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Breeding programmes of Norway spruce *Picea abies* (L.) Karst. in the Czech Republic

Abstract: In the Czech Republic, Norway spruce has a natural representation in all forest altitudinal vegetation zones, in some of which (FAVZ 1, 2 and 9), however, it is scarce. The three basic climatic ecotypes of spruce identified in the Czech territory, i.e. an upland ecotype, a higher elevation ecotype and a mountain ecotype, can be characterised on the basis of the forest altitudinal vegetation zones of their origin. The paper presents the breeding work completed so far and all the breeding programmes implemented for Norway spruce, including projects worked out for the Krkonoše National Park.

Additional key words: ecotype, altitudinal vegetation zone

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Introduction

Breeding programs for forest tree species in the Czech Republic must consider the great variability of its natural conditions. Geologically, the country is divided into two areas: Hercynian and Carpathian. A total of 41 natural forest areas (NFA) have been established on the basis of a typological study of forests. These areas differ in the soil-forming parent rocks, configuration of the terrain, and macroclimate (Plíva and Žlábek 1986). Most of NFA belong to the Hercynian area and a smaller part (NFA No 32 and 35–41) lie in the Carpathian area. This division of the country is very important to forestry, among other things, to the transfer of the reproduction material of forest tree species.

Spruce distribution

On the basis of current knowledge it is assumed that the natural proportion of Norway spruce *Picea abies* (L.) Karst. was formerly at a level of 11.2% by area. However, at present, spruce stands constitute 54.1% of the area of forests in the country. Most of those stands were artificially planted in the past. Consequently, pure spruce stands predominate also in unsuitable locations. The origin of the reproduction material employed is frequently unknown. In the past, the natural reproduction of spruce occurred only at poorly accessible sites. As a result, there are only few original populations of Norway spruce in the Czech Republic.

Climatic ecotypes

Within the Czech Republic, nine forest vegetation zones (FVZ) are distinguished. Norway spruce is naturally present in all these zones, but in vegetation zones 1, 2 and 9 its proportion is minimal. In the country, it is possible to identify three basic climatic ecotypes of spruce: upland, higher elevation and mountain (Hynek 1997). Each of these ecotypes can be described both by its forest vegetation zones, in which natural selection occurrs, and by almost identical phenotypic characteristics. However, current legislation, concerned with permitted transfers of spruce reproduction material, ignores these ecotypes.

Breeding of Norway spruce in the Czech Republic

The first provenance areas, among them those in the Beskids, were established in the 1940s within a series of IUFRO areas. These areas are permanently evaluated and the results are regularly presented by the employees of VÚLHM (Research Institute of Forestry and Game Management; RIFGM) Jíloviště-Strnady. Further provenance areas in the IUFRO series were established in the 60s, once again by the employees of RIFGM. Provenance research further continued, e.g. in a series of provenance areas established in cooperation between the research institutes in Strnady and Graupa. All these areas were evaluated primarily by Vančura and Vinš (1983) and also by Beran (1996) from RIFGM.

Towards the end of the 70s, work was commenced on the vegetative propagation of spruce by grafting and cuttings, and later by propagation *in vitro*. These activities led to the establishment of seed orchards. The more extensive use of cuttings was connected with a gradual improvement in this technique of vegetative propagation. To date, the techniques of propagation by cuttings from adult spruce trees, surviving in areas with high pollution levels such as the Krkonoše and the Ore Mts, have been mastered relatively well (Chmelíková and Cudlín 1993).

New methods in spruce breeding are connected with controlled crossing. The first work involving controlled crossing was carried out on adult trees by Vinš, the results, however, have not been published. Grafts for controlled crossing were not used until the beginning of the 80s (Hynek 1982).

The testing of the progeny of approved stands was started in the 70s by Šindelář (1982). Test plantings were established the same way as classic provenance areas. Short-term tests of these progenies were not performed. Such an approach was implemented only later in the testing of approved stands and seed orchards of Scots pine (*Pinus sylvestris* L.) and European larch (*Larix decidua* Mill.). At the present time, tests are carried out both on generative progeny from uncontrolled pollination and controlled crossing and on vegetative progeny from grafting and cuttings. The number of individuals grown from cultures *in vitro* is negligible and thus cannot be evaluated.

Genetic markers of forest tree species, with the exception of monoterpenes (Kaňák 1999), were not used until the 1990s. Currently, two institutions are studying the subject of spruce trees: RIFGM Jíloviště-Strnady (Ivanek 2001) and the Šumava National Park and NFA (Mánek 2001). At the laboratory in Šumava, tests were carried out on the differences between the climatic ecotypes of spruce over the whole area of the country using bioenzymes and also partly using DNA. Significant results were obtained from these tests, e.g. for spruce originating from the 9th forest vegetation zone in the Krkonoše Mts and for several other populations of the upland ecotype. Mánek (2001) obtained remarkable results in testing a population originating from the Boubín National Nature Reserve.

Spruce breeding programmes

The preparation and implementation of breeding programmes is based on two or three kinds of populations. A source, or basic, population is considered to consist of the best-phenotype adult spruce stands. A breeding population consists of selected parts of the source population which are subjected to appropriate testing. A production population is employed for further propagation of the material from breeding. Source and production populations are included in all breeding programmes. Simpler and thus less effective breeding programmes do not involve a breeding population. The first-generation seed orchards are classic examples: here the reproduction material is used without testing the individual clones employed.

Targets of breeding programmes

Under the conditions as variable as those in the Czech Republic, it is useful to prepare breeding programmes for particular forest tree species and their climatic ecotypes separately for each natural forest area. The purpose and target of each breeding programme proposed are established in relation to the current condition of the Norway spruce population.

- The basic objective of breeding programmes is to increase the production of wood and to enhance its quality.
- As a consequence of the interference in the original genetic sources of domestic forest tree species, there is a growing need to preserve autochthonous populations of forest trees.
- In relation to the burden placed on forest ecosystems by anthropogenic activity, especially by industrial emissions, it is also necessary to preserve populations that are not autochthonous, but are of good quality.

Breeding programmes for Norway spruce implemented under the conditions of the Czech Republic

Establishment of operational spruce seed orchards is considered to constitute the simplest breeding programme. Among the orchards those originating in forest vegetation zone 8 are also important. In the

Czech Republic, spruce seed orchards were established using clones from the Hrubý Jeseník, Šumava, Krkonoše, Jizerské and Ore Mts. Most of the oldest seed orchards were established *ex situ*. In relation to the limited fertility of spruce grafts, the amount of seed material from these orchards is not significant. Nonetheless, a number of seed orchards are now productive. In some cases, however, the production of these orchards is not even fully utilised.

So far, no spruce seed orchards has been tested in the area of the Czech Republic. The same applies to most seed orchards of other forest tree species in the country. This is because it has not been possible to obtain the necessary financial means for testing. Preliminary practical experience suggests that seed orchards should be planted either *in situ* or, for mountain ecotypes, under the conditions as close as possible to those of their site of origin.

It will be necessary to propose closing a number of the existing Norway spruce seed orchards for various reasons, e.g., an unsuitable location of a seed orchard, an improper set of clones, restitution rights of owners, etc.

The first breeding programme for forest tree species, developed in the Czech Republic, was concerned with the rescuing and reproduction of Norway spruce originating in the Krkonoše National Park (KRNAP). The reproduction populations of this programme consist of multiclone mixtures obtained from cuttings. The parent trees are individuals grown from young seedlings. This quite simple breeding programme, drawn up by Šindelář (1977), was implemented in cooperation between KRNAP and the RIFGM research station in Opočno (Jurásek et al. 1994) and over the years was extended in cooperation with the Academy of Sciences in České Budějovice. At present, the parent trees planted are being supplemented with clones from cuttings obtained from adult individuals having a higher tolerance to air pollution. Excess cuttings are set out in forest stands in the Krkonoše Mts to supplement the natural or artificial regeneration programmes. A similar programme for growing spruce cuttings from tolerant individuals was worked out for the requirements of the Ore Mts in cooperation with the Czech State Forests (Jurásek et al. 1999).

Several breeding programmes are under way for highly polluted areas such as the Ore Mts and the Jizerské Mts (Hynek 1990). These programmes include the creation of clone collections – clone archives of adult trees that either exhibit a greater tolerance to industrial air pollution (these are populations from higher elevations, particularly from forest vegetation zones 7 and 8) or constitute residues of the until-recently ignored upland ecotype originating in forest vegetation zones 3 and 4. In addition to testing the health state of these clones, the programmes provide for the testing of their generative progeny. With this in view, several areas in the Ore Mts and the Jizerské Mts have been planted with spruce grafts from higher locations (FVZ 7 and 8). It is expected that the planting of grafts of the upland ecotype of spruce from the Ore Mts will probably be carried out in 2004. The upland ecotype has not yet been employed in the Jizerské Mts. The first collections of a limited amount of seeds have already been made in the Ore Mts (Hynek and Malá 2000). Similar programmes have been developed for the area of Šumava where the planting of grafts is carried out regularly (Červenský and Hynek 1991).

The generative progeny of clones from the free pollination and controlled crossing of 1981 are already tested within the breeding programme for spruce from higher locations in the Ore Mts. Simultaneously, part of these progeny are also tested as rooted cuttings that are planted directly in the Ore Mts (Hynek and Malá 2000).

Over the last decade, greater emphasis was placed throughout the Czech Republic on the upland ecotype of spruce which was neglected until recently by foresters although individual trees of upland spruce frequently reach a height of over 50 m. In the past, this spruce was known only in the area around Kostelec nad Černými lesy and around Hluboká nad Vltavou. At present, larger populations are located in the Ore Mts (where the breeding programme is carried out in cooperation with the District Authority of Teplice (Hynek and Malá 2000), in the Labské pískovce NFA and in the České Švýcarsko NP (where the breeding programme is carried out together with the nature protection authorities), in the Křivoklát area, in Nízký Jeseník (establishment of a seed orchard has been prepared), Moravský kras and the Podyjí NP (Hynek and Malá 2000). In other natural forest areas, the occurrence of this ecotype is either lower or has not yet been recorded.

Example of a programme for the conservation of autochthonous spruce populations in the Krkonoše National Park

The native populations of spruce in our oldest national park are distinguishable by their age and phenotypic look.

Approximately until 1750, all spruce stands on the Czech side of the Krkonoše Mts reproduced naturally. In the following 100 years, until 1848, artificial reproduction was used, but the seedlings originated from the Krkonoše. During this reforestation, height transfer was not respected and seedlings from lower altitudes were planted at higher elevations. After 1848, seeds from other areas of the Czech Republic and

from abroad were imported into the Krkonoše region. For the reasons mentioned, all spruce trees and their stands older than 250 years in the Krkonoše are considered as autochthonous populations of this tree species. Such populations differ from allochthonous ones in the features of bark which is darker and rougher. At higher altitudes, the native populations have significantly narrower crowns with overhanging branches.

The new forest management plan envisages that 600 ha of stands would be classified as phenotypic category D. It is supposed that the area of such stands of all ages will be about 1000 ha. Furthermore, the fact that the allochthonous populations undergo intensive natural reproduction means significant difficulties.

The ongoing and partly realised programme for the conservation of the Krkonoše spruce has the following basic goals:

1. To identify autochthonous spruce populations (forest vegetation zones 5–8). In the mountain pine zone (FVZ 9), reforestation with spruce is not planned at all.
2. To use the autochthonous populations for generative reproduction as much as possible.
3. To use the cloning of spruce, above all, the propagation by cuttings from autochthonous populations or their offsprings (cutting of adult as well as young individuals).
4. To plant suitable broadleaved species and silver fir *Abies alba* Mill. under the canopy of allochthonous spruce stands to be converted.
5. To reduce natural reproduction in 1/3 of allochthonous spruce stands and plant under their canopy the reproduction material from the neighbouring autochthonous spruce stands.
6. To reach agreement with forest workers on making silvicultural interventions in spruce stands.

An obvious prerequisite for the success of the programme was to carefully document the work completed so far. This required convincing the outdoor forestry staff of the sense and importance of the project and preparing them for the task. A corresponding theoretical training course with practical demonstration took place already in 2001.

Further prospects of the spruce breeding programme

Spruce populations at the highest elevations (FVZ 8) are most endangered in the Ore Mts, Jizerské Mts, Krkonoše and Hrubý Jeseník Mts by air pollution, and, in the Šumava Mts, by bark beetles. Air pollution also threatens spruce populations in FVZ 7 in the Ore Mts and the Jizerské Mts, and, in recent years, especially in the Orlické Mts. In the latter case, the scantest attention has been paid so far to the Orlické Mts. The existence of other spruce populations is not in danger.

Breeding programmes for Norway spruce and, in general, for all forest tree species are long-term projects. In recent years, financial means for the breeding of forest trees have been substantially limited by the relevant ministries. Primarily because of cash shortages, a separate research project for testing seed orchards has not been launched. The private sector and the processing industry continue to underestimate the importance of forest tree breeding. In spite of these difficulties, however, it has been at least possible to ensure the survival of a certain part of the endangered populations of Norway spruce, either by approving these stands for seed harvesting and granting them the relevant period of protection, or by preserving some of the endangered populations through clone plantings.

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