and Water Management in the period 2004 – 2006 (Šijačić-Nikolić et al. 2006, 2007, Šijačić-Nikolić, Milovanović, Knežević 2006).

During the 1980s in Serbia, 74 beech test trees (plus trees) were designated, and the clonal progeny has been obtained from 64 trees to date. A high degree of rooting of up to 90 to 100% was achieved by autovegetative propagation of beech by aerial rooted cuttings, using growth stimulators such as β-indole butyric acid in concentrations 0.5, 1.0 and 2.0%. Two live archives of beech (Belgrade

and Beočin) were established by propagated vegetative copies, as the basis of the collection of secondary scions and further vegetative reproduction of plus trees. A beech clonal seed orchard was established by planting grafts of 30 clones in the Arboretum «Šuplja Stena» on Mt. Avala near Belgrade (Jovanović 1971).

Within the last series of European provenance tests in 2007, funded by the Ministry of Agriculture, Forestry and Water Management RS, two provenance tests were established in Serbia: one on Mt. Fruška Gora and the other in the Faculty of Forestry Teaching Centre at Debeli lug. The above tests were established from two- and three-year old seedlings of 24 European provenances. The experiment established on Fruška Gora is situated in FMU 3804 Popovica-Majdan-Zmajevac, compartment 29f, managed by NP "Fruška Gora". It is characterized by Northwest aspect, altitude 350 – 380 m, area 1 ha, with sample plot area 0.4 ha, on acid brown to lessivé acid brown soil, slope 11 – 15°. The Faculty of Forestry site "Pripor-Felješana" at Debeli lug is at the altitude of 742 m, east aspect, ridge of uniform slope, on humus-siliceous soil, with humid continental climate.

The monitoring of the development and phenology of the represented provenances started during 2008, within the project "Research of forest tree genetic potential within the network of European provenance tests" funded by the Ministry of Agriculture, Forestry and Water Management of Republic of Serbia.

Fig. 1: Location Debeli lug, Serbia, photo Mirjana Šijačić Nikolić, 2008

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Reviewed

Contacts:

Prof. dr. Mirjana Šijačić-Nikolić
Faculty of Forestry, University of Belgrade
Kneza Višeslava 1, 11030 Belgrade, Republic of Serbia
tel. + 381 11 3053873
e-mail: sijacic68@open.telekom.rs

Prof. dr. Saša Orlović
University of Novi Sad, Institute of Lowland Forestry and Environment
Antona Čehova 13, 21000 Novi Sad, Republic of Serbia
e-mail: sasa.orlovic@minpolj.sr.gov.yu

EUROPEAN BEECH (*FAGUS SYLVATICA* L.) GENETIC RESOURCES IN SLOVAKIA

Dušan Gömöry[1] – Ladislav Paule[1] – Roman Longauer[2]

[1] Technical University in Zvolen, Faculty of Forestry, T. G. Masaryka 24, SK-96053 Zvolen, Slovakia
[2] National Forestry Centre, T. G. Masaryka 22, SK-96092 Zvolen, Slovakia

ABSTRACT

The study gives an overview of the current state of European beech (*Fagus sylvatica* L.) and its genetic resources in Slovakia. Basic information about the horizontal and vertical distribution, representation in forest stands, plant communities and management of beech stands is provided, along with an overview on the sources of forest reproductive material and gene conservation measures. Past and recent research activities on the field of beech genetics are also mentioned.

Key words: European beech (*Fagus sylvatica* L.), European beech, buk lesný (in Slovak), distribution range, gene-pool conservation, forest reproductive material, Slovakia

DISTRIBUTION OF EUROPEAN BEECH IN SLOVAKIA

Slovakia with the proportion of forested land of 41% belongs to the most forested countries of Europe. The total area of forests is 1,932,900 ha, the average standing stock is 232 $m^3.ha^{-1}$.

Beech is one of the most important forest tree species in Slovakia. It is the most widespread one, sharing 31.2% of the present tree species composition (Ministry of Agriculture 2008), whereby this share is quite stable over the last 60 years or more. The natural range covers almost the whole country from the Small Carpathians in the west to the Poloniny Mts. in the east, with the exception of lowlands (Zahorie, Danube and East-Slovakian lowlands), river valleys, dry karst plains of southeastern Slovakia, and subalpine and alpine environments. Beech is also absent at the southern slopes of the Tatra Mts. even at lower elevations. However, in several regions the share of beech in the tree species composition was severely reduced during the last centuries, when indigenous broadleaved and mixed forests were replaced by conifer (mainly spruce) monocultures (Upper-Hron valley in Central Slovakia, Orava and Kysuce regions in the northwest).

Generally, continuous distribution of beechwoods is limited by approx. 330 m and 1,200 m a. s. l. However, sporadic occurrence of beech has been reported at the elevations of 120 m in the Burda Mts. in the southwest and at 180 m in the Vihorlat Mts., in eastern Slovakia; on the upper limit, beech climbs up to 1,480 m a. s. l. in the Low Tatra Mts. (Blattný, Šťastný 1959). In several mountain ranges such as the Velka Fatra Mts. or Poloniny Mts., where summits were deforested during the Wallachian colonization in the 16th century to obtain pastures for sheep, beech forms an artificial upper forest limit. Although no true krummholz beech stands are found in Slovakia, in several mountains stand height is severely reduced at sites exposed to wind and low temperatures.

Because of its high share in the tree species composition, beech is represented in many primeval forest remnants (56 out of 74 forest national nature reserves, whereas in 36 it is a dominant species, cf. Korpeľ 1989). Four virgin forests (Stužica, Havešová, Rožok, Kyjov), together with the Ukrainian beech reserves, have been recorded since July 28, 2007, in the UNESCO World Natural Heritage list.

BEECH COMMUNITIES

In Slovakia, beech occurs naturally in six out of eight vertical forest vegetation zones, from the 2nd up to the 7th. The optimum for beech constitutes the 4th vegetation zone, where even natural pure beechwoods occur. However, beech is naturally represented in most forest plant communities of Slovakia, covering almost 90% of the forest area (Table 1). At low elevations, beech occurs in the mixture with sessile oak and hornbeam. In the optimum, beech forms dense pure stands with a very poor herb layer (communities *Fagetum pauper*) or communities with the occurrence of typical beechwood species such as *Galium odoratum*, *Dentaria bulbifera*, *Galeobdolon luteum* or *Asarum europaeum* (*Fagetum typicum*). With increasing altitude, silver fir and Norway spruce become admixed; this so-called "Carpathian mixture" represents the most productive forests of Central Europe (typical representatives can be found in nature reserves Dobroč or Hrončecký Grúň, where beech reaches heights up to 47 m (Holeksa et al. 2009). On sites with a rapid nitrogen turnover, beech is mixed with sycamore, common ash, mountain elm and linden, on rocky sites with Scots pine and European larch.

The most common soil types in Slovak beechwoods are cambisols. However, beech is able to survive and compete on a broad variety of soil types from podzols over andosols on volcanic bedrock up to rankers and rendzinas on carbonate rocks, on the other hand it avoids heavy soils on loess. The distribution of beech communities according to the CORINE classification including the

Tab. 1: Review of the phytosociological units (groups of forest types sensu Zlatník) containing beech (Randuška, Vorel, Plíva 1986)

Typological unit	Vegetation zone	Share (%)
Fagetum quercinum	2	2.70
Fageto-Quercetum	2	15.53
Querceto-Fagetum	3	8.40
Fagetum pauper	4	18.25
Fagetum typicum	4	3.80
Fagetum dealpinum	4	4.00
Abieto-Fagetum	5	11.50
Fageto-Abietum	6	9.20
Fageto-Aceretum	6	3.50
Fagetum abietino-piceosum	6	5.50
Remaining communities		6.85
Total		89.23

corresponding typological units can be found on the webside of the National Forestry Centre (http://www.forestportal.sk/ForestPortal/).

MANAGEMENT OF BEECH STANDS

Beech is an important commercial tree species, but primarily it is considered a stabilizing element of forest stands. It is reflected also in the health state: beech is generally considered resistant to native pests and pathogens, the mean defoliation degree on a 0 to 4 scale is 0.86 compared to 1.36 in the case of Norway spruce. Therefore, it is not an object of intensive breeding, but much more emphasis is given to the preservation of its adaptedness and ecological stability through the gene-pool conservation of the existing indigenous populations. Natural regeneration is generally considered the best tool for fulfilling these tasks. Therefore, silvicultural systems based on natural regeneration have traditionally been applied in beech forests. A tendency towards forest management close to nature is declared and reported in Green Reports of the Ministry of Agriculture. Officially, the share of clearcuts in the forests of Slovakia decreased from 85% in 1990 to 32% in 2007. However, the reality may deviate from official declarations, with an increasing use of heavy mechanization, there is a shift from shelterwood group cuttings towards logging schemes allowing higher logging concentration such as strip felling, and even small-scale clearcuts are sometimes applied also in beechwoods. This is also documented by the extent of natural regeneration: although it increased from 18% in 1990 to 34% in 2007, it does not correspond to the declared decrease of clearcuts.

Beech mostly grows in high forests, beech coppices are exceptional. Generally, the proportion of coppices is very low in Slovakia, being 1.82% in 2007, and the majority of these are oak and hornbeam stands.

As mentioned, the actual proportion of beech is over 31%, but the share on potential natural forest vegetation is much higher, 48%. A long-term target is increasing this proportion to approx. 36%. The average age of beech stands is 71 years, whereby a shift towards a higher representation of older age classes has been observed in recent years. The current annual increment amounts to 5.97 $m^3.ha^{-1}$.

FOREST REPRODUCTIVE MATERIAL AND GENE POOL CONSERVATION

The reconstruction of a more natural tree species composition is hardly possible without extensive reforestation. This is an up-to-date topic mainly in the Kysuce region where conifer plantations, declining today, had replaced natural stands, and a reconstruction of a more natural tree species composition is under way. As very few beech stands remained in this area, finding appropriate seed sources is a difficult task.

In Slovakia, the problems of the biological quality of forest reproductive material have been legally regulated since 1939. At present, there are two legislative norms in this field: the Act no. 217/2004 on Forest Reproductive Material, and the Decree no. 571/2004 on the Sources of Forest Reproductive Material, its Procurement, Production and Use, elaborating detailed rules of procuring and transfer of Forest Reproductive Material (FRM). Both legal norms implemented the rules set by the OECD Scheme and the EU Directive 105/1999/EC. A revision of the legislation is just under preparation, but the basic principles will not be probably changed. In general, reproductive material for forestry

purposes is allowed to be procured only from the sources explicitly given by the law (even in the case when it is collected for own use) and the transfer is also strictly regulated.

Currently, 38 plus trees were selected for beech (out of 4,278 in total). The main source of beech seeds are approved seed stands of two categories: there are 2,342 ha of category A stands and 23,007 ha of category B stands, representing 41% of the approved stands area. Moreover, there are 184 ha of so-called seed stands, which are reproductive plantations established from the material originating from category A approved stands, i. e. serving for the preservation of gene pools of the most valuable stands *ex situ*. There are neither seed orchards nor tested basic material of beech in Slovakia. The use of reproductive material of the category "identified" must be approved by the Ministry of Agriculture and is allowed only when no suitable material of higher categories is available.

Concerning the transfer of FRM, the territory of the country is divided into five provenance regions, out of which three are located within the natural distribution range. Although it is not explicitly stated in the legislative norms, for provenance regions situated within the natural range, transfer is allowed only within a region. Moreover, the decree defines altitudinal zones of 200 m; transfer is allowed only within a zone or into the neighbouring zones. In practice, however, these rules are frequently not followed by foresters and nursery managers. The working capacities of the responsible authority, which is the Centre for the Control of FRM in Liptovský Hrádok, belonging to the National Forestry Centre, are limited, and the attention is primarily paid to conifer species, so that the collection of beech seeds or seedlings from the understorey is rarely supervised by the regional inspectors of the Centre.

Gene reserves as spatially continuous complexes of predominantly indigenous forest stands of more than 100 ha with a balanced age structure can also serve as sources of FRM and are specifically destined for gene conservation *in situ*. At present, there are 18 gene reserves declared only for beech with a total area of 5,017 ha. Moreover, beech is represented in further 24 gene reserves with a total area of 5,480 ha, where its average share is 67.6%.

The supply of beech seeds is variable. Most seeds of forest tree species are processed and stored centrally in a specialized branch of the state forest enterprise Lesy SR (OZ Semenoles, Liptovský Hrádok). The optimum supply of beechnuts, estimated at 56,000 kg, was exceeded only after a mast year in 2006, otherwise there is a permanent deficit in beech seeds. No beechnuts are stored in the gene bank, which is also managed by OZ Semenoles.

During the last ten years, the amount of beech plants in forest nurseries oscillated around 40 millions seedlings and plants of different ages, out of which approximately 15 millions are used for reforestation. Most frequently, bareroot 2-year-old seedlings are used for planting (~4 million of plants), followed by 3-year-old seedlings (~3.5 millions of plants), containerized seedlings are less frequently used with beech. The amount of plants transplanted after one or two years (mostly bareroot) is approx. 6 million of plants.

RESEARCH ACTIVITIES

Provenance research of beech in Slovakia started in the 1960s by establishing a small initial trial with only three provenances (Balkovič 1965). Later, in 1972, a larger provenance experiment with 20 Slovak beech provenances was established on a site at School Forest Enterprise of the University College of Forestry and Wood Technology in Zvolen, which was later evaluated by Paule (1982). The

assessments of both trials focused on height and diameter growth and its seasonal dynamics, as well as spring phenology.

Large-scale exploration of the genetic variation of European beechwoods employing allozyme markers started in the late 1980s in cooperation between the Faculty of Forestry in Zvolen and the team of B. Comps at the University of Bordeaux, later it continued by own activities supported by several successive grants of the Slovak Grant Agency for Science. Within these projects, almost 300 populations covering the whole distribution range of *Fagus orientalis* and the whole eastern half of the range of *F. sylvatica* were analyzed, demonstrating rangewide as well as regional trends and patterns of genetic diversity and differentiation in western-Eurasian beech taxa (Gömöry, Paule, Vyšný 2007).

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Reviewed

Contacts

Doc. Ing. Dušan Gömöry, DrSc., Prof. Ing. Ladislav Paule, PhD.
Technical University in Zvolen, Faculty of Forestry
T. G. Masaryka 24, SK-96053 Zvolen, Slovakia
e-mail: gomory@vsld.tuzvo.sk, paule@vsld.tuzvo.sk

CURRENT STATE OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) GENE POOL IN SLOVENIA

Gregor Božič – Lado Kutnar – Mihej Urbančnič – Dušan Jurc – Andrej Kobler – Tine Grebenc – Hojka Kraigher

Slovenian Forestry Institute, Večna pot 2, 1000 Ljubljana, Slovenia

ABSTRACT

In Slovenia European beech is autochthonous and the most economically and ecologically important tree species. The paper presents the characteristics of Slovenian beech forests regarding their natural distribution range, diversity of beech forest types and site conditions, sustainable co-nature-based management and gene pool conservation. New information about observed beech injuries and future perspectives of beech forests in the territory of Slovenia according to predicted climate changes are included. The mesic beech-forest vegetation may be adversely affected by changing environmental conditions predicted by the existing climate-change scenarios, and the area of prevailing beech forests is likely to decrease in the future.

Key words: *Fagus sylvatica* L., bukev (in Slovenian), natural distribution, forest types, genetic resources, Slovenia

EUROPEAN BEECH FORESTS DISTRIBUTION IN SLOVENIA

Slovenia belongs to one of the most forested countries in Europe. At the end of 2005 forests covered an area of 1,216,815 ha which represents 60% of the total country. According to Perko (2007), 70% of forests in Slovenia grow on potential beech (44%), fir-beech (15%) or beech-oak (11%) sites. According to palynology data (Culiberg 1994, 1999) the proportion of potential beech sites is probably higher, as records confirm that beech used to be more common in Sub-Mediterranean (Karst) region, where its current infrequency is associated with centuries-long anthropozoogenous influence (Dakskobler 2008).

European beech (*Fagus sylvatica* L.) is among 71 naturally growing trees in Slovenia (Kotar, Brus 1999). The highest area of growing stock has the following tree species: *Fagus sylvatica* L. (32%), *Picea abies* (L.) Karst. (32%), *Abies alba* Mill. (8%) and different species of *Quercus* sp. (7%) (Lesnik, Matijašić 2006).

Beech covers a major part of the forested area of the country and occurs mainly in the montane zone. From the hilly zone, where many mixed forests of sessile oak (*Quercus petraea* /Matt./ Liebl.) and hornbeam (*Carpinus betulus* L.) have been converted to farmland, to montane zone these mixed forests change gradually into forests, in which beech dominates. In the Alpine region, beech grows in mixture with Norway spruce (*Picea abies* /L./ Karst.), and European larch (*Larix decidua* Mill.), while pure beech forests reach up to the higher belt of the dwarf mountain pine zone (*Pinus mugo* Turra) in the Dinarics. In the Dinaric region, the mixed forest of beech and silver fir (*Abies alba* Mill.) is the most wide spread forest community.

In Slovenian forests diverse vegetation patterns have been recognized (Zupančič 1996). The most important beech forests as regards surface area, their size, economic value and protective and biotopic roles are listed below (Dakskobler 2008). Beech forests on acid (dystric) soil are found under the following: acidophilic beech forest with hard fern (*Blechno-Fagetum*), moderately acidophilic beech forest with chestnut (*Castaneo-Fagetum sylvaticae*), and moderately acidophilic beech forest with white wood-rush (*Luzulo-Fagetum*). In the hilly areas and submontane altitudinal belt the following forest communities on calcareous or calcareous-silicate bedrocks are commonly found: submontane beech forest with pyrenees star-of-Bethlehem (*Ornithogalo pyrenaici-Fagetum*), submontane beech forest with hacquetia (*Hacquetio-Fagetum*), beech and sessile oak forest with ivy (*Hedero-Fagetum*), and subpanonic beech forest with vetch (*Vicio oroboidi-Fagetum*). In the montane and altimontane belt the most extended beech forests are montane beech forest in association with dead nettle (*Lamio orvalae-Fagetum*), beech forest with goatsbeard (*Arunco-Fagetum*), the Dinaric montane fir and beech forest (*Omphalodo-Fagetum*), high-montane beech forest with bitter-cress (*Cardamini savensi-Fagetum*), high-montane beech forest with rue-leaved isopyrum (*Isopyro-Fagetum*), and beech forest with hairy alpine-rose (*Rhododendro hirsuti-Fagetum*). On warmer sites in the submontane and montane belt, beech occurs in termophilic beech and hop-hornbeam forest (*Ostryo-Fagetum*) and beech forest with autumn moor grass (*Seslerio autumnalis-Fagetum*). In the altimontane and subalpine belt predominantly in the Alps, beech occurs in the alpine beech forest (*Anemono trifoliae-Fagetum*), fir and beech forests with homogyne (*Homogyno sylvestris-Fagetum*), altimontane beech forest with large white buttercup (*Ranunculo platanifolii-Fagetum*), and subalpine beech forest with holly-fern (*Polysticho lonchitis-Fagetum*).

Forest stands of all listed communities are part of the habitat types in EU Community interest (Habitat Directive 1992). Surface distribution of beech communities in Slovenia can be found in two vegetation maps in scale 1: 100,000 (Košir et al. 1974, 2003), and in scale 1:400,000 (Čarni et al. 2002).

CHARACTERISTICS AND FOREST MANAGEMENT

European beech in Slovenia grows and forms communities in all phytogeographical regions (Wraber 1969), on all terrain positions and slope orientations, on calcareous, silicate and mixed calcareous-silicate bedrock. It occurs on different soil types: lithosols, regosols, rendzinas, rankers, brown soils on limestones and dolomites, eutric and distric brown soils, lessivé soils, podzols, semipodzols and pseudogleys (Urbančič et al. 2005), from hills (150 m a. s. l.) to the subalpine belt (1,650 m a. s. l.) (Dakskobler 2008).

According to the international soil classification (WRB 2006) different soil groups with soil subunits were determined on beech sites. Fir-beech forests and beech forests on carbonate parent material (as limestones, dolomites, marls, flyschs etc.) mostly overgrow Leptosols, Phaeozems, Cambisols and/or Luvisols with eutric to calcaric properties. For beech-oak forests Luvisols on limestones and dolomites are characteristic. Acidophilic beech forests mostly cover Leptosols, Umbrisols, Cambisols, Alisols and/or Acrisols with dystric properties developed on non-carbonate parent material.

Special beech sites can be rarely found also on folic Histosols (high mountains), Regosols (eroding areas, unconsolided material), Podzols (bases poor siliceous parent material, in areas with high precipitations) or Planosols (on clayey sites).

In the Alpine and Dinaric high mountain belt (alpine vegetation belt), in cold air pools (frost hollows), in lowlands on hydromorphic soil, and on steep, stony, rocky or explicitly sunny and warm sites in

the Sub-Mediterranean and in the hinterland, the climatic and soil conditions are mainly unsuitable for beech.

Forests as a renewable natural resource with their multiple roles are ranked among the country natural wealth. Forestry is traditionally co-nature-based and oriented in sustainable and multifunctional management regardless of the ownership. Clearcuts are forbidden since 1947. Natural regeneration is promoted wherever possible. Renewal work with care for forest young components is carried out on 10,000 – 12,000 ha per annum. If seedlings are used, they should originate from known seed sources in Slovenian forests and from adequate tree species and provenances. Replanting with sowing and seedlings is carried out annually on ca 500 ha, mainly for implementation of the long-term ecological improvement (conversion) from spruce monocultures growing in natural beech or beech-silver fir sites to broadleaved forests. To achieve the conversion, a combination of natural and artificial regeneration starting as advanced planting is preferred (Diaci 2006). On average 130,000 beech seedlings from local provenances are planted annually. Tree seeds and seedlings are collected from officially approved selected seed stands or from the source identified seed stands in the Slovenian forests.

Managements regimes in beech forests are carried out with regard to the site, stand conditions and silviculture technique used (irregular shelterwood system, single tree selection system or group selection system). In managed beech forests only small-scale regeneration practices are applied. The regeneration is usually induced through diffuse opening in the canopy layer. The total growing stock for beech in 2005 was 95,486,453 m^3 (SFS, 2006). Beech is present in 89% (> 1 million ha) of total forested area. In 73% of the area (851,333 ha) its presence in growing stock is more than 5%. Annual harvesting of beech in 2005 was 795,470 m^3, representing 66.1% of total yearly felling of broadleaved tree species in Slovenia and 24.6% of total amount of all trees harvested. Long-term monitoring revealed a 15.8% average level of defoliation of beech in the years 1993 – 2005.

In 2008 the prices of non coniferous roundwood in Slovenia (fco. forest road) were for sawlogs (beech) 63.60 EUR/m^3, pulpwood, round and split 32.56 EUR/m^3, other industrial roundwood 37.32 EUR/m^3, wood fuel 32.60 EUR/m^3 (Statistical Office of the Republic of Slovenia; http://www.stat.si).

Legislation in regards to forestry includes the Forest Act (UL RS, no. 30/93, 13/98, 56/99, 67/02, 110/02, 112/06, 115/06, 110/07) and the Act on Forest Reproductive Material (ULRS, no. 58/02, 85/02), which was based on the Directive on the marketing of forest reproductive material (1999/105/EC). Supporting documents: three regulations, 19 rules and two other legally documents are valid (http://www.mkgp.gov.si).

BEECH DISEASES AND PESTS

In Slovenia, sanitary felling of beech comprised 1,021,000 m^3 in the period 1995 – 2006, which represents 9.9% of all sanitary felling and 3.1% of total felling in this period (Timber, ZGS). The highest percentage in the sanitary felling of beech was due to sleet damages (46%), forest operation damages (18.8%), wind throw (14.2%) and snow (11.5%). Diseases of beech were the cause of 4.6% of sanitary felling while other damages (pests, game, pollution, unknown reasons) were the cause of 4.9% of sanitary felling.

In the last few years different symptoms of beech injuries and dieback were observed locally in Slovenian forests. With expected climate change harmful biotic factors are expected to intensify and extend over wider areas (Jurc 2007, Ogris, Jurc, Jurc 2008). Stands suffering from extreme dry and hot weather were more susceptible to *Armillaria* spp. and unusual cases of fast mycelial

spread in the cambial zone of seemingly healthy beech trees were observed. *Fomes fomentarius* (L.) J. J. Kickx, *Ganoderma* spp., and *Kretzschmaria deusta* (Hoffm.) P. M. D. Martin were frequent invaders of sun-burnt portions of the bark. Oportunistic pathogens as *Nectria coccinea* (Pers.) Fr., *Neonectria ditissima* (Tul. & C. Tul.) Samuels & Rossman and *Nectria cinnabarina* (Tode) Fr.) which are the cause of cankers and branch dieback appeared in a wider extent. In central part of Slovenia infrequent symptoms of *Phytophthora* infections occurred. Isolates in pure cultures were identified as *Phytophthora cambivora* (Petri) Buisman and *P. citricola* Sawada. At the edge of the beech area in Slovenia (E & W parts of the country) cases of massive top dieback of mature beech trees were observed. Bark of the trees was necrotized and some necrosis extended downwards to mid stem heights. On the dead bark numerous stromata of *Biscogniauxia nummularia* (Bull.) Kuntze developed. The trees were occasionally also attacked by beech bark beetle, *Taphrorychus bicolor* Herbst and beech splendour beetle, *Agrilus viridis* L., which, in these cases, were secondary pests. Some stands of beech showed attack of ambrosia beetle *Xyloterus domesticus* L. Although the number of entrance holes on a single trunk could be small, the sourrounding bark dies out in large oval necrosis. Wood degrading fungi spread relatively fast in wounded trunks causing rapid deterioration of their value. In recent years some outbreaks of leaf disease caused by endophytic fungus *Apiognomonia errabunda* (Roberge ex Desm.) Höhn. were also detected. The populations of primary pests reducing leaf tissues (*Rhynchaenus fagi* L.), or sucking on leaves and bark (*Cryptococcus fagisuga* Lindiger, *Phyllaphis fagi* L.), have expanded in recent years, causing considerable defoliation, browning of leaves and weakening of the trees.

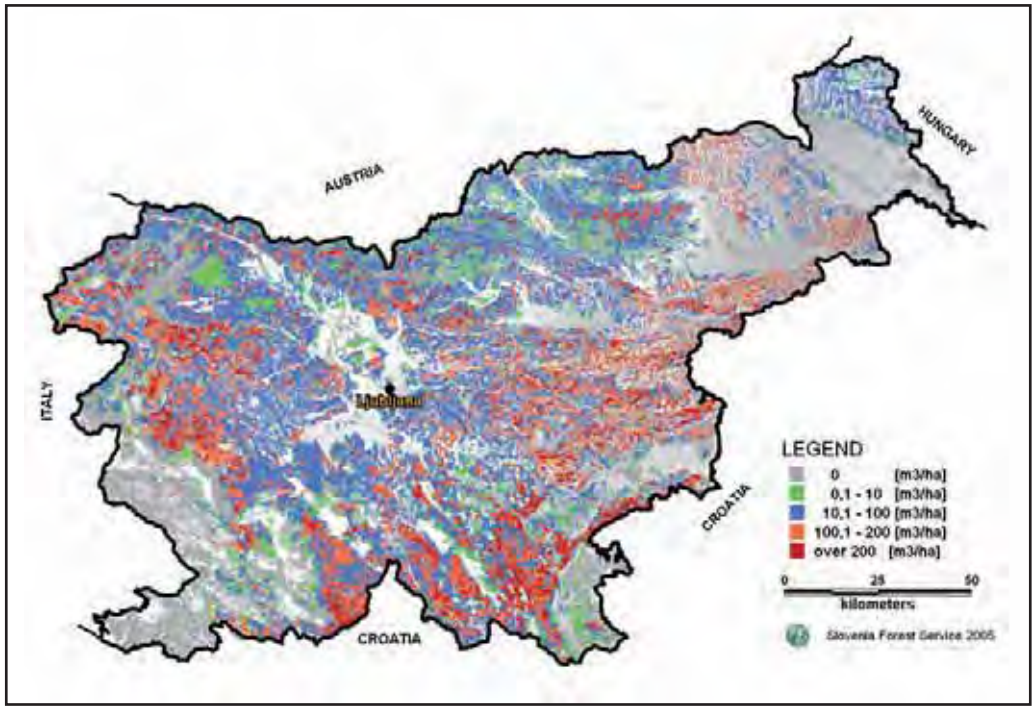

Fig. 1: Present distribution of beech (*Fagus sylvatica* L.) in Slovenia according to its share in growing stock (SFS, Pisek 2005)

EUROPEAN BEECH GENE POOL PRESERVATION AND CONSERVATION ON NATIONAL LEVEL

After the primary succession in the postglacial period, the larger part of the Slovenian territory was overgrown by forests, above all by beech and fir-beech forests (Šercelj 1996). Results of genetic analysis of European beech populations in Central and South Eastern Europe using isoenzymes as gene markers have shown the existence of genetic differences between provenances of beech from north-western part of the investigated area and provenances of beech from eastern part of the Balkan Peninsula (Brus 1999, Brus, Horvat-Marolt, Paule 1999). The obtained results supported the hypothesis that during the ice ages the European beech was present in microrefugia at the South Eastern periphery of the Alps and on the territory of today's Slovenia (Brus, Horvat-Marolt, Paule 2000, Brus 2008a). Findings were confirmed by the Magri et al. (2006) study which analyzed large palaeobotanical and genetical data of common beech in Europe. The territory of today's Slovenia was one of the main source areas for the post-glacial development of beech and supposedly the most important glacial refugia for its re-colonization in Europe (Magri et al. 2006, Brus 2008b). Development of beech forests allowed a possibility that European beech in the territory of present day Slovenia passed the way of genotypic specialization which resulted in locally adapted races or ecotypes.

Conservation of locally adapted races is ensured by approved forest seed objects, through protection of natural parks, natural monuments, and forest reserves (virgin forests). In the network of 173 virgin forest reserves which was established in the 1970s on suitable sites (Mlinšek 1980), beech is the dominant species in 62% with high share in its growing stock (Smolej et al. 1998). However conservation of forest genetic resources in Slovenia is traditionally an integral part of close-to-nature and sustainable forest management and linked to the Forest Act (1993). In order to mitigate the impacts of climate changes on forests and to enhance their sustainability with promotion of dynamic genetic processes for adaptation to changing environmental conditions, collection and use of forest beech reproductive material is strictly implemented through the Act on Forest Reproductive Material (ULRS, no. 58/02, 85/02) and the Rules on requirements and approval procedure of basic forest reproductive material (FRM) in the categories "source identified" and "selected" and Slovenian national list of basic material (ULRS, no. 91/03). The main criteria for approval of seed sources for multifunctional forestry are autochthony, effective population size, adaptation to site conditions, health status and resistance, uniformity, isolation of the stand, age and development stage of population, volume production, quality of wood and the form and growth habit. European beech seed sources which are approved in category "selected" need to be at least 5 ha in extent, to contain 70 phenotypically acceptable fructifying trees, and up to 20% of phenotypically less favourable trees (Kraigher, Pučko, Božič 2004).

The national list of basic forest reproductive material in Slovenia is established and published by the Slovenian Forestry Institute (SFI) each year in the official gazette and on SFI web page. As for current state of European beech basic material (seed sources) for reproductive material in Slovenia, to 01/01/2009 (Kraigher et al. 2009) the following basic material sources have been registered: in the category "source identified" 269 ha (7 seed stands from 3 regions of provenance); in the category "selected" 504 ha (20 seed stands from 7 regions of provenance); whereas four seed stands have been notified out of the total area of 203 ha as European beech dynamic "gene conservation units", of all stands classified under category "selected sources".

Fig. 2: Rajhenavski Rog forest reserve in Kočevje Region is overgrown by Dinaric fir-beech forest (Photo: L. Kutnar)

Fig. 3: Natural regeneration of mountain beech forest on the Gorjanci Mountain near Novo Mesto Region after application of selective thinning treatment (Photo: L. Kutnar)

BEECH DOMINATED FOREST SOIL ECOSYSTEM RESEARCH

Beech dominated forests are important regarding biodiversity both above- and below-ground. The Slovenian Forestry Institute research team in cooperation with several national and international institutions studied the below-ground aspect of beech dominated forests recently, starting from the basic analyses of fine root growth and their importance for soil structure and carbon dynamics (Kraigher et al. 2007, Železnik et al. 2007, 2009, Grebenc, Štupar, Kraigher 2007) to the applied studies of rhizosphere symbionts diversity. The influence of ozone (Grebenc, Kraigher 2007a, b) and small canopy gap (Grebenc 2005, Grebenc et al. 2009) were proven to influence the below-ground components. Several biodiversity analyses were performed in various groups of beech forests soil organisms including ectomycorrhizal fungi (Grebenc 2005, Grebenc et al. 2009), litter decomposing fungi (Bajc et al., in prep.), eubacteria (Grebenc, Bajc, Kraigher 2009, Kraigher et al., in prep.) and pedofauna (Grebenc, Bajc, Kraigher 2009, Grgič et al., in prep.) all indicating a high biodiversity under moderate anthropogenic influence, pronounced differences among sites and within repetitions at sites, and also a general shortage of knowledge on below-ground components in temperate beech forests. Studies represented parts of national and international (EU) projects covering different forest management systems applied in the country, from virgin forests, managed forests, to remediation sites and the international beech provenance trial.

FUTURE PERSPECTIVES OF BEECH FORESTS

Predicted climate changes could cause significant changes in the beech forest distribution. The change of forest vegetation pattern, driven by expected climate changes, has been studied recently (Kutnar, Kobler 2007, Kutnar et al. 2009). Based on the three different climate scenarios, the trend scenario, the hot-and-dry scenario, and the wet-and-less-hot scenario, the simulations showed that the spatial pattern of forest vegetation types would be altered significantly under impacts of predicted changes. In the following decades the vegetation type of major part of forest sites might change. Due to the predicted climate warming, the share of thermophilous forests might increase from the present 14% to range between 21% (wet-less-hot scenario) and 71% (hot-dry scenario). The share of thermophilous forests, which are economically less interesting and more fire-prone, will increase significantly by replacing mesic beech forests. From ecological-, nature-conservation- and forest-management points of view, the predicted decrease of the share of Dinaric fir-beech forest (*Omphalodo-Fagetum*) is especially important (Kutnar, Kobler 2007, Kutnar et al. 2009). Taking into account the most pessimistic hot-dry scenario, and assuming the actual ecological niche of this forest would not change in the future, this forest type might disappear completely from the territory of Slovenia by the end of the 21st century.

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Contacts

Dr. Gregor Božič
Slovenian Forestry Institute
Večna pot 2, 1000 Ljubljana, Slovenia
tel.: +386 1 200 78 21, fax: +386 1 257 35 89
e-mail: gregor.bozic@gozdis.si

CURRENT STATE OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) FOREST AND GENETIC RESOURCES IN SPAIN

Diana Barba[1,3] – Guillermo Madrigal[1,3] – Jose A. Reque[2,3] – Ricardo Alía[1,3]

[1] Dpto de Sistemas y Recursos Forestales. INIA.Carr. Coruña km 7.5 28040 Madrid

[2] Dpto de Producción Vegetal. Universidad de Valladolid.

[3] Sustainable Forest Management Research Institute UVa-INIA [SFM-RI]

ABSTRACT

A summary of the current state of European beech (*Fagus sylvatica* L.) in Spain is provided, including information on the distribution, main typologies of beech forest, plant communities, site conditions, and forest management practices usually applied in Spain. Also include is information concerning genetic aspects of beech: regions of provenance, national register, and status for conservation of genetic resources.

Key words: European beech, *Fagus sylvatica*, haya (in Spanish), distribution, Spain, genetic resources

DISTRIBUTION OF EUROPEAN BEECH IN SPAIN

European beech covers 330,000 ha in Spain, where it reaches the south-western limit of the species distribution. European beech is located at medium and high altitudes in the mountains (above 1,000 meters), usually on north facing slopes. The distribution range covers the Cantabrian Mountain, Pyrenees and Iberian range, with scattered stands in the Coastal Catalonian Range, Beceite Mountains and Central Range (Fig. 1).

The altitudinal range of the species is variable depending on the geographical area where it is located (Tab. 1).

CHARACTERISTICS AND FOREST MANAGEMENT

Typology of beech forests

It is possible to distinguish four main types of beech forests in Spain depending on soil and climatic characteristics (Sainz 1992):

1) The oligotrophous beech forests are distributed in continental and dry climate, with vegetation not very abundant and generally acidophilous. This type of forests reaches a lower density and height in comparison to the eutrophic beech forests.

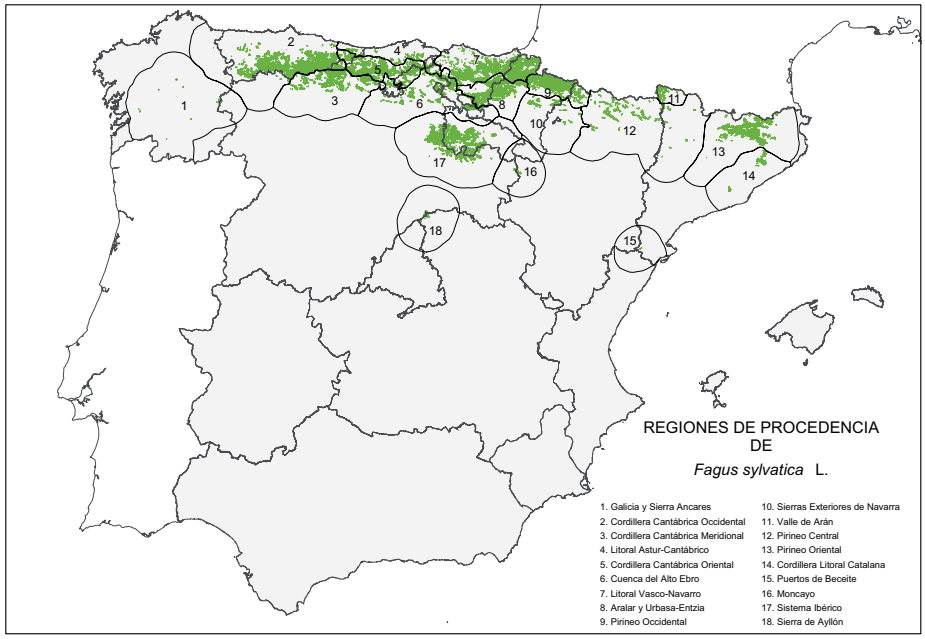

Fig. 1: Distribution of European beech in Spain (including the regions of provenance of the species)

Tab. 1: Altitudinal range and some ecological characteristics of European beech in Spain (Agundez et al. 1995)

Region of provenance	Altitude (m)	Annual rainfall (mm)	DI	Geological background
1. Caurel and Ancares	800 – 1,200	1,972	0	Siliceous
2. Western Cantabrian Range	800 – 1,600	1,713	0	Calcareous/Siliceous
3. Southern Cantabrian Range	1,200 – 1,600	1,367	0.5	Calcareous/Siliceous
4. Cantabrian/Asturias	600 – 1,000	1,824	0	Calcareous
5. Eastern Cantabrian Range	800 – 1,600	1,562	0	Calcareous/Siliceous
6. High Ebro River	800 – 1,200	771	1	Calcareous/Siliceous
7. Litoral Vasco-Navarro	600 – 1,000	1,860	0	Calcareous/Siliceous
8. Aralar and Urbasa-Enznia	800 – 1,200	1,380	0	Calcareous/Siliceous
9. Western Pyrenees	800 – 1,600	1,650	0	Calcareous/Siliceous
10. Navarra Mountains	800 – 1,200	898	0.2	Calcareous/Siliceous
11. Aran Valley	1,000 – 1,800	955	0	Siliceous
12. Central Pyrenees	1,200 – 1,600	1,134	0	Calcareous
13. Eastern Pyrenees	1,000 – 1,400	945	0	Calcareous
14. Montseny	1,000 – 1,400	906	0	Siliceous
15. Beceite Mountains	1,200	789	1.5	Calcareous
16. Moncayo Mountain	1,200 – 1,600	637	1.5	Siliceous
17. Iberian System	1,000 – 1,600	910	0	Siliceous
18. Ayllon Range	1,400 – 1 ,800	942	1.5	Siliceous

DI – Length of drought season (no. of months with Rainfall < 2*Temperature)

2) The eutrophic beech forests are found on deep soils which are rich in nutrients. They are located in flat areras or on low slopes, where this type of soil can develop under any type of substratum, being more frequent in lime soils. These beech forests are the most evolved ones being the habitats with a minor exploitation. In lower altitudes, they are mixed forests. When the climate has a major tendency towards a Mediterranean climate, the air and soil moisture is very low and the accompanying vegetation is very scarce. These zones represent the transition of the beech forests towards sub-Mediterranean type.

3) The sub-Mediterranean calcareous beech forests are located in drier zones, in environments of transition towards the Mediterranean climate, where the importance of the accompanying vegetation is very important, due to low moisture and high pH of the soil. The fraction of area covered by the canopy is lower than in the previous types, which allows the penetration of light and the enrichment of the accompanying vegetation (especially *Buxus sempervirens* and *Amelanchier ovalis*). In some of these sites, the beech forests have low density, and low height, under stony and steep areas.

4) And finally the beech-silver fir (*Abies alba*) forest, where the beech forms a continuous canopy that can reach 30 m in height, and the silver fir up to 35 m. It constitutes a very complex ecosystem, with high productivity and the maximum biological value of the forests of the temperate region. The structure of this type of forest is efficient in the use of water, light and soil resources. This type of formation is distributed principally between 1,000 and 1,700 meters of altitude, occupying valleys, on shady and humid hillsides.

Seed production and regeneration

In Spain seed production starts (commercially), when the trees are 60 – 80 years old, with a mean production of 3 – 10 kg/tree. Mast years occur every 4th – 6th year and are mainly dependent on weather; they can be detected for broad regions (Rodríguez-Guitián, Ferreiro 2005).

Natural regeneration in beech forests is affected by different ecological and management practices. Limitations to regeneration are related to late frost in the Mediterranean region, mortality during the summer due to drought, low levels of air humidity, high levels of radiation, browsing by cattle, and by the existence of ancient coppice forest structures with older and decaying trees with low seed production. These factors have a higher impact under Mediterranean conditions. On the contrary, in the Cantabrian Range production of 900 seed/m^2 have been reported. In this region densities of 100,000 – 200,000 seedlings/ha are observed, with a survival of 10% after 10 years, and the seedlings are usually found in the gaps in the canopy (Blanco et al. 1997).

Regulation and marketing of reproductive material

Commercialization of beech reproductive material is regulated by EU Directive 105/CE, and Spanish RD 289/2003. According to these norms, regions of provenance of the species were defined (Agundez et al. 1995, Alía et al. 2009), and at present basic material (seed sources and stands) from 16 out of the 18 regions of provenance has been included in the Spanish National Register, for production of identified (267 seed sources and stands) or selected (20 stands) forest reproductive material. Seed transfer recommendations have also been established (Martín, Diaz-Fernández, de Miguel 1998) to facilitate the use of forest reproductive material in Spain.

SILVICULTURE AND FOREST MANAGEMENT

In general, the beech forest in Spain has a medium to low productivity in comparison to other European countries. In natural forests, beech is usually found in even-aged stands (Madrigal 1992). In southern and mountainous areas, it is common to find uneven aged stands. Only in open stands it is possible to find uneven aged stands as a result of species mixture or stands of different ages.

Clearcuttings are not used nor recommended in Spain, due to the special ecological characteristics of the stands. The silvicultural treatment most frequently used (to favour natural regeneration) is the shelterwood system (Madrigal 1992). Rotation age in even-aged stands varies from 100 to 150 years, with a regeneration period of 20 to 30 years. In the Spanish beech forests, stands with age class structures close to uneven forests can often be found (Cirac 1992, Sánchez de Medina et al. 2001). Generally these types of structure have their origin in poor silvicultural management or high grading. A major part of the beech forests has traditionally been managed as coppice forests for fuel wood which explains the broad representation of even-aged structures in mountain forests. In this case, low thinning of the pole-woods is the most common treatment.

GROWTH AND PRODUCTION

In general, the growth and the production of the Spanish beech forests are lower than those from Continental Europe (Germany, NE France) and of Atlantic Europe (Great Britain, Belgium, W France). The mean value is 1.9 – 6.0 m^3/ha/year. In Spain, the less productive sites correspond to the Mediterranean beech forest type. Among the different tools for forest management of the beech forests in Spain, can be mentioned the density functions (Ibáñez 1989):

$$N = 10{,}000 * \exp\left[(-0{,}25+0{,}006\ SI)*(H0-3)\right]$$

where, N: no. of trees/ha; SI: site index in m, H0: top height in m.

There are also different yield tables for the Spanish beech forests (Ibáñez 1989, Madrigal 1992). Table 2 includes the value of the mean annual growth, defined for a rotation age of 120 years, and comparing different yield tables for different zones of Europe and the two most representative types of Spain.

Tab. 2: Mean annual increment (m^3/ha/year). Comparison among different site indexes, and for a rotation period of 120 years (Madrigal et al. 2008)

Navarra, Spain (Madrigal 1992)	La Rioja, Spain (Ibáñez 1989)	Great Britain	Continental Europe
-	-	9.4	9.4
-	-	7.5	7.5
6.1	-	5.8	-
5.0	4.8	-	5.4
3.9	3.6	4.0	-
2.8	2.3	-	3.4
1.9	1.2	-	1.7

PEST AND DISEASES

The effects of pollution in Spanish forests are lower than in other areas in Europe, although higher concentrations of some elements (Ca, Mg and S) or damages by ozone have been reported in some areas. Economically, the most important disease is the red heart, which depreciates the wood, being caused by the mycelia of some fungi (e. g. *Ungulina marginata*, *Ganoderma applanatum*, *Fomes connatus*) penetrating by wound. In timber already cut, the first two fungi can result in red colorations and putrefactions. The insect *Euproctis chrysorrhoea* consumes leaves, sprouts and flowers, the insect *Orchestes fagi* consumes the leaves.

EUROPEAN BEECH GENE POOL CONSERVATION

European beech is included as one of the priority species within the National Strategy for Forest Genetic Resources Conservation. Studies on the genetic variation of the species in Spain have shown large differences among populations for several traits of interest evaluated mainly in provenance tests. The results (Puertas 1992, Vega et al. 1992, Puertas, Traver, Olave 1995) show that no clear pattern of variation related to the origin is found in nursery or after 10 years in the field. Using isozymes (Comps et al. 1993) it is possible to distinguish three main groups of populations: Cantabrian Mountains, Pyrenees and an Iberian group. Genetic resources of European beech are not endangered in Spain as a whole, although some populations need some conservation activities (Goikoetxea, Agundez 2000) mainly due to new conditions derived from climatic change. Special attention needs to be paid to the correct use of forest reproductive material in afforestation and restoration programmes.

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Contacts

Dr. Ricardo Alía
Dpto de Sistemas y Recursos Forestales
INIA.Carr. Coruña km 7.5 28040 Madrid, Spain
Sustainable Forest Management Research Institute UVa-INIA [SFM-RI]
e-mail: dbarba@inia.es, alia@inia.es

CURRENT STATE OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) IN SWEDEN

Rolf Övergaard[1] – Lars-Göran Stener[2]

[1] Southern Swedish Forest Research Centre,
Swedish University of Agricultural Sciences, P. O. Box 49, S-230 53 Alnarp, Sweden
[2] Skogforsk, Ekebo 2250, S-268 90 Svalöv, Sweden

ABSTRACT

More than half of Sweden is covered with forests. Beech migrated from more southern areas of Europe approximately 4,000 years ago and is today located in the very southernmost part of the country. Beech has been used for several industrial purposes over recent centuries. A large part of the original beech forests was converted into spruce woodland in the 20th century due to economical reasons. As a result the "Hardwood Tree Forestry Act" was approved with the aim to protect beech and other hardwood forests. Today beech forests are primarily regenerated naturally and managed using an intensive thinning program. The rotation period generally varies from 80 to 140 years. It is primarily recommended to use regeneration material from seed orchards or from approved seed stands close to the cultivation location. Research is mainly focused on cost-effective management, but also assesses issues relating to biodiversity, recreation and vitality (indicated by crown defoliation and reduction of soil pH). Tree breeding work with beech is very extensive. Future climate change is predicted to increase yield within the species present distribution and may also lead to an increase of the beech forest area in Sweden.

Key words: European beech, *Fagus sylvatica* L., bok (in Swedish), Sweden, current state

GENERAL FOREST DATA OF SWEDEN

The major part of Sweden belongs to the boreal vegetation zone: in the southernmost part there is the nemoral zone and between, there is a transition zone called the boreo-nemoral or hemi-boreal vegetation zone (Ahti, Hämet-Ahti, Jalas 1968). The total land area of Sweden is 41.3 million hectares of which 23 million hectares (55%) is forest land. The total volume of growing stock is 3 billion m^3 distributed as follows – 38% Scots pine, 42% Norway spruce, 11% birch, 2% hardwoods, 3% other broadleaves and 3% dead trees. The mean growing stock per hectare is 132 m^3. Since the 1920s the growing stock in all of Sweden has increased by 80%, while in the southern part of Sweden it has more than doubled. The mean annual increment per hectare is 5.3 m^3 giving a total annual increment of 110 million m^3. The annual cut is around 80 million m^3 (Swedish National Forest Inventory 2008).

GENERAL INFORMATION ABOUT BEECH IN SWEDEN

The only beech species in Sweden is European beech (*Fagus sylvatica* L.) which was a late migrant to Sweden. It arrived from the south about 4 000 years ago, at the same time as Norway spruce migrated from the north. When humans started to settle in southern Sweden, about 2 500 years ago, beech was mostly concentrated in the outlands, since it competed with different crop species. In the 17th century beech and oak were the dominant tree species in the forests of southern Sweden. The sparse forests were at that time mostly used as pasture land for animals and for fuel-wood. In the 18th and 19th centuries the beech forests were exploited for industrial purposes. Production of potash from beech, used for making soap, glass and gunpowder, was profitable. There was also a great need for beech barrels, used for storing herring. Since the need for arable land was high among farmers, large areas of beech forests were cut down.

Beech was mostly found in areas belonging to the nobility, who could afford to keep forests for hunting purposes. That is the explanation why beech and other hardwood species are called "noble trees" (Eickhoff et al. 1995). During the 20th century many beech forests were converted into Norway spruce stands due to economical reasons and the beech forest area decreased dramatically (Swedish Environmental Protection Agency 1982). In 1974 this resulted in the Beech Forestry Act, with the purpose to preserve the beech forests by appropriate management and forbidding conversion into other tree species (SOU 1971:71). It was replaced in 1984 by the Hardwood Tree Forestry Act with the same purpose, but also including other "noble" tree species such as ash (*Fraxius excelsior*), elm (*Ulmus glabra*), hornbeam (*Carpinus betulus*), lime tree (*Tilia cordata*), maple (*Acer platanoides*), oak (*Quercus petraea, Q. robur*) and wild cherry (*Prunus avium*), (SOU 1992:76). An implication of the Hardwood Tree Forest Act is the prohibition on the conversion of low-yielding beech stands into stands consisting of other tree species potentially better suited to local site conditions. As a result there are many beech forests on sites which are inappropriate for beech production.

Today the primary product of beech is mostly used for floors, furniture and carpentry. Beech is also used for production of high quality paper. There is a big price differential for different log qualities. Large trunks (> 50 cm) receive the highest financial returns. Beech forests often have a long continuity and are important for biodiversity. Many red-listed lichens and insects can be found in old trees. These forests are also very popular for recreation (Eickhoff et al. 1995).

In Sweden beech grows up to around N 58° and up to 200 meter above sea level where the climate is maritime (Dahl 1998) (Fig. 1). Beech is often found on slopes and grows well on silt, calcareous moraines with good water supply. Mixtures with other broadleaved species are common, especially oak, ash and hornbeam, and in the northern parts of the distribution area also pine and spruce can be found. Beech covers an area of about 58,000 hectares defined as areas where more than 65% of the basal area is beech. The total volume is about 21 million m^3. Trees with diameters of at least 25 cm at 1.3 m above ground accounts for roughly 85% of the total volume. The annual increment is approximately 450,000 m^3 and the annual cut approximately 400,000 m^3 (Svensson 1995, The Swedish Forest Agency 2008).

The Swedish name for beech is "bok". Sometimes it is called "rödbok" (red beech) synonymous to the German "Rotbuche". To separate it from "avenbok", the Swedish name for hornbeam, beech is also sometimes named "vanlig bok" (common beech) (The Virtual Flora 2008).

SILVICULTURE AND RESEARCH

The common way to regenerate beech is by natural regeneration. Mast years appear every second or third year, but large variation occurs, depending on the weather conditions (Övergaard, Gemmel, Karlsson 2007). Soil preparation with the intention of exposing large areas of mineral soil should be done before the seed-fall. Seeds should then be covered with soil to protect them from seed-eating animals. During winter a heavy thinning is conducted, leaving just a sparse shelter of trees. This shelter is removed within a 10 – 20-year period by felling trees at 2 – 4 occasions in order to gradually increase the amount of light. Most often some retention trees are left for biodiversity reasons. Since the seedlings are abundant there is mostly no need for fencing. The management is intense in the young stands with at least two cleanings and frequent thinning. When the stand is older, the thinning intervals increase. The normal rotation period varies from 80 – 140 years, shorter on the more fertile sites, but also it depends on the quality of the stand, target diameter and timber prices.

Establishment of beech plantations is often both a costly and risky business. Fencing is necessary and herbicides are needed, at least on former arable land. Using shelter trees, like larch, birch or alder, may be one way to protect the plants from extreme temperatures during the first years of establishment. Problems one always has to consider in new plantations are those caused by rodents and mice.

Photo 1: A Swedish beech forest in the springtime (J. Norman)

Cheaper and better ways to regenerate beech forests are important research issues. Sowing and planting are two methods with a big potential to improve as well as naturally regeneration on poor, acid soils. Examples of questions where the Swedish research tries to find answers are: 1) is it possible to minimize the costs for pre-commercial thinning and to shorten the rotation period with retained stem quality? 2) Could the thinning program be more rational, but less intensive without any major effect on growth and stem quality? Tree-living lichens in close-to-nature managed forests, biodiversity in beech production forests, innovations and use of the beech wood, and recreation and health-aspects of hardwood forests are other research fields also in progress (The broadleaf program 2008).

GENETIC RESOURCES AND LEGISLATION

Climatic adaptation is of great importance for practical forestry. If the reforestation material is not climatically adapted to the plantation site, there will be a considerable risk of damage, reducing growth and deteriorating timber quality, with resultant economic losses. Climatic adaptation is therefore one of the key traits for a successful establishment of high quality beech forests.

Today there is a lack of good Swedish indigenous forest reproductive material of many broadleaved species, among others beech, which is compensated for by importing material mainly from Poland and Germany. However, our knowledge about north transfer effects on survival, vitality and growth is very limited, and might be crucial since the northern limit of natural distribution of many "noble hardwood" species is found in southern Sweden. Thus, it is recommended primarily to use material from seed orchards and as a second choice from approved seed stands close to the cultivation location.

The tree breeding work with beech is very extensive. Earlier activities, in the 1940s and 1950s, had resulted in two seed orchards. Both orchards contain untested plus-trees from southern Sweden. The plus-trees are now being tested in two progeny tests established in year 1998. To increase the knowledge of the transferring effects of different beech material within Europe, two series of international beech provenance trials (1993/95 and 1996/98) were established throughout Europe. One trial in each of the series was established in Sweden.

Only reproductive material from seed sources approved by each of the member countries of EU can be used commercially. In Sweden the application is examined by the Swedish Forest Agency. All approved seed sources in Sweden are registered in a national list which can be found on the web, http://www.svo.se/episerver4/templates/SNormalPage.aspx?id=11530. A seed source is approved when it is expected to produce forest stands with good prerequisites for good development and acceptable yield.

In Sweden, the approved basic material is divided into seed orchards, seed collection stands and seed collection areas. The different seed sources are listed separately and maps over the seed collection areas are provided. The seed collection stands are selected based on factors stipulated by the OECD. The seed collection areas consist of several stands of genetically more or less homogenous, mainly autochthonous forests. Mixing of seeds is only allowed within a region of provenance (Fig. 2). Each seed orchard and seed collection area is considered to be a region of provenance.

HEALTH STATE AND IMPACT OF CLIMATE CHANGE

Special surveys of crown health condition of beech and oak forests in southern Sweden were carried out in 1988, 1993 and 1999, showing increased crown defoliation in the beech stands. The soil condition of the subsurface mineral layer at a depth of 20 – 30 cm was highly acid with a pH value less than 4.2 in 86% of the forest stands surveyed (Andersson, Sonesson 2000).

The beech distribution area (Fig. 1) may be expanded in the future as an effect of climate change, since spring frost, which is an important limiting climatic factor, may be less frequent during flowering. Furthermore, an increased temperature will enhance the breaking-down process of organic material, liberating more nutrients in the soil. This will, together with high nitrogen deposition and longer growing season, promote yield and shorten the rotation period in the present beech distribution area (Berg et al. 2007).

Fig. 1: Beech distribution area

Fig 2: Regions of provenances

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Reviewed

Contacts

Dr. Rolf Övergaard
Southern Swedish Forest Research Centre
Swedish University of Agricultural Sciences
P. O. Box 49, S-230 53 Alnarp, Sweden
e-mail: rolf.overgaard@ess.slu.se

RESOURCES OF BEECH IN SWITZERLAND

Pascale Weber[1] – Andrea R. Pluess[2] – Urs Mühlethaler[3]

[1] Swiss Federal Research Institute WSL, Birmensdorf, Switzerland
[2] Swiss Federal Institute of Technology ETH, Zürich, Switzerland
[3] Bern University of applied Sciences SHL, Forest Ecology, Zollikofen, Switzerland

ABSTRACT

Beech is the second most important tree species in Switzerland, covering a wide range of the forested area with varying site conditions. In many forest communities of the sub-montane and lower montane range, beech is the dominant tree species; whereas from the lower to middle montane zone, beech becomes less important in comparison to spruce and fir. Beech accounts for around 17% of the Swiss total growing stock, which explains its importance for timber production. The rotation time for good quality timber is around 100 – 140 years. Since beech has been regenerated naturally for a long time, beech provenances for artificial regeneration have played only a marginal role so far. Nevertheless, in studies from the beginning of the 20th century, Swiss lowland provenances were compared to provenances from higher altitudes. Furthermore, in the Danish provenance trial, the two tested Swiss provenances Adliswil and Sihlwald were found to be of superior economic returns. However, Switzerland is not carrying out provenance trials under COST E52, although some Swiss provenances have been tested in other European countries. Recently, several projects have been undertaken studying environmental impacts on beech in Switzerland. Further investigations will be needed to understand better the impact of climatic changes and raising CO_2 on the distribution and growth of beech in Switzerland. At least model simulations suggest an altitudinal upward shift in beech distribution due to increasing drought, if beech does not have the plasticity or the evolutionary potential combined with the required time to adapt to future environmental conditions.

Key words: *Fagus sylvatica* L., distribution range, provenance, Switzerland

COUNTRY DATA

Area: 41,285 km^2

Elevation: between 193 m a. s. l. (Lago Maggiore) and 4,634 m a. s. l. (Dufourspitze)

Climate data: annual precipitation: between 521 mm (Ackersand Stalden) and 2,701 mm (Säntis)
annual mean temperature: between -7.9 °C (Jungfraujoch) and 11.6 °C (Lugano)

Climate is regionally diverse.

These climate data are norm values for the period 1961 – 1990 and are taken from the website of the Federal Office of Meteorology and Climatology MeteoSwiss.

Forest area: 12,746 km², 31% of total area (FOEN/WSL 2007)

ECOLOGY AND DISTRIBUTION OF BEECH IN SWITZERLAND

Beech is the second most important tree species in Switzerland. After spruce (*Picea abies* (L.) Karst.) (43.1%), beech covers 17.9% of the forest area (Brassel, Brändli 1999). However, in the colline and sub-montane forest zones of the Jura and the Pre-Alps, beech is the most important tree species with 35.1% and 31.7% of stems, respectively (Brändli 1998). The current presence of beech, as monitored in the National Forest Inventory sample plots, conforms approximately to its suggested natural distribution area (cf. Fig. 1). Beech is very shade tolerant, and therefore, under natural regeneration, occupies a large ecological niche. As illustrated in figure 1, forest associations with beech have the potential to cover Swiss forests to a large part; beech is present from the colline to the subalpine forest zones. However, in particular in the Swiss Plateau (Mittelland), it is assumed that the portion of beech (23.8% of stems) has been replaced substantially by spruce (37.1% of stems) due to former forest management (Brassel, Brändli 1999). Today, the Jura, the Swiss Plateau and the Pre-Alps are the most important regions for beech, with high density growing stock in the forest (Tab. 1).

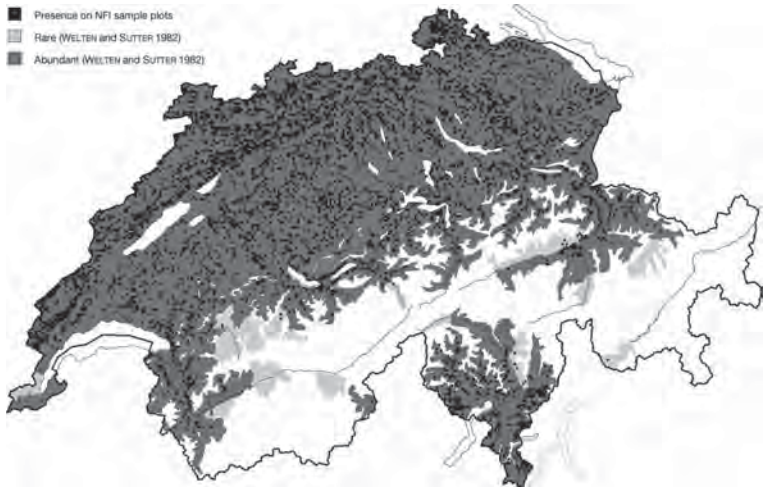

Fig. 1: Distribution map of beech according to Brändli (1998). Current distribution (presence on NFI sample plots) conforms more or less to natural distribution according to Welten, Sutter (1982).

Beech is present in more than half of the 71 forest associations that have been described for Switzerland (Ellenberg, Klötzli 1972, in the following abbreviated EK). In forest associations which are dominated by beech (EK units 1 – 17), the basal area of beech reaches an average of 30% of total forest basal area (Brassel, Brändli 1999). These forest associations belong to the sub-alliances *Luzulo-Fagion* (EK units 1 – 4 on acidic soils), *Eu-Fagion* (EK units 5 – 13 on nutrient-rich soils) and *Cephalanthero-Fagion* (EK units 14 – 17 on dry and nutrient-poor soils, often on steep slopes), and are mainly found in the sub-montane to lower montane forest zones (400 to 1,000 m a. s. l.). In forest associations of the silver fir-beech alliance (*Abieti-Fagion*) (EK units 18 – 21), beech makes up 18.3% of the basal area (Brassel, Brändli 1999). These forests are often found in the lower to middle montane zone (800 to 1,400 m a. s. l.). In the remaining broadleaved forest associations (EK units 22 – 45), beech accounts for 12.5% of total forest basal area (Brasse, Brändli 1999).

Tab. 1: Number of stems (DBH ≥ 12 cm), growing stock and timber use for beech according to the five production regions as estimated from the National Forest Inventory (NFI) (Brassel, Brändli 1999)

	Switzerland	Jura	Swiss Plateau	Pre-Alps	Alps	South of the Alps
Number of stems (1,000)	97,595 ± 2	29,148 ± 4	24,076 ± 4	19,425 ± 5	12,743 ± 8	12,202 ± 9
Portion per region (%)	100.0	29.9	24.7	19.9	13.0	12.5
Portion of all tree species	18.3	32.0	23.8	17.8	7.8	18.1
Growing stock (1,000 m^3)	70,770 ± 2	22,791 ± 4	22,068 ± 4	14,861 ± 6	6,674 ± 8	4,376 ± 10
Portion per region (%)	100.0	32.2	31.2	21.0	9.4	6.2
Portion of all tree species (%)	17.1	31.5	22.3	15.0	5.9	14.5
Timber use (1,000 m^3) Time span: NFI1-NFI2 = 10 yrs	11,521	3,240	5,149	1,922	825	385

GENETIC RESOURCES OF BEECH IN SWITZERLAND

At the beginning of the postglacial period, beech most likely expanded to Switzerland from the Slovenian refuge (Magri et al. 2006). The expansion along the North-Alpine forelands started before the beginning of large-scale Neolithic human activities and therefore, was mainly driven by climatic changes (Tinner, Lotter 2006).

Most of the Swiss forest (around 80%) is regenerated naturally (Brassel, Brändli 1999) and artificial regeneration has ceased continually since 1965. Regarding beech, the portion of natural regeneration is near 100%, due to optimal regenerating conditions for this tree species over a wide area and the difficulties to obtain high quality timber by regenerating beech artificially. This high amount of natural regeneration allows for the conservation of the genetic diversity of native tree species in Switzerland (Bonfils, Rotach 2003). In the case of plantations, national regulations exist for seed collection and utilization (Art. 21), as well as for import and export of seeds (Art. 22) (Verordnung über den Wald). All tree species under these regulations are listed (Anhang 1: Verordnung über forstliches Vermehrungsgut). Seeds are collected and forest genetic resources are handled according to the OECD regulations. For this purpose, Switzerland is divided into 14 provenance regions, which belong to the five main production regions corresponding to geographical regions (Fig. 2). In case of artificial regeneration, foresters are obliged to use the closest available provenance.

Although some Swiss provenances have been tested in different provenance trials in other European countries, no recent provenance trials have been undertaken within Switzerland. Some of the current provenance trials of COST E52 include the Swiss provenances Oberwil and Aarberg (Wühlisch et al. 2008). In an earlier Danish provenance trial, the provenances Sihlwald (cf. Fig. 3) and Adlisberg were tested among other European provenances. They were found to be superior in economic returns due to a higher frequency of trees with straight stems and long boles (Hansen, Jorgensen, Stoltze 2003, Wühlisch 2005). Burger (1948) reported about early provenance tests with different beech provenances in Switzerland, e. g. differences in height growth between provenances of lower and higher altitudes. In these studies, it was shown that fast growing provenances from the lowlands might experience problems at higher altitudes. In recent germination tests at the Swiss Federal Institute WSL the germination capacity of different Swiss beech provenances ranged usually between 50 – 80% (personal communication Anton Burkart).

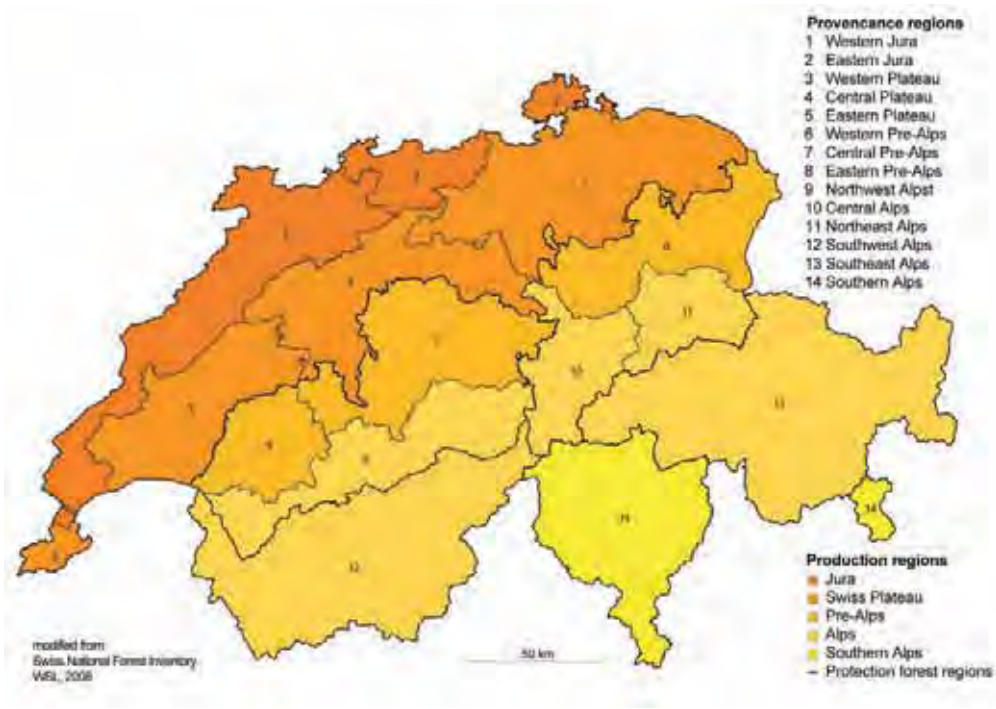

Fig. 2: Map of the Swiss provenance and production regions

FOREST MANAGEMENT AND TIMBER HARVESTING

Due to its high amount of growing stock (17.1% across Switzerland, cf. Tab. 1), beech plays an important role in timber production, in particular in the beech regions Jura (324,000 m^3/yr) and Swiss Plateau (514,900 m^3/yr) (Tab. 1).

Most of the beech trees grow in even-structured high forest (73%, cf. Brändli 1998). In accordance with earlier studies by Leibundgut, Auer, Wieland (1971), Zingg et Ramp (2004) found that thinning in such forests improved stem quality of beech, but also led to a slightly reduced total production. In another study, Zingg (1996) recorded that, after 1950, the basal area increment of pure beech stands moved clearly above the values that were expected from yield tables. This deviation may be partly induced by a changing climate, nitrogen deposition or CO_2-fertilization. However, the complex reasons are still under investigation. Noteworthy is the speciality "plenter forest" – a single-tree management form, leading to a mixture of trees of different sizes, ages and heights – which is common in the Jura and the Emmental. In Switzerland this silvicultural technique is particularly abundant in the silver fir-beech forest in the montane forest belt. Alltogether, around 3% of beech trees grow in plenter forests (Brändli 1998). Along with this practice, *Abies alba* and *Picea abies* trees are often fostered at costs of *Fagus sylvatica* trees (Schütz 2001).

The rotation time for growing high quality timber depends on the prevailing site conditions, but often is between 100 and 140 years. On the other hand, fuelwood, which is optimized for quantity, may be produced within a shorter time. Overall, one third of the Swiss beech forests exhibit a stand age of 80 – 120 years (Brändli 1998). Around 2% of the stands are estimated to be older than 160 years, i. e. the amount of ecologically important old growth forest is comparably low.

Within the European forestry community, it is well known that high quality timber of beech can be found in many places in Switzerland. It is not rare to identify tree heights of 40 m with straight stems up to 20 m (Fig. 3) (cf. Hansen, Jorgensen, Stoltze 2003). However, although the physical

Fig. 3: Beech stand in the forest reserve “Sihlwald” (Picture: P. Weber)

appearance is excellent, red heartwood is abundant. A few studies have been conducted on the occurrence and economic implications of red heartwood in beech in Switzerland (cf. Pöhler, Klingner, Künniger 2004). Red heartwood is developed facultatively and is difficult to diagnose in standing trees. In 2002, a survey of the cantonal forestry departments resulted in approximately 50% of beech timber being affected by red heartwood, leading to a decrease of sometimes up to 50% in value. However, Pöhler, Klingner, Künniger (2004) demonstrated that the mechanical and technological properties of beech wood are not reduced due to red heartwood.

BEECH UNDER CHANGING ENVIRONMENTAL FACTORS

The effect of the increasing atmospheric CO_2 concentration on beech growth was tested in Switzerland on saplings (e. g. Spinnler, Egli, Körner 2003) and adult trees (e. g. Asshoff, Zotz, Körner 2006). Spinnler, Egli, Körner (2003) demonstrated that growth of saplings under elevated atmospheric CO_2 depends on the soil type with increased growth on calcareous and decreased growth on acidic soils. Growth responses of the four tested provenances were highly variable (Spinnler, Egli, Körner 2003) but there was no indication that one of the provenances would be superior under elevated CO_2 conditions. If approximately 100-year old beech trees are exposed to elevated CO_2, stem basal area increased in two of four experimental years (Asshoff, Zotz, Körner 2006). However, Asshoff et al. (2006) stress the point that only three beech trees were exposed to the elevated CO_2 treatment which is not enough to make the case for the whole species. In the same experimental setup Leuzinger et al. (2005) found evidence for a CO_2 driven mitigation during the very hot and dry summer of 2003. Future CO_2 concentration might thus counteract damage by increased temperature and drought. Under ambient CO_2 conditions during the exceptional year 2003, several beech trees throughout Switzerland shed their leaves earlier (Zingg, Brang 2003). However, it is difficult to tell whether this was already an indication that beech locally comes to its physiological limit, or whether beech will be able to adapt within its genetic/phenotypic flexibility to more frequent drought periods.

According to forest model simulations for Switzerland under climate change (Zimmermann et al. 2006), beech is suggested to retreat to higher altitudes and to lose its dominance in the sub-montane and lower montane zone where more drought tolerant species are expected to come to dominance. Currently, it is under investigation, how Mediterranean beech provenances germinate and grow in Switzerland (COST-Action FP07032, Mühlethaler et al.) to potentially introduce such provenances to our natural beech stands.

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Reviewed

Contact

Dr. Pascale Weber
Swiss Federal Research Institute WSL
Birmensdorf, Switzerland
e-mail: pascale.weber@wsl.ch

CURRENT STATE OF ORIENTAL BEECH (*FAGUS ORIENTALIS* LIPSKY) GENETIC RESOURCES CONSERVATION IN TURKEY

GAYE EREN KANDEMIR

Turkish Ministry of Environment and Forestry, Forest Tree Seeds and Tree Breeding Research Directorate, Department of Biotechnology, Gazi Tesisleri, 06560 Ankara, Turkey

ABSTRACT

The purpose of the following paper is to describe the current state of oriental beech (*Fagus orientalis* LIPSKY) in Turkey. It provides information on the distribution of the species, together with details of breeding activities and related seed transfer zones. It also provides information on the conditions of forest stands with associated plant communities. Oriental beech natural distribution in Turkey is 1.7 million ha and it is the main broadleaved species. There are almost 7,000 ha of *in situ* conservation areas of oriental beech in the country.

Key words: oriental beech (*Fagus orientalis* LIPSKY), kayin (in Turkish), distribution, gene-pool current state, Turkey, forestry research

ORIENTAL BEECH DISTRIBUTION IN TURKEY

Forest land covers 21,188,747 ha in Turkey out of a total area of 77,846,000 ha. 10,621,221 ha of forests are productive while 10,567,526 ha are degraded. The composition of forest tree species is mainly represented by conifers (12,772,654 ha). Deciduous forests cover 8,416,093 ha area and conifers-deciduous mixed forests are also included in these figures and account for 2,204,267 ha with the remainder made up of coppice and high forest (http://www.ogm.gov.tr/bilgi/orman_01.htm).

Turkey has two species of beech, oriental beech (*Fagus orientalis* LIPSKY) and European beech (*Fagus sylvatica* L.). The main beech species is oriental beech while European beech has limited distribution. European beech is distributed in Kırklareli-Demirköy, Çanakkale-Bayramiç, Edremit-Kazdağları and Kütahya-Simav area in Turkey (DAVIS 1982) (Fig. 1).

Oaks (6.4 million ha), consisting of 18 different oak species, are predominant in species composition. Pines are the next most important group with Turkish red pine (*Pinus brutia*) covering an area of 5.4 million ha while European black pine (*Pinus nigra*) covers an area of 4.2 million ha. Beech covers an area of 1.7 million ha in Turkey (Anonymous 2006). In the past, most beech stands were felled and replaced generally by conifers and in some cases converted to agricultural lands, especially for the production of tea plantations and for hazelnut production.

Oriental beech is distributed in the northern part of Turkey mainly on the slopes of the mountains overlooking the Black Sea. The optimal spreading areas of oriental beech are the lower slopes of the mountains of Black Sea Region and in the Marmara Region. Dense oriental beech forests in these

regions reach down to the Murat Mountain in the inner Aegian region. In addition to these dense oriental beech forests there are small marginal populations in central Anatolia and in the southern part of Turkey. The oriental beech forests in the southern part of Turkey, particularly in the Amanos Mountains and Adana-Maraş districts, are relic populations. In contrast, European beech which has its main distribution in the European subatlantic climatic regions has a very limited distribution in Turkey. There are also some scattered populations in the Kaz Mountains and in Kütahya-Simav.

Optimal growing conditions for oriental beech are found at the altitude ranging from 700 m to 1,200 m. As the thermal requirement for the species is higher than for fir and spruce, it cannot grow at high altitudes but there are some exceptions. The altitudinal minimum for oriental beech populations is in the locality of Sinop-Bektaşağa from sea level to 30 m along the Black Sea coast. The altitudinal maximum of oriental beech is recorded in the eastern Black Sea Region in the location of Artvin-Yusufeli at 2,100 m. From an economic viewpoint, oriental beech is the most important broadleaved species in Turkey.

Proximity to the sea and climate have positive effects on length of beech vegetation period. Therefore the relatively more temperate, moist and high precipitation areas, as found in parts of the Black Sea region such as in parts of the Marmara Region, are the most suitable lands for growing beech.

The wood of oriental beech has a reddish white colour and reddish brown heartwood formation occurs when the trees reach the age of 80 to 100 years. Beech wood is classified as of medium density (0.66 $g.cm^{-3}$). As a hardwood species, the wood is heavy, hard, strong and highly resistant to shock. It is also suitable for steam bending. Nevertheless, the main use of oriental beech wood is for fuel, but there are other uses such as particleboard, furniture, flooring veneer, mining poles (props), railway sleepers and the paper industry (Kandemir, Kaya 2009). According to research on the wood quality of beech from samples which were taken as cross sections from trees grown at different altitudes,

Photo 1: Oriental beech forest compete with *Rhododendron ponticum* (Kandemir 2008)

the widest annual rings and the highest number of trachea were found in samples from the optimal growth area (Kahvecí, Huss 2009).

Dense vegetation cover, mainly *Rhododendron ponticum* L. and *Rhododendron flaum* Don., in oriental beech growing sites, causes problems for natural regeneration. Other species which have negative effects on the natural regeneration of beech forests are *Ilex aquifolium* L., *Vaccinium arctostaphylos* L., *Prunus laurocerasus*, blackberry (Kahveci, Huss 2009). Other factors which prevent regeneration in oriental beech forests in Turkey are the predators of seed such as rodents and infrequent seed formation.

In the past, especially up to the 1980s, the wood quality of beech was considered to be poorer than that of conifers and therefore degraded and coppiced forests of beech were replaced by conifers (Kahveci, Huss 2009).

In the past, oriental beech forest in Turkey suffered from the effect of improper silvicultural treatments and other anthropogenic factors (Çalikoğlu, Kavgaci 2001). These affected the quality of oriental beech timber and the genetic base of beech stands. The regeneration with seedlings resulted in genetic recombination and the provision of a larger genetic base needed for adaptation to existing or changing environmental conditions. Thus, regeneration of oriental beech forests in such places should be gradually replaced through seedlings rather than coppicing (Kandemir, Kaya 2009).

Photo 2: An example of stem sprouting regeneration of oriental beech in Sinop (Black Sea Region of Turkey) (Kandemir 2008)

CHARACTERISTICS AND FOREST MANAGEMENT

Geographically, Turkey is mainly divided into three phytogeographical regions and the diversity of the species is depending on this division. These floristic regions are:

a) The Euro-Siberian Floristic Region: Black Sea and Marmara Geographical regions are Euro-Siberian phytogeographical regions with vegetation types of broadleaved deciduous forests, humid and sub-humid forests, dry forests and pseudomaquis and maquis. In the eastern Black Sea region, oriental beech is in mixture with *Picea orientalis*, *Alnus barbata*, *Castanea sativa* and *Abies nordmanniana*. In the mid section of Black Sea region, productive beech forests are found together with *Castanea sativa*, *Alnus barbata*, *Prunus* spp., *Carpinus betulus* and *Rhododendron flavum*. At the low elevations of the western Black Sea region, oriental beech is in mixture with *Tilia* spp., *Pinus brutia*, *Laurus*, *Castanea sativa* and *Carpinus betulus* while *Pinus sylvestris*, *Abies bornmulleriana*, *Rhododendron flavum*, *Taxus baccata*, *Quercus* spp., *Prunus* spp., *Acer* spp., *Cornus* spp. generate the species mixture with *F. orientalis* at higher elevations. In the Marmara region, oriental beech *Castanea sativa*, *Carpinus betulus* and *Quercus* spp. are a typical species of low elevations and *Abies* spp., *F. orientalis*, *Pinus nigra* are characteristic at high elevations.

b) Mediterranean (Aegean-Mediterranean) Floristic Region: This region occupies the northern coasts of the Marmara Sea, all of Mediterranean region and sub-region of the Aegean Geographical region. Mediterranean mountain forests are diverse. In the Mediterranean belts (800 – 1,200 m) oriental beech and hornbeam are present as a small group in the Amanos Mountains.

c) Irano-Turanian Floristic Region: This region covers all central, eastern and south eastern Anatolia. Dry oak and Scots pine forests are the main vegetation types of this floristic region. There are some small patchy oriental beech groups in this floristic region (Zencirci et al. 1998).

Oriental beech is the only broadleaved tree in Turkey which has been part of the National Breeding Program. The main purpose of oriental beech breeding is to enhance the height and volume growth, together with maintaining the quality of stem. The natural distribution area of oriental beech has been divided geographically into two main breeding zones based on the climatic and ecological conditions (Atalay 1992). The border between the Black Sea coastal and inland regions is along the first coastal mountains parallel to the Black Sea, where the climate changes slightly from maritime towards continental. The borderline follows township administration boundaries, except for Taşova which is divided by the Kelkit River.

Tab. 1: Oriental beech breeding zones in Turkey (Koski, Antola 1993), Fig. 2

Breeding zones (Sub zones)	Region	Altitude (m a. s. l.)
1 (1.2)	Black Sea Region Coast (mid zone)	500 – 900
1 (1.3)	Black Sea Region Coast (High elevation zone)	901 – 1,300
2 (2.3)	Black Sea Region Inland (High elevation zone)	1,100 – 1,500
3 (3.1)	Marmara Region * (low elevation zone)	0 – 500
3 (3.2)	Marmara Region * (mid zone)	501 – 1,000
3 (3.3)	Marmara Region * (high elevation zone)	1,001 – 1,500
4 (4.1)	Amanos Mountains Region (gene conservation area) (high elevation zone)	1,100 – 1,500

* Thracia is not in the breeding zones, it is only for seed production.

Under these two main breeding zones there are sub-breeding zones and one seed production zone (Tab. 1).

In addition to these breeding zones there are also seed transfer zones for oriental beech in Turkey (Tab. 2, Fig. 2). There are three seed transfer zones and one gene conservation area which are delaminated by geographic, geomorphologic and climatic conditions (Atalay 1992).

Tab. 2: Seed transfer zones and sub zones of oriental beech in Turkey

Seed transfer zones and subzones	Regions
1	***BLACK SEA REGION***
1.1	Camili Basin
1.2	Göktaş-Muratlı Çoruh Basin
1.3	Sarp-Ordu
1.4	Ordu-Sinop
1.5	Sinop-Ereğli
1.6	Ereğli-Akçakoca
1.7	Çatalca-Kocaeli
1.8	Samanlı Mountains
1.9	Istranca Mountains Eastern site
1.10	Istranca Mountains Mid and Western site
1.11	Istranca Mountains Southern site
2	***BACKWARD REGION OF BLACK SEA***
2.1	Ortaköy and Dökmeci Basin
2.2	Artvin Region
2.3	Yukarı Altıparmak (Barhal) Basin
2.4	Orta Harşit Basin
2.5	Koyulhisar-Taşova, Northern site of Kelkit River
2.6	Southern side of Kelkit River
2.7	Ladik-Boyabat Basin
2.8	Kastamonu Basin
2.9	Araç River Basin (Karabük-Araç)
2.10	Dokurcun Basin
3	***MARMARA REGION***
3.1	Samanlı Mountains western site
3.2	Katırlı-Avdan Mountains northern site
3.3	Southern Marmara (Kapıdağ-Karadağ)
3.4	Uludağ-Domaniç Mountains
3.5	Çatal-Ömeraltı Mountains
3.6	Biga-Gönen
3.7	Kazdağı
3.8	Akdağ (Dursunbey)
3.9	Demirci-Şaphane-Murat Mountains (North-East Aegean Site)
4	***GENE CONSERVATION REGION***

Wide distribution of oriental beech in Turkey results in the creation of seed transfer zones to facilitate seed production and afforestation. Beech forests have different growing regions according to site quality, productivity and floristic composition. Therefore all ecological properties which affect the growth of beech are considered when establishing these seed transfer zones. Oriental beech forests are divided into four main seed transfer zones and 30 subzones which have been established taking into consideration precipitation, temperature, aspect, altitude and the floristic compositions of the regions (Atalay 1992).

Oriental beech is important economically. Average prices of the third class beech round wood in Turkey was approximately 135 Turkish Liras (TL)/m^3 (83 €/m^3) in 2005, 138 TL/m^3 (70 €/m^3) (http://www.ogm.gov.tr/ip1/index) in 2008, 165 TL (84 €/m^3) in 2010.

GENETIC CONSERVATION *IN SITU* AND *EX SITU*

Gene pool conservation of oriental beech in Turkey is mainly through *in situ* conservation. These are seed stands, gene conservation areas and national parks. In Turkey there are 23 gene conservation forests of oriental beech. The area of these gene conservation forests is 3,042.9 ha. There are 28 seed stands which cover 3,439.6 ha.

The most important *ex situ* conservation activities are grafting and establishment of clonal archives and seed orchards. Although there are many seed orchards with conifers and some with broadleaves such as *Liquidambar orientalis* and *Sorbus torminalis* in Turkey, there is no seed orchard with oriental beech. There are other conservation programs in other locations such as National Parks and Nature Conservation areas where oriental beech stands can be used as seed sources if allowed. Seeds collected from these areas can be used for reforestation according to the seed transfer zones.

Fig. 1: Natural distribution of oriental beech in Turkey

Conservation of oriental beech genetic resources is done mainly by setting up seed stands and gene conservation forests through *in situ* programs. Seeds collected from these areas can be used for reforestation according to the seed transfer zones. In reforestation programs, although oriental beech is used, the minimum requirement is that the origin of the reproductive material is known and its adaptive characters appropriate for the ecological conditions at the regeneration site. For this purpose, the guidelines for oriental beech seed transfer zones (Atalay 1992) based on climate, soil and bedrock characteristics have been used until a more ecologically and genetically sound seed transfer set of guidelines is prepared.

The establishment of *ex situ* conservation plantations of oriental beech may be necessary in order to conserve the genetic variation of threatened populations that cannot be maintained at the original site such as relic populations. The objective will be to establish a new population that maintains as much as possible of the original genetic variability and allows for long-term adaptation to the local conditions at the new planting site.

FOREST RESEARCH

Research on oriental beech in Turkey is generally concentrated on regeneration and afforestation studies. There is only limited research on the genetics of oriental beech. Because of the requirement of genetic diversity of oriental beech forests a couple of projects has started, supported by the Turkish Ministry of Environment and Forestry and The Scientific and Technological Research Council of Turkey. One of these projects contains 33 populations with representatives from all seed transfer

Fig. 2: Breeding zones of oriental beech in Turkey

zones and marginal populations and this will provide genetic reference data for effective gene conservation activities concerning oriental beech in the future.

There are also research projects on provenance, seedling quality and other characteristics. Other studies include adaptive traits and information on height growth characteristics of various subpopulations under various site conditions. These research plots are of a long-term character, and will continue to provide results with increasing age.

In addition, in the Forestry Faculties of Universities the main purpose of a number of ongoing projects is to study the genetic background, seeds germination-dormancy properties, adaptive properties of seedlings and is mainly directed to the protection and reproduction of oriental beech gene resources. These studies will contribute to creating conditions for preserving and increasing proportion of this species in the forest stands.

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Reviewed

Contact

Dr. Gaye Eren Kandemir
Turkish Ministry of Environment and Forestry
Forest Tree Seeds and Tree Breeding Research Directorate
Dept. of Biotechnology, Gazi Tesisleri, 3'nolu Bina, 06560 Ankara, Turkey
tel.: (+90312)2126519/128
e-mail: gayeeren@gmail.com

EUROPEAN BEECH (*FAGUS SYLVATICA* L.) FORESTS IN THE UKRAINE

Hryhoriy Krynytskyy[1] – Vasyl Parpan[2] – Roman Kuziv[1]

[1] Ukrainian National Forestry University, Gen. Chuprynky Str. 103, 79057 Lviv, Ukraine
[2] Ukrainian Research Institute of Mountain Silviculture
Grushevskogo Str. 31, 79000 Ivano-Frankivsk, Ukraine

ABSTRACT

Information on the distribution of European beech as a forest resource in the Ukraine is presented. The significance of this tree species is discussed, and information on beech virgin forests is also presented. The principal felling methods for beech forests are characterized. Fruiting data and natural reproduction of European beech are outlined. In the Ukraine, European beech occurs naturally only in the Carpathians (up to 1,400 m above the sea level), Sub-Carpathians and at higher elevations in the Volyn-Podillya highlands. The area of beech forests is 503,000 ha, of which beech virgin forests are around 39,000 ha. In the Ukraine beech is characterized by high productivity and an uneven age structure. The beech stands are generally managed under the shelterwood silvicultural system (on 90 – 94% of the area) while much less selective fellings are used (less than 5%) and clearcuts (1.5 – 2%).

Key words: European beech (*Fagus sylvatica* L.), бук (in Ukrainian), Ukraine, distribution, forest resources, methods of principal felling systems, fruitage, natural reproduction

EUROPEAN BEECH DISTRIBUTION IN UKRAINE

In the Ukraine, European beech (*Fagus sylvatica* L.) occurs naturally only in the Carpathians, Sub-Carpathians and at higher elevations in the Volyn-Podillya highlands (Fig. 1). The modern border of the continuous distribution of European beech is almost identical with the border of the Carpathian sub-mountains. At the north-east of this border, beech has only isolated distribution. The border of this isolated distribution of European beech follows approximately the line Volodymyr-Volynskyy, Kremenets, Sataniv, Hermakivka, Kamyanets-Podilskyy (Molotkov 1966). Beyond this borderline, only individual trees or small groups of European beech are reported close to the village Goryngrad, situated 40 km east of Rivne (Molotkov 1966), in the Novomalyn forest of the State Enterprise "Ostrog forestry management" (south of Rivne) (Ivchenko, Voytyuk 1978), north-east of Kremenetsk mountains in the Volyn forest of the State Enterprise "Kremenets forestry management" (Melnyk, Korinko 2005), close to the town Starokostyantynova in the Khmelnytsk area (Melnyk, Korinko 2005, Postrygan 1957, Bilous 1962b), near Kuzminsk in the Vyshnivetske forest of the State Enterprise "Yarmolynets forestry management", near Verbovets in the Grytsiv forest (Khmelnytsk area), close to the village of Stanislavchyk in the Khmelnytsk region and the village of Shenderivka

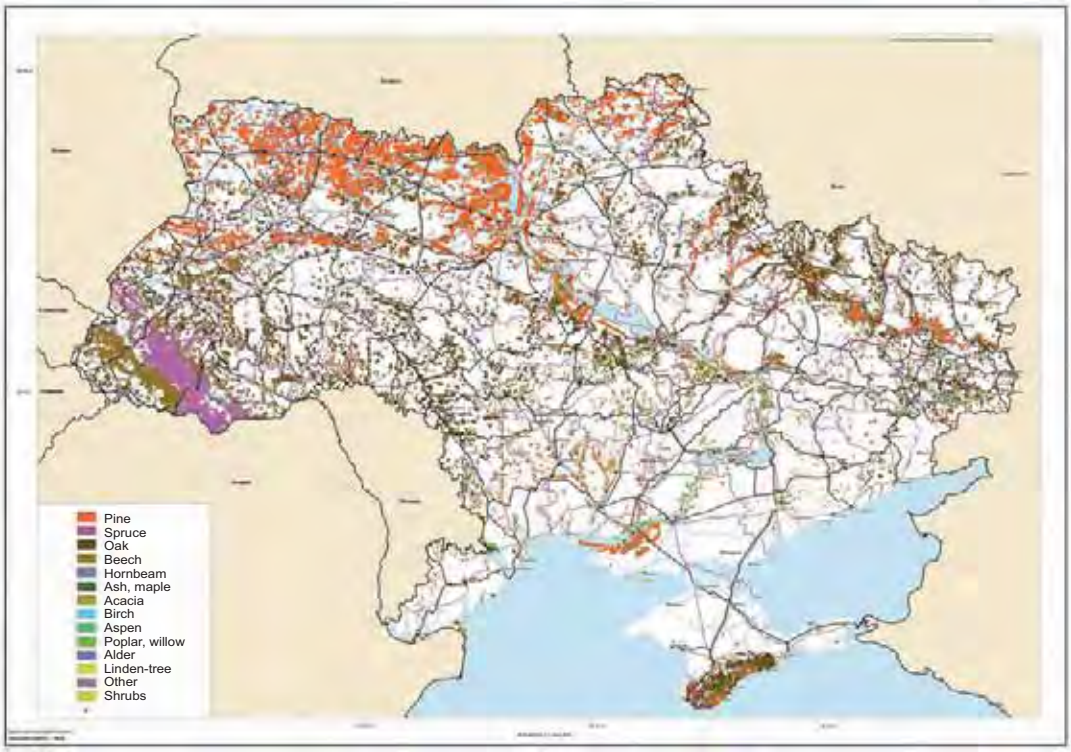

Fig. 1: Distribution map of European beech and other species in Ukraine

Source: developed by Ukrainian Research Institute of Forestry and Forest Melioration named after G. N. Vysotsky (URIFFM)

in the Mogyliv-Podilskyy region of the Vinnytsya area (Bilous 1962b, Zaveruha, Ivchenko 1986), close to the town of Murovani Kurylivtsi and the villages Berezove in the Murovane-Kyrylivetskyy region of the Vinnytsya area (Melnyk, Korinko 2005, Zaveruha, Ivchenko 1986).

Beyond the north-east border of the distribution range in the vicinity of Cherkassy, Zhytomyr, Vinnytsya or Kyiv, European beech is partly present in artificially established stands, and despite a dry continental climate, it grows rather well (Bilous 1962a, c, 1995).

In the Ukraine, the largest beech forest massifs are situated on the southwestern side of the Carpathian mountains, within an altitudinal span of 500 to 1,200 m, characterized by sufficient precipitations (700 to 1,200 mm per year), high air humidity, and mild temperature without major fluctuations in the winter (Shelyag-Sosonko, Andriyenko 1985). Pure beech forests occur in the altitudinal belt between 600 and 800 (900) m a. s. l. This is the ecologically optimal altitudinal range, where beech almost completely out-competes all other species (Molotkov 1966).

In the Carpathians European beech plays an essential role in forming tree stands up to 1,300 to 1,350 m, and solitary beech trees reach elevations up to 1,400 – 1,450 m, for example at the mountain Goverla (Molotkov 1966).

On the eastern limit, beech occurs over 280 m above sea level (Melnyk, Korinko 2005). Here the climate and ecological conditions for European beech are very specific. Temperature fluctuations, particularly the winter minimum temperature, and a lower air humidity negatively influence European beech and limit its range (Molotkov 1966, Pogrebnyak 1968).

FOREST RESOURCES OF EUROPEAN BEECH IN UKRAINE

Stands with the prevalence of European beech in the Ukraine represent almost 7.4% of the forest area (Parpan, Stoyko 1995). The area of beech stands managed by the State Forestry Committee of the Ukraine in six western regions with an almost continuous natural distribution of European beech is 502,889 ha, out of which 53.3% is situated in the Zakarpattya, 18.1% in the Lviv region, 17.5% in the Ivano-Frankivsk region, 8.3% in the Chernivtsi region, and only 2.6% and 0.2% in the Ternopil and Khmelnytsk regions, respectively.

In the mountains, 78.3% of beech forests grow and 21.7% in the highlands. In the Zakarpattya region, mountain conditions represent 99.7% of the area of beech forests, whereas in the Ivano-Frankivsk, Lviv and Chernivtsi regions these shares are 81.4%, 49.5% and 23.3%, respectively.

In the mountains, 9.7% of beech forests grow on very steep slopes (over 30° on south slopes and over 35° on north slopes), 47.9% slopes are steep (21 – 30° on south slopes and 21 – 35° on north slopes), and 35.0% are moderate (11 – 20°). Very steep and steep slopes are most frequent in the Zakarpattya region (11.8% and 52.7%, respectively), which shows the important soil protection, water protection and water regulating function of beech forests in this region.

Optimum, and nearly optimum sites (nutrient-rich fresh and moist soils) represent 64.6% of the beech stands area. Most fresh rich soils are present in the Ternopil and Khmelnytsk regions (90.9 and 92.9% respectively), but a significant part can be found in the Chernivtsi region (41.7%). In the Lviv and Zakarpattya regions, most beech sites are represented by wet rich soils (56.4 and 48.7%, respectively), whereas in the Ivano-Frankivsk region, most represented are wet, moderately rich soils (53.5%). In total, of the range of European beech forests 35.4% are found on sites with fresh and moderately nutrient-rich soils.

Growing mainly in favourable habitats, European beech forms highly productive forest stands: 32.2% of the beechwood area are classified as Ia quality class or higher, and in some places beech stands even of reach quality classes Ic and even Id. The largest percentage of highly productive stands is found in the area of Ternopil (43.5%), followed by Lviv (37.2%), Chernivtsi (35.9%), Khmelnytsk (35.0%), Zakarpattya (33.6%), and Ivano-Frankivsk (18.9%).

Because of poorly regulated control, and after the Second World War destruction of the forest, the current age structure of beech stands is extremely irregular. In particular, large areas are represented by forest stands of the third and fourth age class[1] (22.9% and 24.1%, respectively) and the proportion of the other age classes is quite small. For instance, the 8th, 9th and 10th age classes represent only between 2.8 and 3.9 of the beech stand area. Especially affected is the age structure of beech stands in the Ternopil area, where 43.7% of stands belong to the 4th age class, 21.1% to the 5th, and 13.9% to the 3rd age class. Predominance of beech stands of the 3rd to 5th age classes (especially compared to older stands) is characteristic also for the Lviv, Ivano-Frankivsk and Chernivtsi regions but is less pronounced in the Zakarpattya region.

[1] Age class span is 20 years. The oldest tree stands belong to the 16th age class.

Pure stands represent 57.4% of the beech area, while 42.6% of stands are mixed. The largest proportion of pure stands is found in the Zakarpattya area (64.9%), whereas they are considerably less represented in the other areas (Ivano-Frankivsk 52.3%, Lviv 48.9%, Ternopil 46.0%, Chernivtsi 43.0%), and the lowest proportion is found in the Khmelnytsk area (21.3%), which means that towards the north-eastern limit, the area of pure beech stands is decreasing.

BEECH VIRGIN FORESTS

Beech virgin forests of Ukraine represent a unique natural area. A decision was made by World Heritage UNESCO in June 2007, to include it together with beech virgin forests of eastern Slovakia in the World Natural Heritage category under the designation "Beech Virgin Forests of Carpathians".

The series of UNESCO-protected beech virgin forests consists of ten separate forest complexes situated in a 185 km long east-west gradient from the Chornohirskyy Hrebet in the Ukraine to the Bukovske Verhy and Vihorlat mountains in Slovakia.

Beech virgin forests in Ukraine occupy in total 38,680 ha. The largest massifs are located on the Polonyna ridge (13,500 ha) and in the Svydovets (11,240 ha). Beech virgin forests are also found in the Gorgany (6,094 ha), Chornohory (4,092 ha), Marmarosha regions (3,600 ha), and in the Volcanic Carpathians (154 ha).

Most beech virgin forests are situated below the elevation of 1,000 m a. s. l., and fewer occur within the altitudinal range between 1,000 and 1,400 m and very rarely they are found over 1,400 m. Most frequently they occur on slopes of 20 to 30° inclination.

A major part of beech virgin forests is formed of pure stands, but considerable areas are represented by mixtures with *Picea abies* (L.) Karst., *Abies alba* Mill., *Acer pseudoplatanus* L. and other tree species.

Beech virgin forests are inhabited by many endemic, rare and endangered elements of flora and fauna. They have a very important aesthetic and recreational function.

From the scientific point of view, beech virgin forests of Ukraine represent a valuable object for studies on the history of the development of vegetation cover during the postglacial period. Its structural organization with peculiarly high biotic diversity, developmental dynamics and decomposition processes can be used for building models of sustainable forest use, as well as for the transformation of the current forest use towards close-to-nature management models.

FOREST MANAGEMENT IN BEECH STANDS

At present, beech stands in the Ukraine are generally managed under the shelterwood system. Much less selective fellings are used, and very rarely clearcuts. For the period 1999 to 2008, shelterwood fellings were planned on 93.7% of the area while prescribed cutting, selective fellings and clearcutting were planned for 4.8% and 1.5%, respectively.

However, even though clear fellings are avoided, natural regeneration of beech stands is not always warranted. During the period 1999 to 2008, beech forest stands were naturally regenerated on 69.3%

of felling area only, whereas the remaining felling area (30.7%) necessitated being reforested. This means that on a considerable area, beech natural regeneration was insufficient, not only after clear fellings, which is quite typical, but also after shelterwood fellings. However, as a rule, beech stands of artificial origin with the highest tree quality are regenerated naturally.

There is not a regular periodicity educed in beech fruit set in the Carpathians (Maltsev 1980). Prolific beechnut crop occurs on average once in ten years, moderate crops are repeated more often, every four to six years (Molotkov 1966). In the western part of the Podillya highlands, good harvest of European beech nuts has been recorded once in 12 to 15 years, weak and moderate crops once on a two to four years cycle (Krynytskyy et al. 2004).

Tab. 1: European beech fruitage dynamics in Volyn-Podillya highlands (north-eastern part of beech area)

Year	Nuts harvest, kg/ha	Nuts quantity, 1,000/ha		The proportion of healthy nuts, %	Mass 1,000 seed crops, g	Crop capacity category
		total	good quality			
2003	269 ± 24	2,124 ± 177	447 ± 37	21.0	133.2	very poor
2004	17 ± 2	185 ± 29	0.6 ± 0.1	0.3	90.6	absence
2005	320 ± 23	1,887 ± 129	1,249 ± 85	66.2	169.7	poor
2006	351 ± 19	2,189 ± 181	1,265 ± 69	57.8	160.1	poor
2007	102 ± 12	700 ± 86	227 ± 28	32.4	146.0	absence
2008	323 ± 23	1,905 ± 123	1,095 ± 70	57.5	170.0	poor

Within our research conducted at the Sukhodil beech site (western part of the Podillya highlands) during the period 2003 – 2008, findings show one year of absence of fruiting of European beech, two very poor and three poor crops were registered (Table 1). The proportion of filled living seeds ranged from 0.3 to 66.2%. A considerable part of the nut crop was empty (14.8 – 71.5%) and disease-affected (11.9 – 42.7%). During the autumn and winter periods the healthiest nuts, and in some years even the entire seed crop (99.5%) were predated by murine rodents.

In general, beech regeneration in the Carpathians is good (Golubets, Malynovskyy 1968, Gorshenin 1974, 1976, Hensiruk 1995, Krynytsky, Savych 1973, Krynytsky et al. 2004, Parpan, Viter 1999, Saban 1995, Tretyak 1954 and others]. In mature and over-mature beech and oak-beech stands, up to 5,000 seedlings and undergrowth trees per hectare were recorded in 10% of beech stands, 5,000 to 10,000 seedlings per hectare on 24%, 10,000 to 20,000 seedlings per hectare on 38%, 20,000 to 50,000 seedlings per hectare on 17%, and 50,000 to 100,000 seedlings per hectare on 11% (Molotkov 1966). In optimum conditions, with the stocking of 0.6 – 0.7 and under a rich fruit set, almost 200,000 seedlings per hectare may appear (Krynytsky, Savych 1973, Tretyak 1954).

The relatively low success of natural regeneration in beech stands under current forestry practice is not caused by infrequent heavy-crop years, but rather by insufficient protection of the beech understory during the main felling operations.

Our experiments conducted at the Sukhodil beech site showed that the main methods of shelterwood and selection fellings ensure a satisfactory natural regeneration of European beech. In 2003 – 2008, the highest number of seedlings and understory trees of beech appeared in the compartment where regular two-stage shelterwood felling was performed, namely 23,600 individuals per hectare. Slightly

less seedlings were found in the compartment with the selection ("plenter") fellings of moderate and high intensity (21,300 and 20,300 individuals per hectare). Considerably less seedlings and understory trees appeared in the compartments managed under the three-stage group-selection system, regular three-stage shelterwood cutting and three-stage group-shelterwood fellings (15,600, 13,000 and 10,000 seedlings per hectare, respectively). In the compartments managed using group selection felling and Wagner irregular shelterwood fellings, 8,500 and 7,000 seedling per hectare appeared, whereas on the control plot without any felling, understory density was 6,600 individuals per hectare. In the compartments with clear and strip fellings, the number of understory trees was even considerably smaller compared to the control plot, namely, 2,400 and 3,800 seedlings per hectare.

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Reviewed

Contacts

Prof. Hryhoriy Krynytskyy
Ukrainian National Forestry University
Gen. Chuprynky Str. 103, 79057 Lviv, Ukraine
e-mail: krynytsk@ukr.net

Reviewers Directory

Prof. Alexander H. Alexandrov, D.Sc.
Forest Research Institute
Kliment Ohridski Blvd. 132
BG-1756 Sofia
Bulgaria
E-mail: forestin@bas.bg

Ricardo Alía, Dr.
INIA
Avda A Coruña, km 7.5
ES-28040 Madrid
Spain
E-mail: alia@inia.es

Prof. Alvaro Aunós
Univesity of Lleida
Rovira Roure 191
ES-25.198 Lleida
Spain
E-mail: alvaro.aunos@ull.es

Gregor Božič, Dr.sc.
Slovenian Forestry Institute
Večna pot 2
SI-1000 Ljubljana
Slovenia
E-mail: gregor.bozic@gozdis.si

Peter Brang, Dr.
WSL Swiss Federal Institute of Forest,
Snow and Landscape Research
Zuercherstrasse 111
CH-8903 Birmensdorf
Switzerland
E-mail: brang@wsl.ch

Prof. Dr. Harald Bugmann
Forest Ecology, Inst. of Terrestrial Ecosystems
Dept. of Environmental Sciences
ETH Zurich, CHN G76.1
CH-8092 Zurich
Switzerland
E-mail: harald.bugmann@env.ethz.ch

Dr. ir. Joukje Buiteveld
Alterra, Wageningen UR
P. O. Box 47
NL-6700 AA Wageningen
The Netherlands
E-mail: joukje.buiteveld@wur.nl

RNDr. Václav Buriánek
Forestry and Game Management Research Institute
Strnady 136
CZ-156 04 Praha 5-Zbraslav
Czech Republic
E-mail: burianek@vulhm.cz

Ing. Rudolf Bruchánik, PhD.
Lesy SR, š. p.
Námestie SNP 8
SK-975 66 Banská Bystrica
Slovakia
E-mail: rudolf.bruchanik@lesy.sk

Dr. Alexander Delkov
Forest Research Institute
St. Kliment Ohridski Blvd.132
BG-1756 Sofia
Bulgaria
E-mail: forestin@bas.bg

Rumen Dobrev, D.Sc.
Forest Research Institute
Kliment Ohridski Blvd. 132
BG-1756 Sofia
Bulgaria
E-mail: r.d.dobrev@mail.bg

Dr. Bruno Fady, senior scientist
INRA-URFM
Domaine St Paul
FR-84914 Avignon
France
E-mail: fady@avignon.inra.fr

John Fennessy, M.Sc.
Research Manager Tree Improvement & Non-wood Forest
COFORD
Department of Agriculture (4W)
Kildare Street
Dublin 2
Ireland
E-mail: john.fennessy@coford.ie

PD Dr. Matthias Fladung
vTI, Institute of Forest Genetics
Sieker Landstr. 2
D-22927 Grosshansdorf
Germany
E-mail: matthias.fladung@vti.bund.de

Norbert Frank PhD.
associate professor
Institute of Silviculture and Forest Protection
Faculty of Forestry
University of West Hungary
Ady E. str. 5.
HU-9400 Sopron
Hungary
E-mail: frank@emk.nyme.hu

Ing. Josef Frýdl, CSc.
Forestry and Game Management Research Institute
Strnady 136
CZ-156 04 Praha 5-Zbraslav
Czech Republic
E-mail: frydl@vulhm.cz

Univ-Doz. Dr. Dr. Thomas Geburek
Federal Research Centre for Forests, Natural Hazards and Landscape
Department of Genetics
Hauptstraße 7,
A-1140 Wien,
Austria
E-mail: thomas.geburek@bfw.gv.at

Doc. Ing. Dušan Gömöry, DrSc.
Technical University in Zvolen
TG Masaryka 24
SK-960 53 Zvolen
Slovakia
E-mail: gomory@vsld.tuzvo.sk

Dr. Bernhard Götz
University of Applied Sciences
Botanical Gardens
Am Zainhammer 5
D-16225 Eberswalde
Germany
E-mail: bgoetz@fh-eberswalde.de

Dr. Joso Gračan
Hrvoja Macanovića 43
HR-10 000 Zagreb
Croatia
E-mail: josog@sumins.hr

Jon Kehlet Hansen, Dr.
Senior Scientist
Forest & Landscape Denmark
Hørsholm Kongevej 11
DK-2970 Hørsholm
Denmark
E-mail: JKH@life.ku.dk

Prof. Dr. Hajri Haska
Director of Forest Directory
Agency of Environment and Forestry
Ministry of Environment, Forest and Water Administration
Rruga : "Halil Bega", Nr: 23, Tirane
Albania
E-mail: haskahajri@yahoo.com

Alwin Janßen, Dr. forest. Dipl.-Forstwirt,
Northwest German Forest Research Institute
Department of Forest Genetic Resources
Prof.-Oelkers-Str. 6
D-34346 Hann. Muenden
Germany
E-mail: alwin.janssen@nw-fva.de

Ir. Jitze Kopinga
Alterra Wageningen UR
Postbus 47
NL-6700 AA Wageningen
The Netherlands
Email: jitze.kopinga@wur.nl

Dr. François Lefevre
INRA, URFM - Ecologie des Forets Mediterraneennes
Domaine Saint Paul, Site Agroparc,
FR-84914 Avignon Cedex 9
France
E-mail: lefevre@avignon.inra.fr

Ing. Roman Longauer, CSc.
National Forest Centre – Forest Research Institute
T. G. Masaryka 22
SK-960 92 Zvolen
Slovakia
E-mail: Roman.Longauer@fris.sk

Doc. Ing. Ivan Lukáčik, CSc.
Technical University in Zvolen
TG Masaryka 24
SK-960 53 Zvolen
Slovakia
E-mail: lukacik@vsld.tuzvo.sk

Prof.dr.M.Sc. Valeriu-Norocel Nicolescu
University "Transilvania" of Brasov
Faculty of Silviculture and Forest Engineering
Sirul Beethoven nr. 1
RO-500123 Brasov
Romania
E-mail: nvnicolescu@unitbv.ro

Dr. Eduardo Notivol
C.I.T.A. – Government of Aragon
Forest Resources Unit
Zaragoza
Spain
E-mail: enotivol@aragon.es

Prof. Ing. Ladislav Paule, PhD.
Technical University in Zvolen
TG Masaryka 24
SK-960 53 Zvolen
Slovakia
E-mail: paule@vsld.tuzvo.sk

Alistair Pfeifer, M.Sc.
Research Programme Manager
Research Division, Department of Agriculture
Kildare Street, Dublin 2
Ireland
E-mail: alistair.pfeifer@gmail.com

Dr. Flaviu Popescu
Forest Research and Management Institut - Simeria
Str. Biscaria. 1,
Simeria, HUNEDOARA
Romania
E-mail: flaviu.popescu@rdslink.ro

Dr. Peter Rotach
Forest Management Group, Department of Environmental Sciences, Swiss Federal Institute of Technology (ETH)
Zürich
Switzerland
E-mail: peter.rotach@env.ethz.ch

Prof. dr hab. Janusz Sabor
Al. 29 Listopada 46
PL-31-425 Kraków
Poland
E-mail: rlsabor@cyf-kr.edu.pl

Heinz Peter Schmitt, Dr.
Forstdirektor
Am Hang 1
D 59872 Meschede
Germany
E-mail: Schmitt-Remblinghausen@t-online.de

Prof. Dr. Álvaro Soto de Viana
Universidad Politécnica de Madrid
ETSI Montes. UD Anatomía, Fisiología y Genética
Ciudad Universitaria s/n
ES-28040 Madrid
Spain
E-mail: alvaro.soto.deviana@upm.es

Ing Alain Valadon
Conservatoire Génétique des Arbres Forestiers
USC ONF-INRA
Centre de Recherches d'Orléans
2163 Avenue de la pomme de pin
CS 40001 ARDON
F-45 075 OrleansS Cedex 2
France
E-mail: valadon@orleans.inra.fr

Prof. dr. Dragica Vilotić
Faculty of Forestry University in Belgrade
Kneza Viseslava 1
RS-11030 Belgrade
Serbia
E-mail: vilotic@ptt.rs

Ir. Sven M.G. de Vries
PO BOX 47
NL-6700 AA Wageningen
The Netherlands
E-mail: sven.devries@wur.nl

Dr. Georg von Wühlisch
Institute for Forest Genetics
Sieker Landstr. 2
D-22927 Großhansdorf
Germany
E-mail: georg.wuehlisch@vti.bund.de

Asc.Prof.Dr. Petar Zhelev
University of Forestry
BG-1756 Sofia
Bulgaria
E-mail: zhelev@ltu.bg

www.vulhm.cz