ACTA SILVATICA & LIGNARIA HUNGARICA

AN INTERNATIONAL JOURNAL IN FOREST, WOOD AND ENVIRONMENTAL SCIENCES

VOLUME 12
SPECIAL EDITION
2016

UNIVERSITY OF WEST HUNGARY
PRESS

ACTA SILVATICA ET LIGNARIA HUNGARICA
AN INTERNATIONAL JOURNAL IN FOREST, WOOD AND ENVIRONMENTAL SCIENCES
issued by the Forestry Commission of the Hungarian Academy of Sciences

The journal is financially supported by the
- *Hungarian Academy of Sciences (HAS),*
- *Faculty of Forestry, University of West Hungary (FF-UWH),*
- *Simonyi Károly Faculty of Engineering, Wood Sciences and Applied Arts, University of West Hungary (SKF-UWH),*
- *National Agricultural Research and Innovation Center, Forest Research Institute (NARIC-FRI),*
- *Sopron Scientists' Society of the Hungarian Academy of Sciences (SSS).*

HU ISSN 1786-691X (Print)
HU ISSN 1787-064X (Online)

Manuscripts and editorial correspondence should be addressed to
MAGDOLNA STARK, ASLH EDITORIAL OFFICE
UNIVERSITY OF WEST HUNGARY, PF. 132, H-9401 SOPRON, HUNGARY

Phone: +36 99 518 122
Fax: +36 99 329 911
E-mail: aslh@nyme.hu
Information and electronic edition: http://aslh.nyme.hu

The journal is indexed in the CAB ABSTRACTS database of CAB International; by SCOPUS, Elsevier's Bibliographic Database, by EBSCOhost database and by De Gruyter Open Sp. z. o. o., Warsaw

Published by UNIVERSITY OF WEST HUNGARY PRESS,
BAJCSY-ZS. U. 4., H-9400 SOPRON, HUNGARY
Cover design by ANDREA KLAUSZ
Printed by LŐVÉR-PRINT KFT., SOPRON

DE GRUYTER OPEN DOI: 10.1515/aslh-2016-0001 *Acta Silv. Lign. Hung., Vol. 12, Spec. Edition (2016)*

The IUFRO 1964/68 Inventory Provenance Trial of Norway Spruce in Nyírjes, Hungary – results and conclusions of five decades

Éva Ujvári-Jármay

NARIC Forest Research Institute, Mátrafüred, Hungary

László Nagy

NARIC Forest Research Institute, Sárvár, Hungary

Csaba Mátyás

University of West Hungary,
9401 Sopron, Pf. 132, Hungary, e-mail: cm@emk.nyme.hu
(corresponding author)

The publication of this documentary study has been supported by the project „*Towards the Sustainable Management of Forest Genetic Resources*"
FORGER FP7- 289119, financed by the European Commission

About the authors

Éva Ujvári-Jármay is retired research counselor at the Experiment Station of the NARIC Forest Research Institute (ERTI) in Mátrafüred, Hungary

László Nagy is senior research associate at the Headquarters of the NARIC Forest Research Institute (ERTI) in Sárvár, Hungary

Csaba Mátyás, corresponding author, is professor emeritus at the Institute of Environmental and Earth Sciences, Faculty of Forestry, University of West Hungary, Sopron, Hungary

Citation of the paper

Ujvári-Jármay, É. – L. Nagy – Cs. Mátyás:
The IUFRO 1964/68 inventory provenance trial of Norway spruce in Nyírjes, Hungary – results and conclusions of five decades. Documentary study. *Acta Silvatica & Lignaria Hungarica*, Vol. 12, Special Edition (2016) 178 p. DOI: 10.1515/aslh-2016-0001

Contents

1 INTRODUCTION: The changing image of provenance tests

Provenance experiments are a forgotten treasure of forest research. For two centuries, well before the concept of genes and genetics was formulated, silviculturists started internationally supported experiments to investigate the *heritable differences* between populations of the same species, but of various origin (Langlet 1971). The original aim was to maximize productivity of artificially regenerated forests with best suited reproductive material. These tests had become the pioneering objects of study of intraspecific genetic variation. More than a century before Turesson described ecologically generated differentiation within plant species (Turesson 1925), foresters were already aware of the selective role of the environmental factors (first of all of climate) influencing the phenotypic appearance of trees and consequently also their vitality and economic value.

The tested populations considered autochthonous and adapted to the local site conditions they inhabited over many generations, were termed “provenances”. While detailed information about abiotic and genetic-biotic environmental factors shaping the standing genetic variation of the populations were unavailable (and, typically, remained so until the present), provenances were and are characterised by the site denomination where the seeds were collected; being usually a single, mature stand (e.g. a subcompartment), but often a larger area or even a forest district. In strict sense, “provenance” should be distinguished from “origin”: the latter stands for a seed source originating from a stand which has been artificially regenerated (transferred) on a location different from its original site. E.g. pedunculate oak of Slavonian provenance has been planted widely in Central Europe; the denomination of the seed collected in a transferred, second generation stand will be “Slavonian provenance of given origin”. In case of species widely transferred in historic times, usually this distinction cannot be made; this is especially the case with Norway spruce. Therefore the term provenance is used in this study without distinguishing between natural and planted populations, assuming at the same time a rather effective selective effect of local adaptive factors (see also chapter 2.2). In this sense, provenance is synonymous with “population grown from known seed source”.

It is not surprising that the interest about within-species differentiation of forest trees and its importance in forestry (Szőnyi – Ujvári 1970, 1975), leading to the initiation of international provenance trials of forest trees was the impetus for the founding of IUFRO in 1900 (Mátyás 1999). It is all the more strange that conclusions of these experiments with forest trees remained unnoticed for plant science until recent times.

The question has to be raised *why the analysis of phenotypic behavior measured in common gardens is still indispensable* when refined and fast molecular association techniques may serve as surrogates for common garden observations. In addition to the complexity of the inheritance background of quantitative traits, an *interpretation problem of molecular genetic results* arises from the fact that a*ssociation of DNA variation patterns with directly observable (phenotypic) traits along climatic clines* provides *no safe basis yet for clarifying processes* *and patterns of genetic adaptation*. For such reasons the importance of provenance tests remains also in an age of general dominance of molecular arguments.

There is another reason for the reanalysis and rediscovery of provenance tests: climate change. It turned out that changes in environment can be successfully mimicked with provenance tests. These tests provide a unique and the only chance to estimate the future behavior of tree populations in rapidly changing climates (Mátyás 1994). Therefore, *provenance testing of forest trees may still be one of the most important contributions of forestry to biological sciences* (Mátyás et al. 2010), because phenotypic traits (growth, phenology, health) measured in comparative tests can be directly interpreted as a simulation of climatic changes. They are unique because they have been mostly established with natural-state populations, adapted to specific conditions. They are unique also because these tests have been established across different climates, at numerous sites and maintained over decades. Due to the long-term character of the tests, these experiments may undergo during their lifetime also rare extreme events with high selective power, providing valuable insights to (micro-)evolutionary processes (see *Figures 8* and *9*).

Figure 1. View of the Nyírjes experiment in the Mátra Mts. (regular rectangles in the centre of the photo). Picture taken facing to North, with Galya Mountain in the background

2 HISTORY: Planning and establishment of the international test series

In 1959, on the proposal of Olof Langlet (Royal College of Forestry, Stockholm, Sweden), a second international provenance test was initiated by IUFRO for Norway spruce (the first test was started in 1938/39). The test was intended as an inventory, the purpose was *to test as many provenances as possible*, *regardless whether the seed sources were autochthonous or not*, and regardless whether the sampled stands were within or outside the borders of the natural distribution of Norway spruce (*Figure 2*).

"General aim of the experiment was the investigation of the intraspecific genetic variation of Norway spruce. Do regions of specific (eco-)types of Norway spruce exist, and how big is the variation between and within these regions? For practical purposes, it was important to find the best regions or provenances for seed supply. The final goal was to test a large number of sources and to select among them for further tree breeding" (*Krutzsch 1974*).

The project was organized by the Forestry College of the Royal University at Stockholm under the guidance of Peter Krutzsch and carried out from the beginning under the auspices of the Provenance Trial Working Group of the 22nd Section of IUFRO (Szőnyi – Ujvári 1970). An intensive period of seed collecting extended over the following 4 years. In 1964 the seed collection reached the volume of 1615 lots. In Hungary 11 seed sources were selected and provided for the Stockholm collection (see also *Tables 14*, *15*, in chapter 3.4 and *Appendix*, *Table A.4*[1]).

The seed lots were of very different kind, called "seed class" by Krutzsch, to express the presumed genetic differences due to the way of collecting the seed lot. First, the seeds were collected in different years. Secondly, there were lots from single tree collections, from stands, from a number of adjacent stands etc. Finally there were samples from commercial collections, identified only by the forest district and the elevation (see *Table A.15*).

In 1963, the detailed plans of the international trial were made in collaboration with Klaus Stern and Wolfgang Langner (Institute of Forest Genetics and Forest Tree Breeding at Schmalenbeck, Germany). In the spring of 1964, 1300 samples were sown in the nurseries of the Institute. In 1966, the seedlings were transplanted to the nurseries of Pein & Pein at Halstenbeck. No replications were used in sowing or in transplanting. The planting stock amounted to 1.1 million seedlings. Pein & Pein Nursery was in charge of transplanting, labeling, lifting, sorting and shipping of the material and had therefore an essential part in the success of the trial series.

Single tree plots seemed the only possibility to deal with the vast number of treatments, i.e. provenances. As a precaution against uncontrolled plant losses during the first years after plantation, the number of 25 replications was chosen.

Due to plant losses and for some other reasons, ultimately 1100 provenances were available at the end of the nursery period (*Figure 2*). This number was split up into 11 groups of 100 provenances each. As strata in the applied stratified randomization, geographical

[1] In order to limit the volume of the study, basic data and additional statistics have been placed into the Appendix (to be reached at the end of the paper). Appendix tables and figures are marked with the initial „A".

regions (Krutzsch 1974, *Figure 5*) were chosen, assuming that neighboring provenances should be equal or similar in performance. Thus the experimental unit of the trial is the block of 100 provenances with 25 plants each. The blocks are independent of each other, and each block can be regarded as a complete provenance trial in itself, containing material from the entire range of the collection. The 11 blocks were assumed to be equal in mean and within-block variance, thus directly comparable. The trial was initially planned for an active observation period of 20 years.

The design was presented at the 1967 provenance trial meeting of IUFRO at Pont-à-Mousson, France and all interested institutions were invited to participate in the field trials. The Hungarian Forest Research Institute (ERTI) applied for and obtained one of the 20 planned international experiments (*Table 1*).

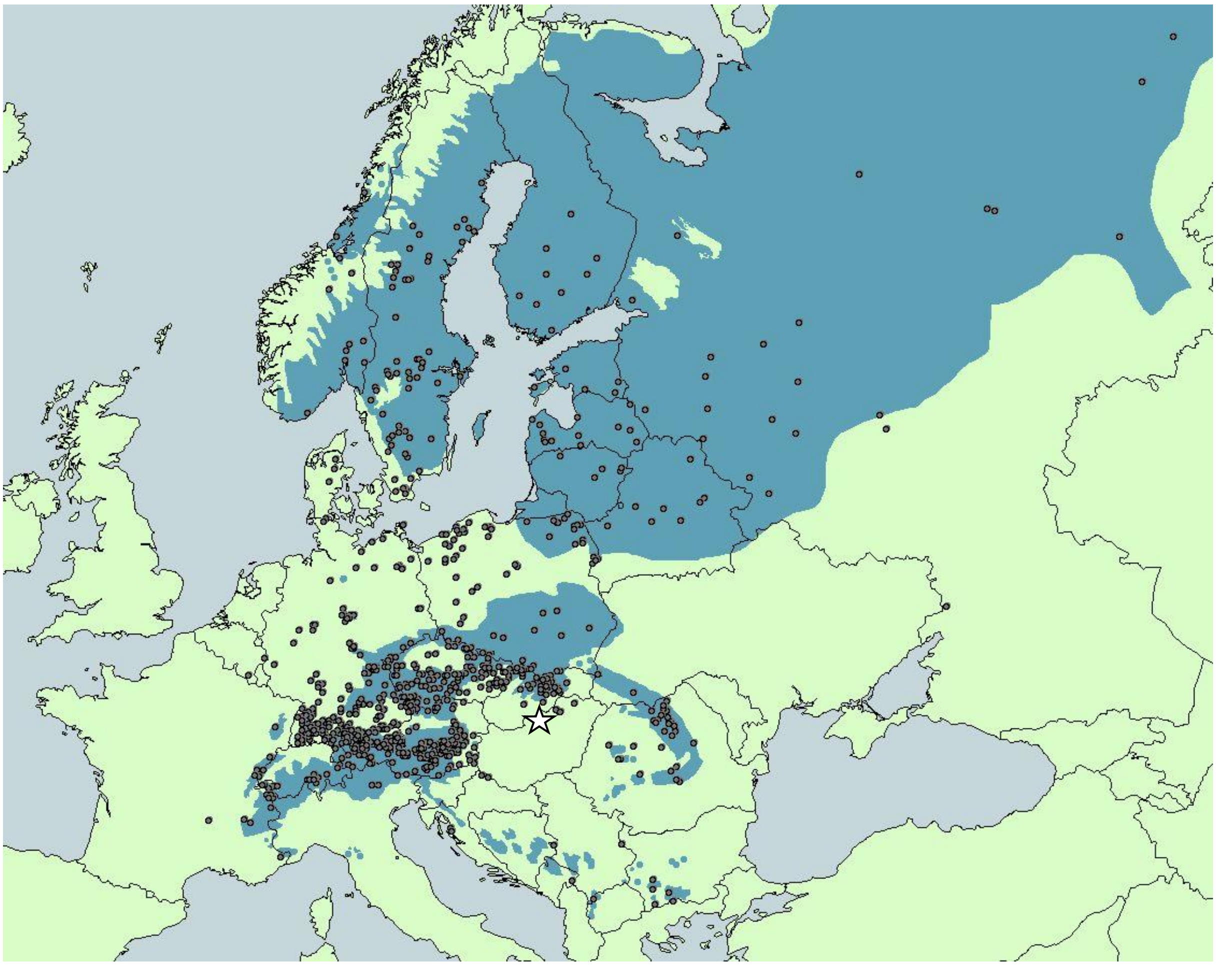


Figure 2. Natural distribution of Norway spruce (source: EUFORGEN, 2013) and location of provenances included in the trial (the star indicates the Nyírjes trial location)

2.1 Participants and trial sites

The 20 trials were established in 13 countries (*Table 1*, *Figures 3, 4*). Details of the field trials are listed in Appendix (*Table A.1*)

Table 1. List of trial sites and persons in charge in 1968 (Krutzsch 1973)

No	Country	Location of site	Responsible
01	Canada	Bronson, New Brunswick	D. P. Fowler
02	Ireland	Castlemorris, SW of Dublin	J. O'Driscol
03	England	Salisbury, SW of London	L. Pearce
04	Norway	Ilsvag, near Haugesund[1]	H. Robak
05	Norway	Near Kongsvinger and Tönsberg[2]	J. Dietrichson
06	Sweden	Abild, near the West coast	P. Krutzsch
07	Sweden	Lisjö, Central Sweden	P. Krutzsch
08	Sweden	Lappkojberget, N. Sweden, Lat. 63° 25′	P. Krutzsch
09	Finland	Haapastensyrjä, near Helsinki[3]	L. Kärki
10	France	Amance, near Nancy	P. Bouvarel
11	Belgium	blocks 2, 4 and 6[1, 2]	A. Nanson
12	Belgium	Gendron-Celle (blocks 1, 3 and 5)[1]	A. Jamblinne
13	Germany	Near Kaiserslautern[2]	W. Langner
14	Germany	Near Hildesheim-Kassel[2]	W. Langner
15	Germany	NW Germany[2]	W. Langner
16	Scotland	blocks 8, 9, 10 and 11[1, 2]	R. Lines
17	Czech Rep.	SE of Praha[2]	B. Vinš
18	Austria	blockwise, throughout the country[2]	L. Günzl
19	Poland	Kraków (Krynica)	S. Balut
20	Hungary	Nyírjes, NE of Budapest	L. Szőnyi

[1] incomplete trial; [2] trial spread over numerous sites; [3] non experimental

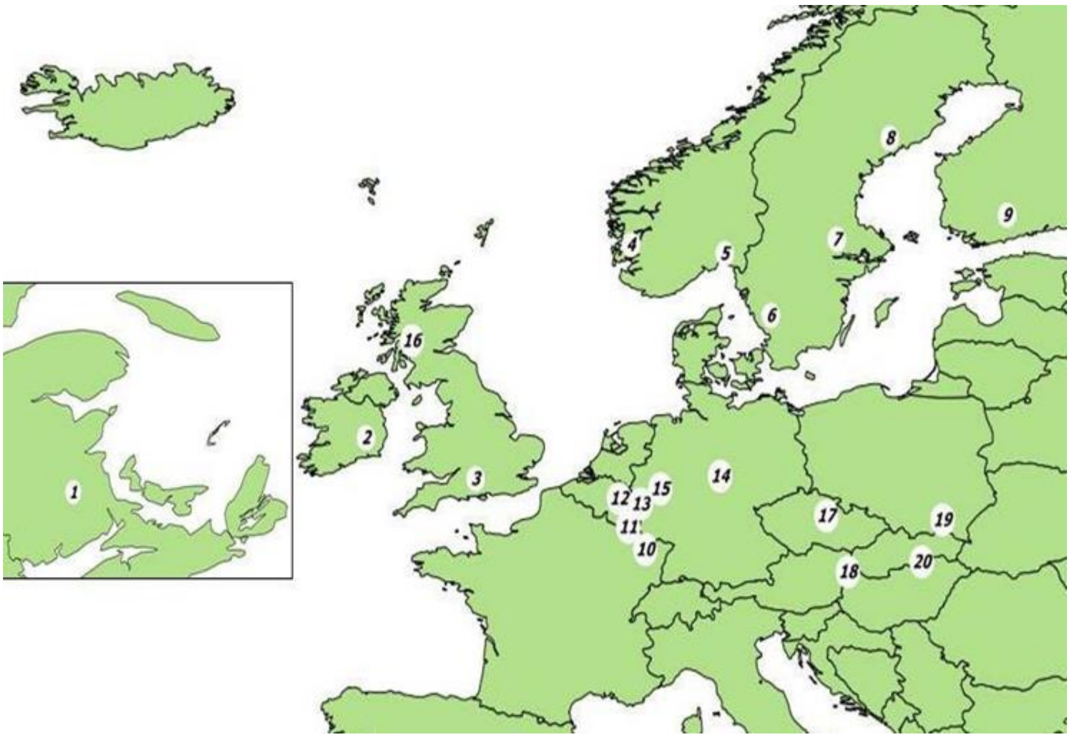


Figure 3. Location of the 20 sites of the provenance trial in Europe and Canada. In case of experiments, where blocks have been spread to different locations, the site is given where most blocks (including block 7) were planted (design: A. Horváth)

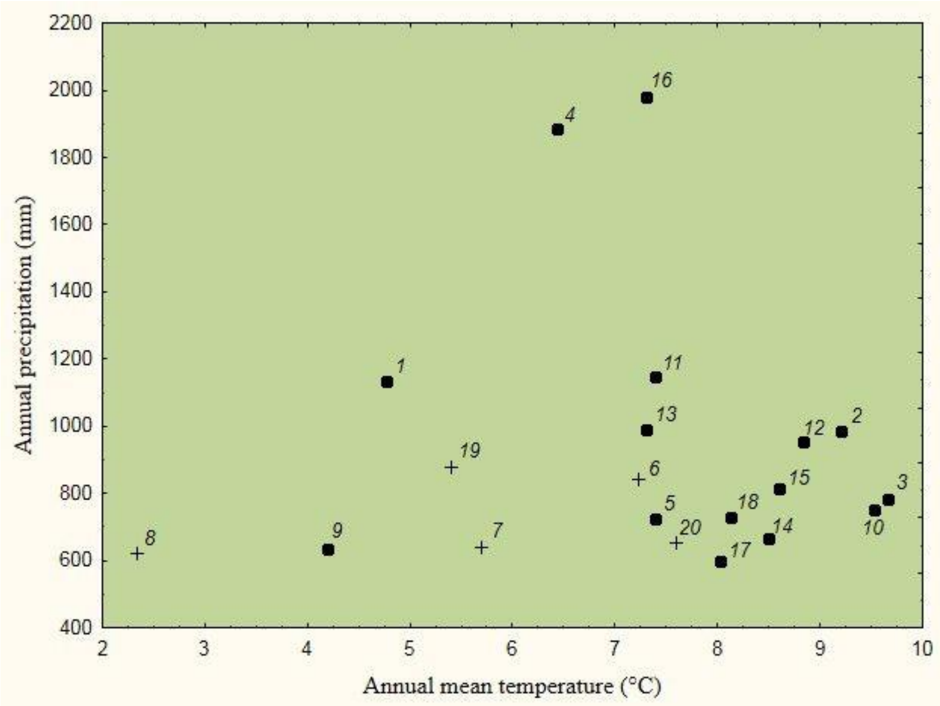


Figure 4. Location of the 20 field experiments (see Table 1) in the climatic space of annual temperature and precipitation (database: Worldclim). In case the individual experiments were spread to different sites, the climate of site including block 7 was used as reference. Locations marked with crosses were used for comparative analyses. Further data in Appendix: Table A.1 (design: A. Horváth)

2.2 Grouping of provenances (regions and zones)

The documentation of provenance data has been provided from Stockholm. Decks of 80 column punch cards were sent to all participants in the trial in order to guarantee uniformity. The detailed documentation of 1100 provenances can be found in the Appendix (*Tables A.2.1-12*). List of provenances in alphabetical order and grouping of provenances by country are also in the Appendix (*Table A.3* and *Table A.4*)

The seed samples cover most of the present (artificially extended) range of Norway spruce, with some areas heavily overrepresented. In order to facilitate the handling of the material, a grouping of provenances into regions has been made by Krutzsch (1974). Independent from the distribution of the provenances into field blocks, an assemblage into 96 geographical regions has been suggested to facilitate easier and more uniform handling of results. The aim was to gather provenances into natural groups not too small in number and not too large either. Therefore the size of the regions is very different (*Figure 5*). A list of regions with number of provenances can be found in the Appendix (*Table A.5*).

The originally suggested regions had been clustered into greater units already by Krutzsch (1974, 1976 pers. comm.). Further efforts have been put into making the zones homogeneous related to geography and climate.

The 96 geographical regions were the basis for 20 zones used later by Dietrichson – Skrøppa (1977) to describe the geographical patterns of variation in winter damage. This has been further refined by identifying seed samples that logically belong to different zones

(Fottland – Skrøppa 1989, *Figure A.14*). The postglacial areas of origin for Norway spruce (Schmidt-Vogt 1977) have also been considered. The zones covered occurrences of Norway spruce both natural and planted. It was generally not possible to distinguish between autochthonous and allochthonous seed sources because artificial seeding and planting have long traditions over the whole area. In spite of this, the term "provenance" was uniformly applied to all seed samples.

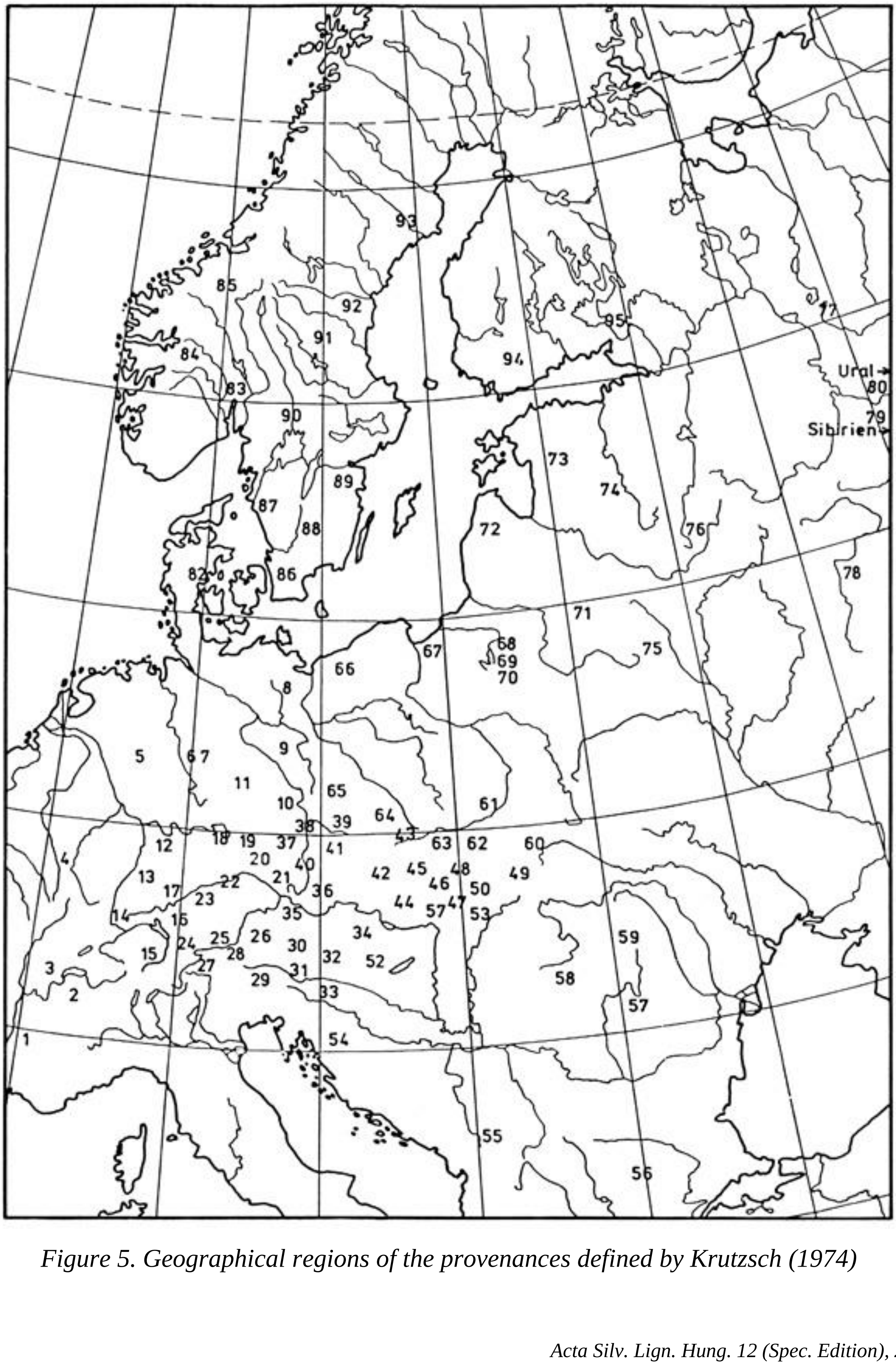


Figure 5. Geographical regions of the provenances defined by Krutzsch (1974)

2.3 The IUFRO 1964/68 Provenance Trial in Hungary

The Hungarian test in the international context

“The IUFRO initiative to establish a whole-range provenance trial of Norway spruce was an exceptional undertaking. There are, however, few locations such as Nyírjes in Hungary, where the whole diversity of sampled populations of the species may be compared up to the present day, on a single site. This was at the start the concept which led to the finding of financial support, of contacts for reliable planting material, and brought about the selecting a proper forest company and location, skilled and able staff for management and scientists who understood the importance of the task and maintained the experiment up to the present day with responsibility and care. It is also in my view a rare value. I am grateful to Eva Ujvári and her collaborators whose work was indispensable for the success of this venture.”

(László Szőnyi, initiator of the Nyírjes experiment,
personal comment for the present study, 2015)

The 1968 series of IUFRO’s spruce provenance test is among the largest accomplishments of the organization, from point of view of quantity of sampled and analyzed material and the methodical care applied for the planning and execution. The fate of the experimental series followed the usual destiny of long-term international initiatives. Although the original idea was to plant the tests as similar as possible, not all countries followed the recommendations. In addition to certain fatal mishaps, the interest in the test declined and responsible persons were assigned other tasks. The common evaluation of the results did not materialize as the whole concept of provenance tests has fallen into discredit much before the planned termination after 20 years.

The Hungarian test stands out from among the experiments with a contiguous design (all 11 blocks in one subcompartment), favorable site conditions, which ensured an unusually good starting survival, with a fair history of a still acceptable amount of calamities (moderate bark beetle attack, only one heavy storm damage) and finally with *a history of unchanged interest and care in maintaining the experiment* well over the originally planned period of 20 years. This renders the test to receive special attention from the domestic and international professional community beyond tree breeders and geneticists.

While the idea of starting a new, comprehensive trial series with Norway spruce was a quite realistic goal in the consolidated post-war years, it needs special explanation why Hungary joined the group of “classic” Norway spruce growing countries. Hungary lies in the zone of deciduous forests. In this country spruce is not native and its cultivation was restricted to small isolated stands. However, due to the post-war political and economic restrictions, the supply of conifer timber relied exclusively on Russian imports. A government program to boost self-supply through fast growing conifer species, first of all with Scots pine and Norway spruce, has been initiated already in the fifties. This included not only extensive afforestation with conifers, but also the intensification of tree breeding. Breeding and improvement of Norway spruce started in 1963 by selecting plus trees primarily on drought-exposed sites. The decision to join the IUFRO Norway spruce provenance trial was considered as an important contribution in solving the future softwood supply of Hungary.

Initiation and selecting the trial site

The establishment of the trial was initiated by the head of Department for Forest Tree Breeding in the Forest Research Institute, dr. László Szőnyi. The practical importance of the IUFRO Inventory Provenance Trial was recognized by the Hungarian Ministry of Food and Agriculture and the complete set of this uniquely large experimental material was obtained with the support of the authorities. The costs for one set of experimental material – 1100 provenances with 27 500 plants – amounted to 5000 DM, transport fees excluded. Similar to the general goal of the trial, the contemporary aim in Hungary was also *to select and recommend outstanding provenances suitable for planting.*

For the valuable trial a productive, safe, relatively uniform and ecologically suitable site for the species had to be found. Decision was taken to establish the trial at one location, in the region of activity of the Mátrafüred Experiment Station of Forest Research Institute (ERTI). This station has got the task of research and development of cultivation of fast growing conifers, first of all Norway spruce.

The selected location of the trial was Gyöngyössolymos, sub-compartment 32 C. The denomination of the site is "*Nyírjes*", in the study this name will be used for the trial for the sake of simplicity. The location is situated in the Mátra Mountains, in the Hungarian Central Mountain Range, which is the southern extension of the Northern Carpathians (Szőnyi – Ujvári 1970). The area was administered at the time of the establishment of the test by the Mátra State Forest Company (at present: Egererdő State Forest Co.)

Description of the trial site

Geographical coordinates: N. latitude: 47.893956, E. longitude: 19.950366

The *elevation* of the experiment ranges from 550 to 630 m above sea level (average 600 m). The *slope* is moderate in block 1 and 2, gentle in block 3, 4, 10, 11 and very gentle in block 5–9. *Aspect*: South-East to East.

Previous forest cover of the site: the compartment was covered by stands of semihumid beech-hornbeam-sessile oak mixed forests (beech 25%, hornbeam 75% with few sessile and Turkey oaks). The 45–50 years old stands had a canopy closure of 70% and were to 80% of coppice origin. The area has been harvested in spring 1967 and in winter 1967/68. The yield amounted to 111.1 m^3/ha (round wood 48.8, m^3/ha, fuel wood 62.3 m^3/ha). The gross cutting area amounted to 18.7 ha while the net experimental area is 11.0 ha. The complete trial (11 blocks) was established in the same forest compartment (*Figure 6).*

Figure 6. Location and layout of the trial Nyírjes

Soil characteristics

The forest soil developed on andesite bedrock, which is frequent in the Mátra Mountains. There are differences between blocks in the granulometric composition and the intensity of gleying process (*Table 2*). The soil depth varies as well, e.g. in block 2 because of high stone content and in block 7 because of a pseudogley layer. The site of block 7 was found as not properly suited for Norway spruce (Z. Járó, pers. comm.). This block suffered later a bark beetle attack, followed by heavy windbreak (see *Figure 6* and section on health condition and mortality). Within blocks the sites were rather homogenous, except in blocks 4, 5, 6 where wet parts have had to be drained. The site survey was carried out by Z. Járó, the lab analysis by É. Ujvári-Jármay in 1967 (ERTI Experiment Station, Mátrafüred)

Bedrock and soil types in the investigated profiles

Profile I. (Block 7)

Bedrock: Andesite tuff

Soil type: Pseudogleyic, clay-enriched brown forest soil

Profile II. (Block 11)

Bedrock: Hydroandesite

Soil type: Clay-enriched brown forest soil

Profile III. (next to block 2, with raw humus)
Bedrock: Hydroandesite
Soil type: Highly acid brown forest soil
Profile IV. (Block 2)
Bedrock: Pyroxene andesite
Soil type: Slightly podzolized brown forest soil.

Table 2. Soil test data (Szőnyi – Ujvári 1970)

Profile	Horizon depth	pH		hy	$CaCO_3$	Humus	K_A	Stones, gravel	Mechanical analysis			
									clay	silt	fine sand	coarse sand
	cm	H_2O	KCl	%	%	%		%	%			
I. Block 7	0 – 10	4.9	3.9	3.01	–	5.1	53	41.7	7.80	32.34	39.86	20.0
	10 – 30	4.9	3.8	1.93	–	1.2	34	40.2	10.80	34.89	35.91	18.4
	30 – 100	4.7	3.5	2.58	–	0.5	62[1]	21.7	29.68[1]	25.17	29.15	16.0
	100 –	4.5	4.0	3.07	–	–	42	18.1	0.44	50.29	26.87	22.4
II. Block 11	0 – 15	5.2	4.2	3.46	–	5.4	58	44.5	4.56	33.67	40.17	21.6
	15 – 45	5.5	4.0	2.22	–	1.0	31	24.4	10.68	36.85	33.27	19.2
	45 – 80	5.5	4.4	2.35	–	0.3	34	45.3	14.08	27.18	34.74	24.0
	80 –	5.8	4.5	2.14	–	–	36	25.4	12.40	19.13	38.10	30.4
III. next Block 2	0 – 15	4.1	3.3	10.54	–	30.3	–	69.5	–	–	–	–
	15 – 35	4.7	3.6	3.45	–	4.7	55	90.0	7.32	29.44	36.84	26.4
	35 –	5.0	3.7	–	–	–	30	87.0	8.12	24.25	31.63	36.0
IV. Block 2	0 – 6	4.8	3.9	4.19	–	8.6	66	54.2	4.76	21.91	56.53	16.8
	6 – 20	4.9	3.7	2.86	–	3.3	45	46.3	6.52	30.07	45.81	17.6
	20 – 65	5.8	4.2	3.10	–	1.0	28	26.2	9.00	25.79	41.21	24.0
	65 –	6.3	4.7	5.71	–	–	38	31.6	11.68	17.13	41.59	29.6

[1] Very high values for compaction (K_A): pseudogley type soil in Block 7.

Climate

The analysis of the trial needed the determination of the climatic conditions at the test site Nyírjes, also at all other test sites where data have been used from, and for all provenances in question. At the time of starting the reanalysis and statistical evaluation of the data, no digital climate surfaces were available to check the sporadically available and usually quite inaccurate climatic data. Therefore all the climatic variables used in the analyses were produced by interpolation of climate station data, performed by E. Rasztovits (U. of West Hungary). Main climatic variables of Nyírjes were determined as 7.5 °C mean annual temperature and 782 mm mean annual precipitation. These interpolated climate data were used for the analysis of climate-related responses of provenances.

A few recent analyses in the study use presently available databases such as Worldclim (www.worldclim.org) or Carpatclim[2] (www.carpatclim-eu.org) – in such cases the use of

[2] Carpatclim is a regionally developed database for Central-Southeast Europe and cannot be used on European scale

alternate databases is always indicated. Accordingly, not all climatic data are compatible. Similarly, the climate variables for Nyírjes change when using the mentioned databases: the digital surface of Worldclim (1950–2000) produces for the coordinates of Nyírjes 7.6 °C mean temperature and 654 mm mean rainfall. On the other hand, Carpatclim's values are 7.5 °C and 710 mm. The picture gets more complicated if the change of the climatic conditions is also considered. The summer temperature has increased in the last 30 years by at least +2°C (Bartholy et al. 2011). The precipitation shows no clear trend, the annual average during the trial existence may be estimated for the most important part of the trial (blocks 7, 8 and 9) around 680 mm. Obviously, the precipitation data are probably less accurate (as usual in meteorology). The temperature estimations – which are more important for the analysis – seem to be rather exact.

The climate of Nyírjes is by Köppen's classification humid continental (Dfb: mild summer, wet all year). In the warmest months of the year mean temperatures exceed 15 °C. Annual distribution of precipitation indicates a slight moisture deficit from July to September (*Figure 7)*. According to the Hungarian classification of climatic forest zones, the Walter diagram may be interpreted as "beech climate".

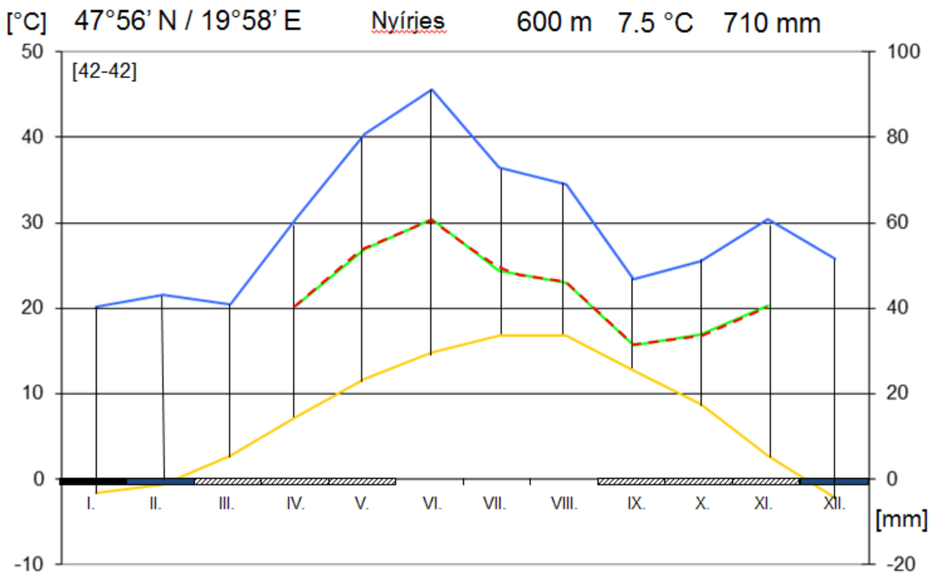


Figure 7. Walter - Lieth climate diagram of Nyírjes based on data of Carpatclim (www.carpatclim-eu.org; design: E. Rasztovits and N. Móricz)

Summer temperature shows an increasing tendency since 1961. In the last two decades almost all summers were warmer than the average of 1971–2000. Precipitation has a pronounced inter-annual variation without any significant trend during the last 50 years (*Figure 8*). In the periods of 1981–1983, 1992–1998 and 2007–2009 long-lasting droughts have been observed. *Figure 8* shows that summers with precipitation sum below the 30-year mean often have extreme high temperatures as well. It has to be underlined that climate projections unequivocally indicate a further increase of summer extremes which renders the future of Norway spruce cultivation improbable not only in Hungary (Gálos et al. 2007), but also in lower elevations of neighboring countries.

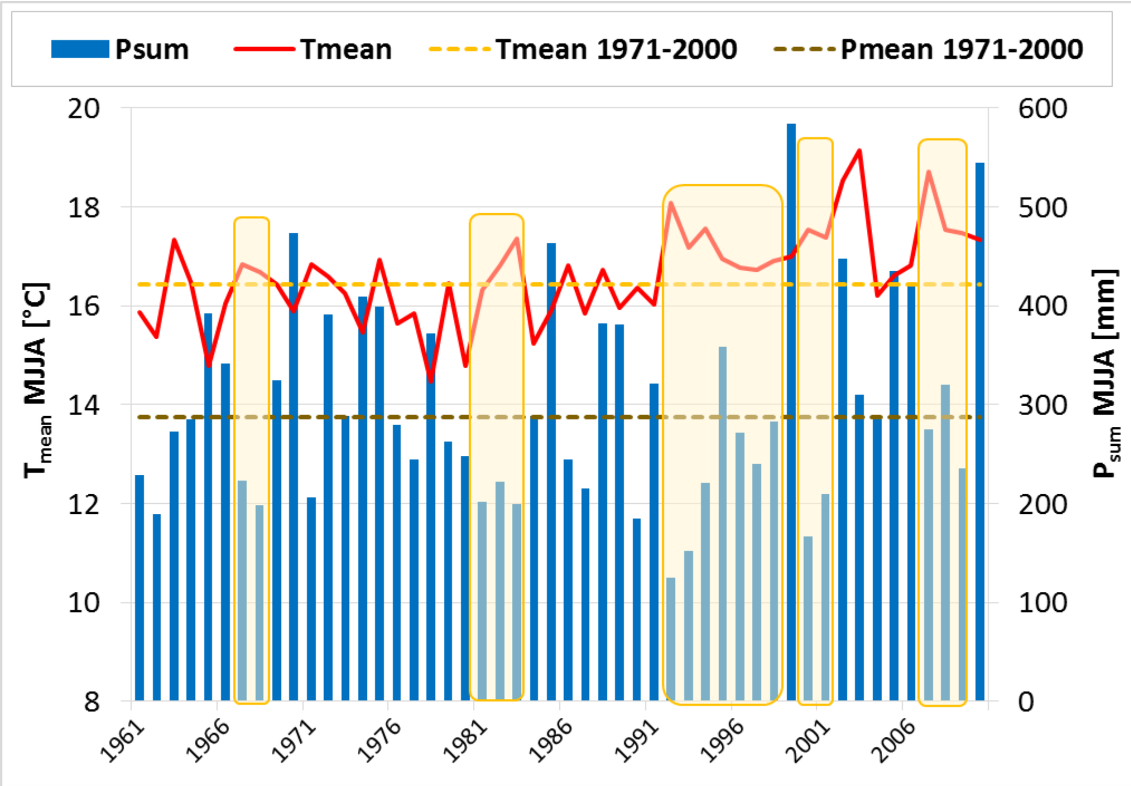


Figure 8. Monthly mean temperature and monthly precipitation of extreme dry and hot consecutive summers (MJJA) in the recent decades, based on data of Carpatclim (www.carpatclim-eu.org) for the nearest meteo station Kékestető (design: B. Gálos)

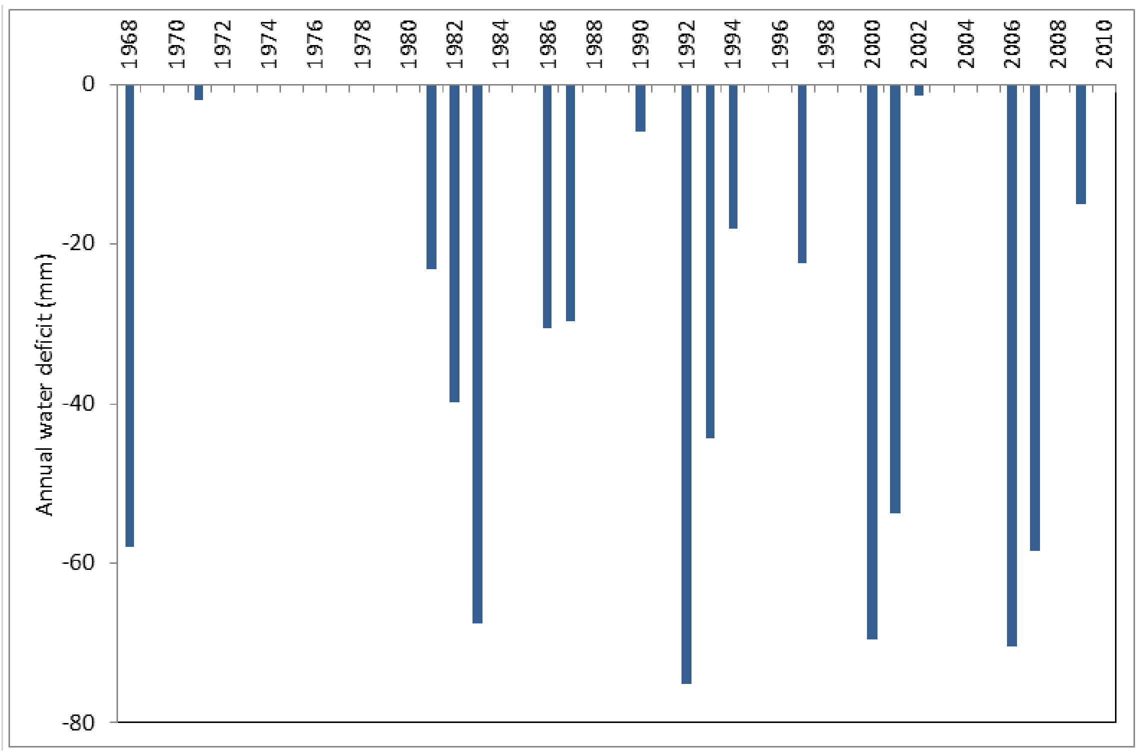


Figure 9. Annual water deficit causing stress for Norway spruce at Nyírjes,from 1968 to 2010. Data from Carpatclim (design: E. Rasztovits and N. Móricz)

The annual water deficit modeled by the *Thornthwaite – Mather* (*1955*) method also shows the recurring drought periods from the early 80's (*Figure 9*). Water deficit is expressed as the difference of the actually available water content in the soil and the soil water content which initiates water stress for spruce (40% of the maximum available soil water content). The obvious need of closer follow-up of climate extremes during the maintenance period of the experiment has led to the establishment of a local climate station within the trial in 1999.

Trial layout

The Hungarian trial layout followed the internationally agreed method described before. All 11 blocks were established on one site and planted in a spacing of 2 x 2 m.

The experimental material

The preparations for the trial were well organized and represent still a high standard to be followed, and therefore details are given. In December 1967 the logistic documents were obtained. The identification number of the provenances contained first two digits (ranging from 01 to 11) for the numbers of blocks, and following two digits (ranging from 00 to 99) were the provenance numbers within the block. The attached lists contained the name of localities of seed collection, the geographical characteristics (latitude, longitude and altitude, see *Tables A.2.1-12*) and the seed class (*Table A.15*).

The plants lifted in 1967 autumn at an age of 2+2 and held during the winter in cold storage in Hamburg were transported with a phytosanitary certificate of the Plant Protection Service in Germany from the nursery directly to the planting site. 25 plants per provenance were placed into intransparent white plastic bags. On each bag both the respective block number and the number of provenance was marked. Until planting the plants were stored in bags in shadow *(Figures 10, 11).*

Figure 10. Storage of labelled plants in plastic bags

Every single plant was labeled for block and provenance number. A colored label inscription on each tenth plant gave the block number according to a color system. The key for block identification by color was enclosed as well. According to regulations of the Hungarian Plant Health Service, prior to planting the loose nursery soil had to be washed off from the plants (*Figure 12)* and buried after disinfection in a 2 m deep pit. The work was controlled several times. Then the roots of plants were clay-coated. Due to the single tree plot layout, the 25 plants of all 100 provenances were distributed one by one among the 25 within-block plots. Consequently each provenance was evenly distributed across the block.

Figure 11. 2+2 plants and the numbered bag (Block: 8, Prov. 0825)

Figure 12. Washing roots before planting

Planting and mapping

The clay-coated plants were planted between the 6th and 20th April 1968 in a spacing of 2 x 2 meters in 40 x 40 cm manually prepared planting holes (*Figure 13*). The surplus plants were planted in additional rows. Between blocks there were extra rows with Douglas fir, after 8–10 years they were cut. Several working groups, up to 40 employees of the forest management unit worked on the area at the same time. Still, the planting was successful, no mistake has happened.

Figure 13. Planting in April 1968

The area was fenced against game damage and each plant was treated in autumn with *Cervacol*. In spite of this, at the end of winter a game damage of 35 to 40% was recorded on lateral shoots, however this had practically no effect on survival and growth of trees.

The identification of each plant right after planting was of great importance. A field map recording each plants position was prepared and crosschecked. During transportation and planting, several plants have lost their marking ribbons. The unidentified plants were planted too but marked by an "x" sign. Empty planting holes had no marks.

The map was punched on cards in Sweden. For mapping 80 col. punch cards were used (*Figure 14*). The layout of the punch card was provided by the organizer. The data processing and evaluation of the experiment was planned on computer (type: IBM 1401, 16 K). From the periodical assessments an extensive database was compiled and processed.

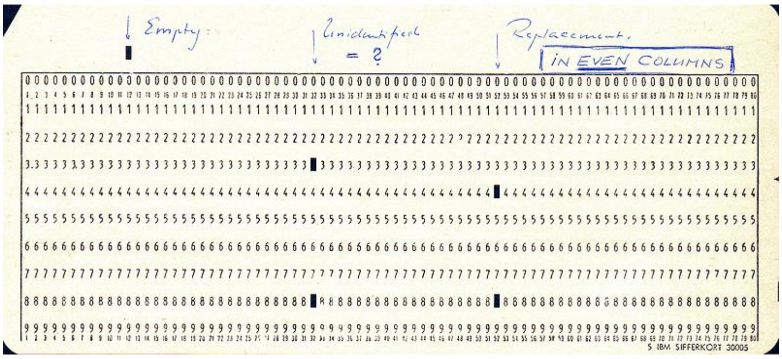


Figure 14. Punch card used for the IBM computer

The establishment and mapping of the provenance trial was a very demanding job. Citation from a letter of R. Lines (Scotland) to L. Szőnyi: "The research forester in charge of the Salisbury experiment was given some special leave to recuperate from the mental strain of dealing with such a complicated trial."

Main contributors to the establishment of the Nyírjes experiment

- The organization of the trial was coordinated by László Szőnyi, chief of Department of Forest Tree Breeding (Forest Research Institute, ERTI, Budapest).
- Ferenc Ujvári, research associate (Experiment Station Mátrafüred) was responsible for the trial's establishment and managed it for many years.
- Éva Ujvári-Jármay research associate, Tibor Szeniczey, István Hevér, Irma Póka, József Kertész technicians were taking part in the establishment of the field trial, in surveys and data processing.
- Éva Ujvári-Jármay took over the coordination of activities and data analysis in 1990.
- Béla Varga, head of Department of Silviculture of Mátra State Forest Co. provided professional support in selecting the site and execution of the work.
- Since 1997 László Nagy research associate (Forest Research Institute, ERTI, Sárvár) is responsible for the experiment in cooperation with É. Ujvári-Jármay.
- At present the experimental area is managed by the Mátrafüred forest district (head: B. Dudás) of the Egererdő State Forest Co.

3 DATA ANALYSIS AND RESULTS

3.1 Research activities in the trial

Summary of activities in the Nyírjes trial, arranged in chronological order

1968	Planting and survival assessment
1972	First detailed assessment (all blocks): height 1970, 1972; Lammas shoots; damages caused by *Sacchiphantes sp.* and deer; phenology
1973	Selection of plus trees for vegetative propagation, collection of cuttings
1977	Second detailed assessment (all blocks): height; DBH; Lammas shoots; vitality; damages: *Sacchiphantes sp.*, deer
1978	Revision of plus trees, additional selection, collection of cuttings
1980	Cone collection for progeny testing
1983	Detailed assessments in blocks 7, 8, and 9: height; DBH; diameter of branches; number of branches per whorl; vitality; deer damages. Collection of cuttings for further propagation from the best provenances of E. Carpathians and Bihor Mountains (regions 58, 59 and 60).
1983–1986	First thinning (every block, 2 different methods).
1985	Collection of cross-sections of felled trees for wood anatomical studies.
1992–1993	Assessments in blocks 1, 4, 7, 8, 9, 10, 11: health condition; DBH.
1992–2012	Observation and monitoring of health condition.
1993	Experimental height measurement using aerial photos
1994	Felling of 12 sample trees to study biomass and allocation.
1995–1996	Collection of needle samples for investigation of genetic polymorphism (G. Mátyás and C. Sperisen, Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf, Switzerland).
1999	Inventory and assessment in blocks 1, 4, 7, 8, 9, 11: DBH.
1999–2001	Second thinning (sanitary cutting, every block).
2002–2004	Inventory and assessment in blocks 2, 3, 5, 6, 7, 8, 9, 10: DBH
2011	Last inventory and assessment: remaining trees; DBH (whole trial, all blocks).

Explanations to the surveys

Classification and data survey were carried out according to a uniform system, determined for the international experiment by P. Krutzsch. Following complete assessments at age 5 and 10, height and DBH at age 16 were assessed in 1983 in only 3 blocks (7, 8 and 9) due to crown closure. (Age of plants is given in years after planting, other cases are noted.) An experimental interpretation of individual tree heights from aerial photos, taken in 1993, was carried out in 2015; informative results are presented in chapter 5.3. Since 1990 measurements of diameter were carried out several times (in 1992, 1999, 2003 and 2011). The block means are summarized in *Table 7*, the provenance means in the Appendix (*Tables A.6.1-11*).

Two total assessments were made for *survival* in1968 and 1969, at the end of the growing season. In spring 1972, detailed *phenological observations* were carried out on the whole material (*Table 3*).

For data collection field survey sheets suitable for direct computer processing were used (Szőnyi – Ujvári 1975). Processing of data in 1972 was supported by P. Krutzsch with an IBM 1401 computer in the Royal College of Forestry at Stockholm using the mathematical model P. Krutzsch and B. Matern. Data of the 1977 and 1983 survey were processed by F. Ujvári with a Monroe 180-44 computer at the Mátrafüred Experimental Station, using statistics and programs prepared by Z. Jablonkay and G. Ujvári.

Table 3. Suggestions of Krutzsch (1973b) for assessing flushing phases

Observations should refer to the average of terminal buds on the uppermost whorl of branches.

0. Dormant buds
1. Buds slightly swollen, needles below buds bent backwards and outwards
2. Buds swollen, green to grey-green in colour, bud scales still closed
3. Burst of bud scales, tips of needles emerging
4. First elongation of needles to about double bud length
5. First spread of needles, buds have now the appearance of a painter’s brush
6. Elongation of shoot , basal needles not yet spread
7. Differentiation of shoot, basal needles spread
8. All needles more or less spread, new buds developing.

The first thinning commenced in autumn 1984, and was going on in next two years. The thinning followed Prof. Dietrichson´s (chairman of the IUFRO WP on Provenance Trials of Norway spruce) recommendations. Blocks 8, 9, and 11 were thinned in systematic way, every second tree was cut in row and alternating in adjacent rows schematically. The other blocks were thinned according to silvicultural considerations.

In the early nineties, with an abrupt change of research priorities the Experiment Station was inconsiderately reorganized and part of survey data, photos and processed results were lost. Financial and manpower support declined and surveys had to be concentrated to a few blocks. Therefore some of the results are incomplete. Luckily, thanks to the foresight of the layout planners, individual blocks may be treated as separate experiments and general conclusions can be drawn from them. In the present study the attempt was made to reanalyze and reconstruct the original dataset. A full survey of all blocks could be organized again only in 2011.

Grouping of provenances applied for the analysis of the Hungarian trial

The necessity of reducing the number of main units (regions, zones) in order to handle the large data volume has arisen in case of the Hungarian trial as well. There was no chance to analyse individual provenances especially because only data of few parallel experiments were available. For the statistical analysis of the climatic response of the investigated 291 provenances of 3 selected blocks (7, 8 and 9), 10 larger zone groups were formed (*Figure 15*, *Table 4*) based on the following criteria:

- The groups should contain populations of similar phenotypic response. We considered various heritable traits such as phenology (bud brake, Langner – Stern 1964) and growth observed in the Hungarian trial. We have taken into account also the genetic diversity as expressed by isozyme analyses, genetic distances (Krutovskii – Bergmann 1993), mtDNS investigations (Sperisen et al. 2001) as well as presumed postglacial migration routes (Schmidt-Vogt 1977).
- The geographical differentiation of zone groups was maintained in order to keep the necessary overview of data. The delineation was based on the 96 regions of Krutzsch (1974) and on the 20 zones of Dietrichson – Skrøppa (1977) and Fottland – Skrøppa (1989). Further refinement and correction of borders was applied where deemed necessary. This does not mean that zone groups are homogenous, neither in phenotypic, nor in molecular genetic sense (e.g. zone 2).
- In order to maintain statistical comparability (e.g. for R^2 calculations), zone groups had to contain a minimum number of provenances.

With zone groups the larger trends in climatic response (e.g. *Figure 30*, chapter 4.2) and comparisons for stability (*Figure 39*, *Tables 21, 22*) could be properly presented.

Table 4. List of zone groups, included regions and number of provenances, compiled by Ujvári-Jármay (2006, 2010), (based on Krutzsch, 1974, Dietrichson – Skrøppa 1977, Fottland – Skrøppa 1989 and A. Persson – B. Persson 1992)

Number and name of zone groups		Included regions (Krutzsch 1974)	Nr. of provenances
1	NW Europe	4, 5, 8, 9, 12, 66	53
2	Jura Mts., Schwarzwald, Alps, Foothills of Alps[1]	1, 2, 3, 13, 14, 15, 16, 17, 18, 22, 23, 24, 25, 26, 27, 28, 30, 31, 32, 33, 34, 35, 52	411
3	Harz and foothills, Böhmerwald	6, 7, 10, 11, 19, 20, 21, 36, 37, 38, 40, 41, 42	201
4	Sudeten, Beskids, Tatra, Besczady Mts.	39, 43, 44, 45, 62, 63, 64, 46, 47, 48, 49, 50	148
5	Carpathian Mts, Bihor Mts, N- Hungarian Central Mts, S Poland [2]	51, 53, 58, 59, 60, 61, 65	53
6	SE Europe	29, 54, 55, 56, 57	31
7	Baltic States, NE Poland, White Russia, W Russia	67, 68, 69, 70, 71, 72, 73, 74, 75, 76	71
8	Finland, N Sweden, Central Norway	85, 91, 92, 93, 94, 95	39
9	SE Norway, Central Sweden S Sweden, Denmark	82, 83, 84, 86, 87, 88, 89, 90	66
10	Russia	77, 78, 79, 80	19
	Not classified (missing or unidentified)	81, 96	8

[1] Group 2 should be further divided on basis of recent genetic research results (e.g. Kapeller et al. 2012)
[2] Group 5 contains numerous regions and provenances, the majority originating from the E. Carpathians, therefore the group is mentioned in the text as „E. Carpathians"

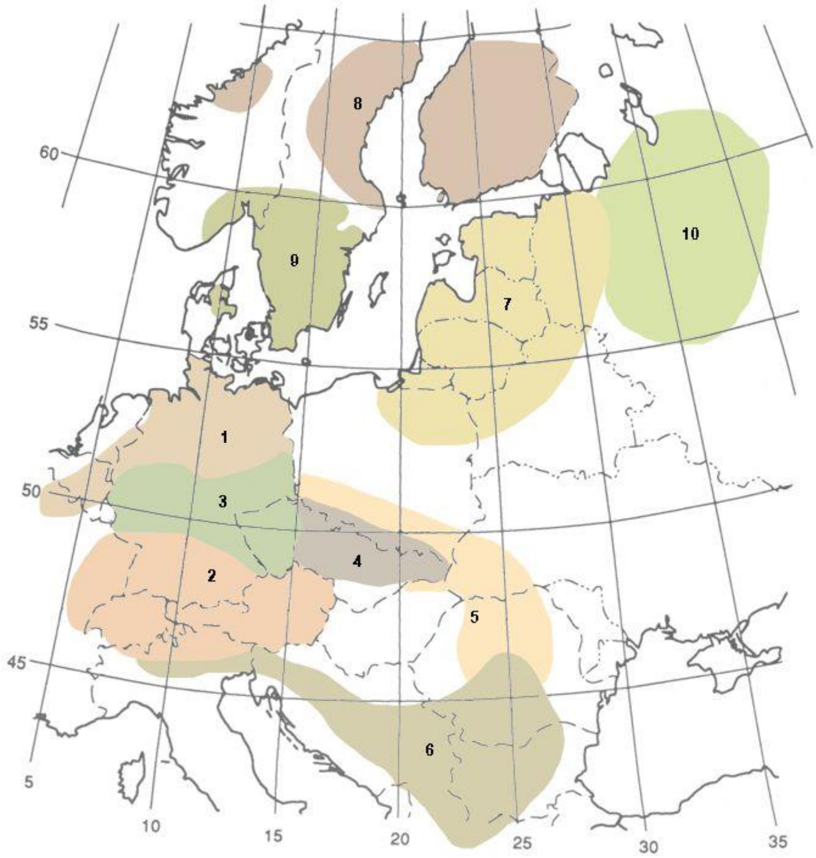


Figure 15. Geographical zone groups, focusing on the Norway spruce provenances of the blocks 7, 8 and 9[3], compiled by Ujvári-Jármay 2006 (based on Krutzsch 1974; Dietrichson – Skroppa 1977 and Fottland – Skroppa 1989; approximate boundaries, design: L. Nagy)

3.2 Results at juvenile age

For the analysis, the following objectives were followed (arranged in an approximate chronological order of changing priorities):

- analyzing the tolerance and vulnerability of provenances (survival after planting, damages, mortality etc.);
- investigating the dynamism of growth and the variation in height and diameter growth between and within provenances;
- selecting recommendable, outstanding provenances for forestry in Hungary or abroad;
- investigating of genetic (molecular) diversity, based on mtDNA;
- analyzing the phenotypic stability ("plasticity") of transferred provenances;
- modeling the impact of predicted climate change on Norway spruce provenances;
- introducing the results into other projects related to the experiment.

[3] These provenances were tested in detail, see chapter 4

Survival after planting

In the year of planting (1968), Hungary had an extremely dry and hot summer (*Figures 8, 9*). At the Mátrafüred Experimental Station precipitation amounted to only 464 mm, that is 63% of the 740 mm recorded as the average of six hydrological years. In July 1968, 15–20% of the plants lost their needles, the remained needles became brown. As a response to July and August precipitation, however, the majority of plants flushed again (Szőnyi – Ujvári 1970).

The survival rate at the end of the first growing season (1968) was 96.3% and 92.5% in autumn 1969. In 1972 and 1977 (age 5 and 10) survival varied according to block site between 63.0 – 98.7%, the experiment average amounted to 89.7% in 1972 and also in 1977 (*Table 7*). Survival of each provenance in 1977 (and also for blocks 7, 8 and 9 in 1983) is shown in Appendix (*Tables A.6.1-11).*

To check the survival of Norway spruce provenances in different climates, two parallel Swedish tests (Krutzsch 1974, Ujvári-Jármay and Ujvári 2006) have been related to the data of Nyirjes. Comparing Nyírjes with the survival of Swedish experiments, the patterns show a marked differentiation. In Abild it was 97% in 1977 and 79% in 1983, at Lisjö 61% in 1977 and 57% in 1985 and at the very northern site in Lappkojberget (63° 25′) 50% in 1977 and only 44% in 1986 (A. Persson – B. Persson 1992). The climatic location of the Hungarian and 2 Swedish sites – compared to the scatter of tested provenances – is shown in *Figure 16*. The three tests represent a relatively equidistant transect through the lower precipitation part of the climatic niche, representing the thermic (upper) and xeric (lower) limits and the optimum for Norway spruce. It turned out that contrary to original expectations, the Hungarian site lies not in the extreme part of the range which is also indicated by the very high survival (and growth, see later) at the site (*Figure 16*).

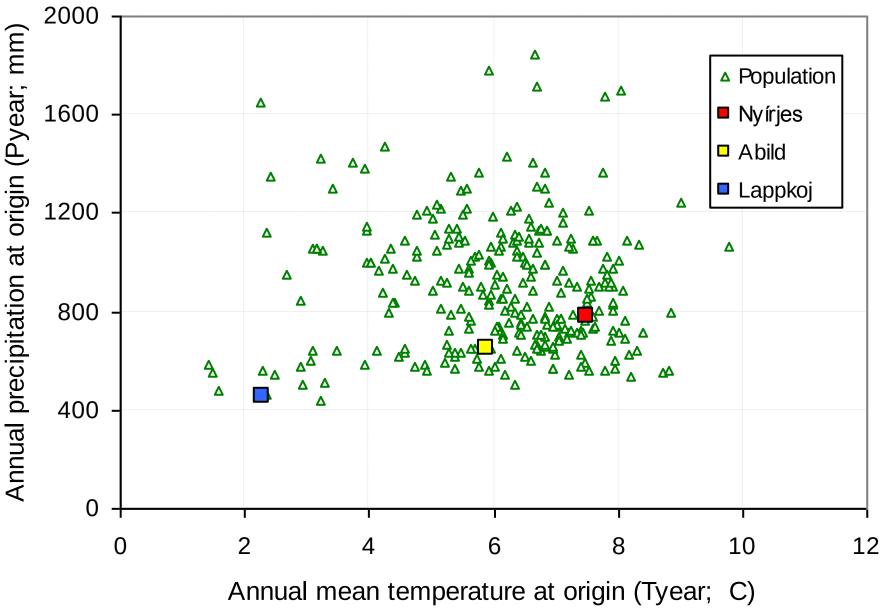


Figure 16. Climatic position of provenances from blocks Nr. 7, 8, 9 in the space of annual temperature and precipitation and the climatic location of Nyírjes and of two Swedish sites (not all provenance locations are visible due to overlay)

Juvenile development of the provenance trial

To facilitate comparisons between assessments and to provide an overall picture of provenance performance, all available data on height growth and diameter have been tabulated by blocks and by individual provenances. For each assessment height and diameter were expressed in percent of the block mean (Appendix, *Tables A.6.1-11*).

Analysis of variance of 1972 (age 5) height data in Nyírjes was executed in Sweden, the evaluation method and the output was published by Krutzsch (1973). The calculations and partial results of Nyírjes have been reviewed, developed and grouped by F. Ujvári (*Table 5*).

Table 5. Summary of Norway spruce height and survival data after 5 years by blocks, 1972 (revised by F. Ujvári, unpublished)

Block No.	Number of plants[1]		No. of prov. in block	Survival	Mean height (H72)	Coeff. of interclass correl.	sign.diff. (at p = 0.05)	F value[2]
	1968	1972		%	m	%	m	
1	2333	2208	100	94.6	1.13	0.167	0.20	5.43
2	2412	2083	100	86.4	1.15	0.169	0.20	5.24
3	2409	2109	100	87.6	1.23	0.155	0.19	4.86
4	2412	2157	100	89.4	1.18	0.136	0.22	4.39
5	2432	1510	100	63.0	0.96	0.053	0.32	1.85
6	2413	1876	100	77.7	1.21	0.072	0.26	2.46
7	2423	2340	100	96.6	1.39	0.154	0.20	5.27
8	2434	2363	100	97.1	1.37	0.200	0.19	6.92
9	2397	2364	99	98.7	1.31	0.153	0.20	5.31
10	2453	2394	100	97.6	1.37	0.132	0.20	4.63
11	2398	2351	100	98.0	1.26	0.137	0.19	4.72
Sum/aver	26516	23755	1099	89.6	1.23		0.21	

[1] unidentified plants excluded
[2] all F values were statistically significant at p = 0.001 level

Results of the first evaluation, both height growth and survival, were satisfactory (*Table 5*). The grand mean of experiment (11 blocks) measured in 1972 was 123.5 cm, the block means ranged 96–139 cm. Resemblance between the individuals of the same provenance (class) is expressed as interclass coefficient of correlation. Because of soil inhomogeneity in blocks 5 and 6 the coefficients (and F values) were lower.

The F values show high significant differences between provenances (p = 0.001). The least significant difference (LSD) between provenances was similar in most blocks (0.19 – 0.22 m at p = 0.05 level), higher only in the two inhomogeneous blocks 5 and 6.

9.5% of total variance was attributable to blocks, 12.6% to provenance differences and 77.9 percent to variability within provenances. The variance analysis has also shown that the effect of provenances and of blocks on height growth was significant at p = 0.001 level (*Table 6*).

Detailed data by blocks and by provenances are found in the Appendix (*Tables A.6.1-11*). The mean of each provenance was adjusted by block effects, to enable direct comparison. Krutzsch's region means and their F values are also in the Appendix (*Table A.7*).

Figure 17. View of provenance trial in 1973 (age 6) one year after first assessment (Photo: ERTI archive)

Table 6. Analysis of variance and relative components of variance for height growth in 1972 (Unidentified plants excluded) (after F. Ujvári, unpublished)

Source of variation	Degrees of Freedom	Mean Square	F value	Components of variance %
Between blocks	10	33.56	267.1***	9.5
Between provenances	1088	0.56	4.5***	12.6
Error	22656	0.13		77.9

The results show that 38 foreign provenances were taller than Hungarians (Appendix, *Table A.8)* Based on the 1972 results, Krutzsch (1973a) has already proposed provenance regions suitable for Hungarian conditions (Appendix, *Table A.9)* Among the regions considered as superior there were 5 Polish, 4 Moravian, 3 Bohemian, 3 Slovakian, 2 Romanian, 1 Austrian, 1 Ukrainian and 1 Hungarian provenance regions. Out of these the ones from Bihor Mts. and from the Eastern Carpathians were outstanding. At the same time, certain regions had been considered as unfit for imports of reproductive material such as Scandinavia, much of the Alpine area and Bulgaria (Lines, 1979). This statement also applies to Hungary. Of course all these suggestions were born at a time when the changing climatic conditions and the tolerance to droughts and pests had not to be considered. Also, due to the very early age of the trial, the judgments have to be seen as a reflection of historic interest, although some of them maintained validity even to the present.

Figure 18. Complete data survey and selection of mother trees for vegetative propagation in 1977 (age 10)

The second complete survey was carried out in 1977 (age 10). The original purpose of the analysis was to further narrow down the number of provenances recommendable for plantation forestry in Hungary. The experimental mean of height amounted to 3.86 m and the least significant difference between provenances was 0.60 m. The mean height of 11 Hungarian provenances was 4.07 m (in the range of 3.51 – 4.48). After adjustment, 80 provenances were found significantly taller than the experimental mean and 20 provenances were significantly (at $p = 0.05$) taller than the Hungarian mean (*Table A.10*).

The results have shown that, in agreement with the results of the previous 5-year survey, East Carpathian, Bihor Mts. and Beskids Mts. provenances display the best height growth. It was stated, that there was significant rank correlation between flushing and *Sacchiphantes* infection; early flushing provenances were more susceptible. No significant correlation was found between *Sacchiphantes* infection and height growth (F. Ujvári unpublished). Between height data and DBH, measured in 1972 and 1977, a significant correlation at $p = 0.001$ level was found (Ujvári-Jármay – Ujvári 1979, 1980).

At a symposium of IUFRO WP 2.02.11 on Norway Spruce Provenances, held in 1973 in Biri (Norway), a decision was made to have a joint compilation of 10-year (from seed) height growth results. At the meeting of the Working Party during the IUFRO congress in Oslo (1976) a booklet with height data at age 9–12 from 8 countries and 14 experiments (Dietrichson et al. 1976) was distributed among the participants (Giertych 2001). In general a wide scatter of height data could be observed on each test site. A few provenances were well adapted to all sites, such as provenances from the Eastern Carpathians, NE-Poland, White Russia, and Bihor Mts. (see also chapter 4.5). Due to an administrative mistake, data of the Hungarian experiment were not included in this compilation.

Phenology, frost damage

As shown by numerous studies, spring flushing has a high heritability and thus may be used as a criterion for the determination of genetic differences between populations. It is also commonly recognized that the time of spring flushing is closely related to the damage caused by late spring frost (Lines 1973, Sabor 2002).

Comprehensive investigations of flushing were made by Lines (1973) in Scotland, Günzl (1979) in Austria and Sabor (2002) in Poland. In order to obtain as much early information as possible an anatomical study was made by Dietrichson (1969) in the nursery. The geographic variation of spring-frost resistance and growth cessation were investigated.

The assessments in the Hungarian experiment were made from April 6 to June 19 in 1972. A classification of developmental phases of spruce suggested by Krutzsch (1973) was used (*Table 3*).

The flushing started in the second half of April. Late frost may occur in Nyírjes several times even in May. Plants become frost sensitive after budburst (stage 3). On May 2 1972, a late frost damaged the early flushing trees. The mean degree of injury varied from 24 to 40% in early flushing provenances. Development of buds and distribution of early and late flushing provenances of block 7 can be seen in *Figure 20* (Ujvári-Jármay 2002).

Figure 19. Late frost damaged the side shoots only

Besides the bud development the variation between and within regions and provenances were studied. The provenance variation proved very highly significant (p <0.001) between regions (F. Ujvári, unpubl.). Provenances from Finland and high elevation of Alps were the earliest flushers, whereas very late flushing provenances were found among East Carpathian and Baltic provenances (*Figure 21*).

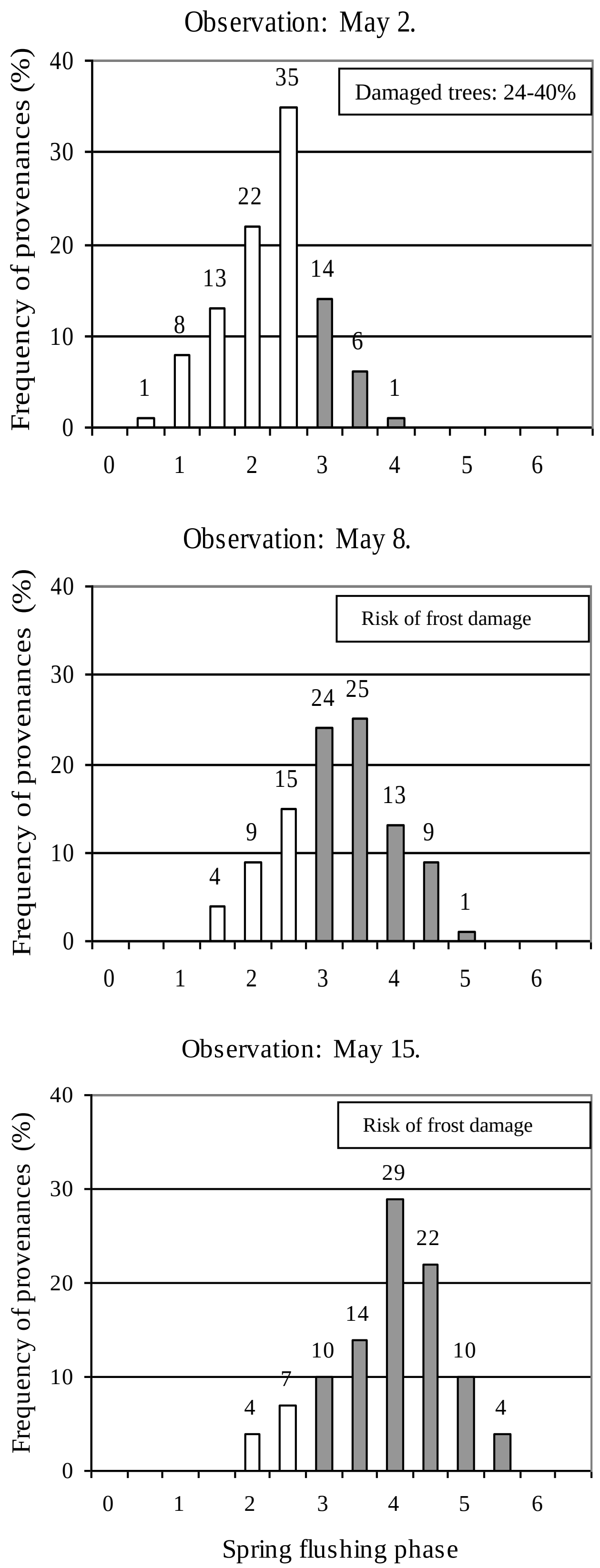


Figure 20. Distribution of provenances of block 7 according to development of buds (see Table 3 for stage codes) at three surveys in 1972 (shading: injured provenances on May 2 and provenances endangered by late frost on May 8 and 15) (Ujvári-Jármay 2002)

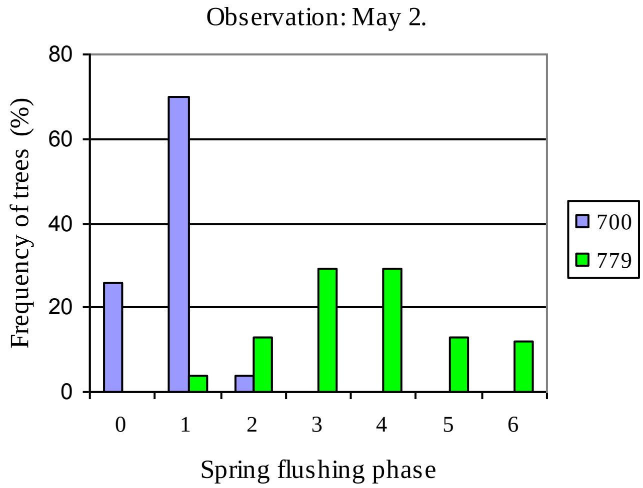


Figure 21. Within-provenance phenotypic variation of two provenances by developmental stage of buds (see Table 3 for stage codes) on May 2, 1972. A late flushing (0700 Cosna, Cucureasa, E. Carpathians, Romania) and an early flushing provenance (0779, Urjala, Finland) is shown

Flushing scores for the different provenances at different European sites were almost identical. Comparing the published results at different locations (Dietrichson 1969, Lines 1973, Sabor 2002), the patterns in term of early flushing and late flushing provenances were similar to the Nyírjes experiment.

On May 2, 1972 late frosts damaged the side shoots only of the early flushing provenances. Terminal shoots didn't suffer any damage, so there were no increment losses in Nyírjes (*Figure 19*). However, rank correlation proved that there was a significant correlation between flushing and height growth at p = 0.05 level (R = –0.257* with 100 pairs). Late flushing provenances grew better than early flushers.

Winter frosts, early and late frosts cause less harm in Hungary then in Scandinavia. At Abild, South Sweden, a severe autumn frost in September 1968 (the year of planting) caused considerable damage, and only about 20% of the plants were free from visible damage (Krutzsch, 1974). It was found, that trees suffering severe winter damage showed reduced growth the following summer and often led to stem faults and forking (Dietrichson – Skrøppa 1977, A. Persson – B. Persson 1992).

3.3 Results after age 15

Growth and survival of provenances in course of the assessment period

A comparison of block means of height and diameter growth as well as survival before and after age 15 is summarized in *Table 7.* Detailed list by blocks and by provenances are found in the Appendix (*Tables A.6.1-11*). The initial differentiation by block means (i.e. site quality) seems to remain across the whole assessment period. The same is true for provenance performance, which is treated in detail in the section on age correlation (chapter 3.4).

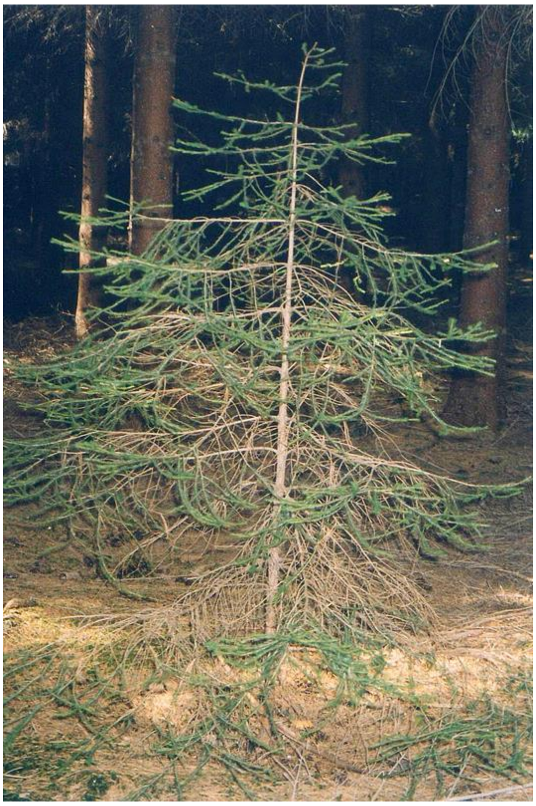


Figure 22. Height growth differences in 1991, at age 24.
In the foreground provenance Urjala (0779, Finland, Lat. 61.1°), the plant died in 2004. Directly behind are provenances 0747 Kuernach, Lat. 49.7° and 0776 Rabenstein, Lat. 49.1° (Germany)

Table 7. Summary table of block means of height, diameter and survival in different years of survey (only identified provenances were taken into account)

Block No.	Height m			Diameter cm						Survival %	
	1972	1977	1983	1977	1983	1992	1999	2003	2011	1977	1983
01	1.13	3.28		4.0		12.9	16.5		20.4	94.6	
02	1.15	3.36		4.1				17.2	19.8	86.4	
03	1.23	3.62		4.6				17.1	19.8	87.6	
04	1.18	3.60		4.6		14.9	17.5		22.9	89.4	
05	0.96	3.51		4.3				20.4	23.6	63.0	
06	1.21	3.96		5.0				19.5	21.6	77.7	
07	1.39	4.50	9.11	5.9	10.8	16.6	19.2	21.1	24.8	96.5	95.5
08	1.37	4.41	8.98	5.6	10.3	17.0	20.3	22.3	25.4	97.0	95.9
09	1.31	4.20	8.63	5.4	10.2	16.4	19.7	21.5	24.2	98.7	97.7
10	1.37	4.17		5.3		15.9		19.7	22.0	97.6	
11	1.26	3.81		4.9		15.9	19.0		24.3	98.0	
Experimental mean:	**1.23**	**3.86**		**4.9**					**22.6**	**89.7**	

Effects of first thinning

The survey of 1983 was followed by the first thinning. Results of two thinning methods are presented in *Table 8*, on the example of two blocks, 7 and 9. Both mean height and DBH in block 7 were generally higher, than in block 9. Effects of thinning on the different provenances were evaluated on the basis of the field map. After the selective, silvicultural thinning (block 7), mean height increased by 6.3%. Relatively few trees were cut from the best 12 provenances (23.3%), while trees from the less vigorous provenances were reduced by 60.9%.

Block 09 was thinned systematically. After thinning no significant mean height change was detected. A small increase could be explained by the fact, that the detailed assessment in the tenth year (1977) was followed by marking the tallest, healthy trees for autovegetative propagation. The systematic thinning was changed where a superior tree appeared in a position marked for removal. In such cases a neighbor was cut. The number of remaining trees was similar in the most vigorous and in the poorest 12 provenances. After thinning the ranking of provenances changed only slightly.

Table 8. Effect of thinning in 1984 on mean height and on number of trees in two blocks (unidentified plants were included)

Characteristics	Before thinning	After thinning	Change %
Silvicultural thinning, Block 7			
Block mean height (m)	9.10	9,67	+6.3
Number of plants in the block	2 389	1 436	–39.9
Mean height of 12 best provenances (m)	10.06	10.28	+2.2
Number of plants of the best 12 provenances	288	221	–23.3
Mean height of poorest 12 provenances (m)	7.49	8.12	+8.4
Number of plants of poorest 12 provenances	261	102	–60.9
Systematic thinning, Block 9			
Block mean height (m)	8.65	8.69	+0.5
Number of plants in block	2 443	1 274	–47.9
Mean height of 12 best provenances (m)	9.61	9.68	+0.7
Number of plants of best 12 provenances	285	166	–41.8
Mean height of poorest 12 provenances (m)	6.79	6.85	+0.9
Number of plants of poorest 12 provenances	251	142	–43.4

Health condition and mortality

A survey of health condition was carried out almost every year. Until the 1980s very slight mortality was recorded. Some trees died because of stagnant water in lower part of the experiment (block 4, 5, 6) and game damage was repeatedly observed.

The injuries of bark beetle (*Ips typographus*) were first noticed in block 7 in mid-1990s. In some years it spread in the whole block. Summer drought associated with higher temperatures has given rise to outbreaks of bark beetle, but damage remained limited, considering the whole experiment. In block 7 edaphic problems (pseudogley) led to significant mortality. The dynamism of mortality was monitored, and differences between provenances were observed (Ujvári-Jármay, 2002). The range of tolerance to bark beetle damage is presented in *Table 9.* In block 7 the most sensitive provenance originated from Sumava National Park. At the same time, there were provenances in the same block – e.g. from regions Ardennes, Masurian Lakeland, Scandinavia and Eastern-Carpathians – without any damages.

During the meeting of IUFRO WP 2.02.11 held in Stara Lesna (Slovakia, 1997) and in Krynica (Poland, 1997) the sensitivity to infection of bark beetles of the Sumava National Park provenance (Czech Republic) was also reported.

Table 9. Spruce mortality caused by bark beetle in the Nyírjes trial block 7 between 1996 and 1999. The most sensitive 10 provenances are listed

No.	Provenance IUFRO No. and name		Region No. and name		Country code	Mortality %
1	0702	Nove Hrady-Dolni H.	36	Lower AT, Sumava East	CZ	33.3
2	0775	Clausthal	07	Harz Mts.	DE	27.3
3	0793	Passau-Sued	20	Bavarian Forest	DE	20.0
4	0763	Kloten	90	Karlstad, Västmanland	SE	15.3
5	0780	Landsberg	23	Svabian-Bavarian Upland	DE	13.3
6	0760	Siessen	17	South Schwarzwald	DE	12.7
7	0735	Knittelfeld	32	Styria	AT	12.5
8	0745	Ruzomberok	46	Fatra	SK	10.5
9	0765	Stübing/Gamskogel	32	Styria	AT	10.0
10	0746	Wismar	08	Mecklenburg	DE	9.5
Block average:						**4.2**

Survival at age 44 (2011)

Data on the numbers of remaining trees in complete experiment at the latest assessment, aged 44 and surviving trees expressed in percent of initial stem numbers by provenances and by blocks can be found in the Appendix *(Table A.12* and *Table A.13).*

Windbreak damage

The spruce mortality in block 7 was followed by windthrow and windbreak, therefore 2/3 of the whole block had to be harvested in 2007 (*Figures 23*, *24*). Fortunately the damage in other blocks was very slight.

Figure 23. Windbreak in block 7, in 2007 (photo: Gy. Csóka)

Figure 24. Clear cutting, natural and artificial regeneration after windbreak in block 7 in 2010

Figure 25. View of experiment from North in 1991 (in center of photo)

Stem cracks

Fast growing trees suffered often from stem cracks in Scandinavian trials. In the Hungarian experiment this phenomenon was observed on less than 1% of the stems of adult trees, mainly on the edge of blocks (*Figure 26*). Thus the damage was much less than in the Nordic countries (Dietrichson et al. 1985).

Figure 26. Stem cracks. Trees standing on the edge of blocks were damaged

3.4 Data of the adult trial (age 44)

A complete survey was carried out after a long interruption of support in 2011, at the age of 44 years. Due to the dense canopy closure, ground-based height measurements proved to be inaccurate, therefore only tree diameters have been recorded. All available data of the diameter survey have been tabulated in percent of the corresponding block mean (Appendix, *Tables A6.1-11*). *Table 10* summarizes the results of the analysis of variance for diameter. The number of trees declined to less than half due to thinning and mortality. The 2007 windbreak left a low number of undamaged trees in block 7, so hundred provenances (0700-0799) had to be excluded, i.e. a complete block is missing. This analysis, although not directly comparable to the earlier ones on height growth, shows similar results i.e. highly significant between-block site effects and between-provenance variation.

Table 10. Analysis of variance results for diameter at age of 44 (2011)

Source of variation	DF	MS	F-value
Between blocks	9	15 983.17	30.15***
Between provenances	992	104.92	3.84***
Error	9744	27.33	

Figure 27. View of the provenance trial at the survey in 2011, at age 44.
In the foreground provenance 0895 Liptovsky Hrádok (photo: Gy. Csóka)

Effect of test site conditions on between-provenance variance of diameter

A recurrent misinterpretation of provenance test results originates from the fact when variance components for site differences are compared to the genetic ones, leading to the statement "site effects are much more important than within-species variation". As an example, data from Nyírjes and of three German test sites were used for analysing the effect of site conditions on the variation and interaction of 100 selected provenances (Liesebach et al. 2001). To quantify the effects of sites, provenances and interaction an analysis of variance was run for diameter at age 29. The results are listed in *Table 11.* 38% of the total variance could be explained by variation between locations (site conditions), 9% by effects of the provenance and about 1% by the site – provenance interaction.

Table 11. Analysis of variance and relative components of variance for diameter growth in four trials at age 29 (Liesebach et al. 2001).

Source of variation	DF	MS	F value	Components of variance (%)
Test site	3	10 405	884.06***	38
Provenance	99	118	9.99***	9
Site × provenance	297	16	1.32***	1
Error	5 554	12		52

The effect of provenances is significant, however that of sites is much higher. The seemingly stronger effect of sites is of course primarily *the result of strongly differentiated site potentials of the test locations*, and has little relevance from point of view of the studied within-species genetic patterns. The choice of analyzed treatments (provenances) and of test sites will strongly influence the significance of the variance source "provenance".

Compared to the provenance component, the contribution of interactions is negligible; it may, however, grow considerably if sites in different climate zones are compared.

Age correlation, after two thinnings

A comparison of juvenile height and adult diameter results (H10 and D44) was done after the trial was thinned two times. Blocks 8, 9 and 11 were thinned first systematically, then, the second time (2003) only a slight sanitary cutting was applied. Thus the standard design did not change and the blocks were appropriate for computing of age correlations. Results of both provenance-level and individual-level age correlations are presented for systematically thinned block 9 in *Tables 12* and *13*.

List of provenances significantly better than the experimental mean, and of provenances significantly better than Hungarian average, based on juvenile height at age 10 and of diameter at age of 44 may be found and compared in the Appendix (*Tables A.10* and *A.11).* When comparing the two Appendix tables, it turns out that from the provenances significantly better by height at age 10, the ones representing the regions 6, 10, 22, 27, 38, 39, 41, 44, 45, 48-50, 52 and 62 are not among the significantly better provenances according to diameter at age 44. The provenances losing their superiority were from Central, Southern and Eastern Germany, Czechia, parts of Moravia, most of Slovakia and the Eastern Beskids. The provenances from Eastern Mazuria and the Baltics also lost their leading status. The provenances maintaining their high productivity at age 44 were first of all provenances from the lower elevations of Slovakian mountains (Cierny Váh, Liptovsky Hrádok) and from Istebna (from the Western Beskids - an introduced provenance of unknown origin!), but first of all, not surprisingly, from the Eastern Carpathians (Dorna Cindreni, Jasina) and the Bihor Mts. in Romania. Some lower elevation populations from Moravia, Central Germany, North Poland (Pomorze/Pomerania) and Lower Austria (Jaidhof) were also among the best. A few from the latter might be among the superior provenances for some random reason. A surprise is the performance of a Scanian provenance (1145 Barsebaeck) which is most probably a non-local, introduced population.

In general, both provenance-level and individual-level age correlations indicate a convincingly strong correspondence between age 10 and age 44 data (*Tables 12 and 13*). Taking into account that all correlation coefficients were significant at p = 0.001 for both levels, the results of the experiment may be considered as a realistic, long-term indicator of both provenance and individual growth responses. The decline of individual early age (5–10 yr.) correlations compared to results at age above 30 is partly due to growing competition effects and to sanitary removals during the second thinning.

Table 12. Provenance-level age correlations (R) for growth traits (block 9)[1]

Growth traits	Height		Diameter					
	1977 10-y	1983 16-y	1977 10-y	1983 16-y	1992 25-y	1999 32-y	2003 36-y	2011 44-y
Height 1972 (n=99)	0.950	0.891	0.938	0.907	0.835	0.806	0.758	0.733
Height 1977 (n=99)		0.970	0.966	0,962	0.884	0.851	0.791	0.763
Height 1983 (n=99)			0.934	0,963	0.900	0.871	0.818	0.794
Diameter 1977 (n=99)				0.976	0.903	0.875	0.832	0.803
Diameter 1983 (n=99)					0.931	0.902	0.862	0.838
Diameter 1992 (n=99)						0.983	0.950	0.929
Diameter 1999 (n=99)							0.969	0.954
Diameter 2003 (n=98)								0.991
Diameter 2011 (n=98)								

[1] All correlation coefficients were statistically significant at p = 0.001

Table 13. Individual-level age correlations (R) for growth traits (block 9)[1]

Growth traits	Height		Diameter					
	1977 10-y	1983 16-y	1977 10-y	1983 16-y	1992 25-y	1999 32-y	2003 36-y	2011 44-y
Height 1972 (n=2464)	0.829	0.694	0.847	0.722	0,639	0.571	0.492	0.448
Height 1977 (n=2461)		0.860	0.910	0.836	0.774	0.708	0.632	0.580
Height 1983 (n=2437)			0.806	0.840	0.829	0.778	0.712	0.666
Diameter 1977 (n=2446)				0.893	0.814	0.747	0.676	0.623
Diameter 1983 (n=2431)					0.925	0.877	0.829	0.781
Diameter 1992 (n=1250)						0.979	0.960	0.924
Diameter 1999 (n=1226)							0.991	0.971
Diameter 2003 (n=1041)								0.985
Diameter 2011 (n=1022)								1

[1] All correlation coefficients were statistically significant at p = 0.001

It has to be highlighted that the correlation found between DBH at 10 years and 44 years is very strong at provenance level (0.803***). Even the correlation between 10 years height and DBH at age 44 is highly significant, which indicates the reliability of early measurements already at the age of 10 years. Naturally, the success of trial establishment and the relative uniformity of the site contribute to the observed high correlation.

DBH measured at age 44 (in 2011) characterizes the trait after more than half of the usual rotation age applied for Norway spruce in the Northern Central Mountains region. According to the regular procedures applied in domestic forest tree breeding, growth data at half-rotation age are accepted as final results, characterizing the potential of the population at felling age.

Value and adaptability of Hungarian provenances

A question of primary importance at the establishment of the Hungarian trial, the performance of local spruce provenances, lost its eminence due to the changes in the species preference of foresters. This conversion was brought about by the growing valuation of native species and by the concerns caused by expected climate changes. So the question needs to be reformulated to “how successful was the introduction of spruce to Hungary? How well were the provenances selected; would have been populations from other sources better adapted for planting in a new environment?”

On the basis of Dietrichson’s (1976) compilation, the adaptability of Hungarian provenances in foreign trials has been investigated (*Table 14*). On all sites – except for Canada and Sweden – the Hungarian provenances exceeded the experimental average. (Significant differences calculated for age 9 (4 + 5) from seed are to be found in *Table 5*).

Table 14. Relative mean height of 11 Hungarian provenances at 9 to 11 years from seed (1972–1974) at 15 sites in percents of the corresponding block means (source Dietrichson et al. 1976 and Ujvári-Jármay & Ujvári 1980)

No	IUFRO Ref. No. and compartment name		Country code and experiment No.														
			CA	NO	NO	SE	SE	SE	FR	BE	BE	DE	DE	DE	GB	CZ	HU
			1	4	5	6	7	8	10	11	12	13	14	15	16	17	20
1	0154	Magyarlak 2 A	92	84	98	91	–	74	97	–	–	112	110	103	–	100	113
2	0271	Háromhuta 19 B	93	105	97	96	92	86	98	98	–	107	102	87	–	97	101
3	0341	Sopron 203 D	95	92	112	103	115	99	80	–	108	115	116	102	–	101	111
4	0455	Kőszeg 60 A	83	113	113	93	113	90	107	–	–	124	116	113	–	115	118
5	0510	Szentgotthárd 1 C	116	116	107	97	83	85	111	-109	–	114	124	104	–	119	120
6	0633	Kercaszom. 20 A	91	108	105	93	–	89	98	–	–	109	102	118	–	109	97
7	0796	Bükkszentkereszt	101	103	94	108	103	117	101	–	–	114	119	91	–	116	103
8	0905	N.Kanizsa Iharos	97	99	113	81	–	101	109	–	–	108	123	99	115	103	113
9	1044	Mályinka 49 F	81	86	87	84	81	89	82	–	–	94	99	97	93	81	100
10	1090	Kőszeg 1 C	96	105	108	114	64	102	104	–	–	106	109	93	110	94	118
11	1163	Lillafüred 82 A	110	118	109	–	88	108	111		–	105	106	110	111	117	107
Mean of Hungarian prov.			**96**	**103**	**104**	**96**	**92**	**95**	**100**	**104**	**108**	**110**	**111**	**112**	**107**	**105**	**109**
	0613	Remeti, Z.[1] (RO)	127	115	121	127	–	97	126	107	–	119	133	122	–	127	139
	0768	Vallen B.[2] (SE)	55	69	94	73	68	113	57	–	–	53	63	55	–	58	49

[1] most vigorous provenance in the Hungarian experiment
[2] poorest provenance in the Hungarian experiment

Regarding the early performance of Hungarian provenances, a citation from Lines (1979) says: "Mean diameter of the two tallest trees per plot at Drummond Hill (GB, Experiment No.16) ranged from 8.75 cm for the Hungarian origin (1090) Koeszeg, down to 3.05 cm for the Swedish origin (1093) Kloevsjoe, averaging 6.96 cm, 11 years after planting". Some Hungarian provenances showed superior DBH in other trials even at age of 20 to 40 such as in Poland (No. 19, Krynica), which is a mountain site at 750m elevation, with 890 mm annual precipitation and 6,1 °C annual mean temperature (*Table 15*, *Figure 28*).

Table 15. Relative mean height and DBH of 11 Hungarian provenances in different years of observation (1977–2011), on 5 sites in percents of corresponding block means (sources: A. Persson – B. Persson, 1992; Sabor, 1997; Bałut – Sabor 2002; Ujvári-Jármay and Ujvári – Nagy, unpublished data)

No	Hungarian provenances IUFRO No. and name		Experiment No. and country code Growth traits and age										
			6 SE	7 SE	8 SE	19 PL				20 HU			
			H16	H18	H19	H11	H16	H21	D28	H10	D25	D36	D44
1	0154	Magyarlak 2 A	78	–	85	78	86	91	–	109	105	–	98
2	0271	Háromhuta 19 B	99	95	70	105	107	103	100	90	–	109	109
3	0341	Sopron 203 D	104	110	94	117	115	111	–	103	–	115	115
4	0455	Kőszeg 60 A	98	111	96	155	143	138	–	115	116	–	111
5	0510	Szentgotthárd 1 C	83	87	82	104	98	100	–	102	–	101	104
6	0633	Kercaszomor 20	86	–	92	115	114	113	118	101	–	107	100
7	0796	Bükkszentkereszt	111	110	130	107	102	99	–	105	100	97	*
8	0905	N.Kanizsa Iharos	65	–	118	105	103	103	–	115	109	113	112
9	1044	Mályinka 49 F	88	79	98	108	100	99	99	103	103	100	101
10	1090	Kőszeg 1 C	104	81	109	115	101	106	115	108	105	103	100
11	1163	Lillafüred 82 A	–	98	110	110	108	104	–	108	114	–	116
Mean of Hungarian provenances			**92**	**96**	**99**	**111**	**107**	**106**	**108**	**105**	**107**	**106**	**107**

* could not be evaluated due to storm damage

It has been already stated that Norway spruce has never been native within the present boundaries of the country. The species was introduced sporadically in the second half of the 19th century, with the advent of regulated forestry, in a climatic phase of more Atlantic type than at present. The relatively small scale plantings did not originate from commercial imports. The reproductive material originated most probably from the adjacent Northern and Eastern Carpathians – at that time part of the country. The second wave of spruce planting in Hungary occurred in the postwar period of voluntarist economy, to solve the serious problem of softwood supply. Knowing the relative commercial isolation and the shortage of foreign currency in these years, it is most probable that the reproductive material of this generation of stands originated from domestic sources as well. The stands and mother trees used for seed collection for the experiment were predominantly descendants of the first generation of introduced populations. Their growth and adaptability in foreign trials and also in the domestic one indicates that the selection of sources was quite successful and the probability of Carpathian origin is high. E.g. provenance 0796 Bükkszentkereszt (*Table 16*, chapter 4.1) used as local standard in the analyses, is also of unknown origin, but its late flushing, above average growth, and the declinig tendency of diameter/height ratio with age, seem to support its origin from the Eastern Carpathians. Up to now no investigations were carried out to prove this hypothesis.

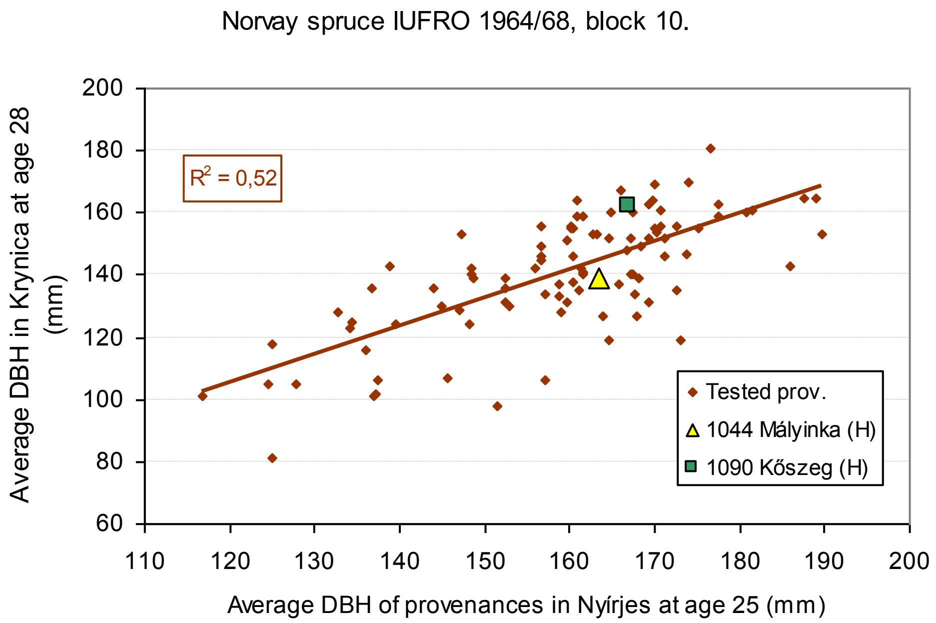


Figure 28. Regression of Krynica's (No. 19, PL) average DBH of provenances versus Nyírjes's (HU) data at age of 25 and 28 years. Maximum provenance diameter means at Nyírjes: 1062 Jasina (190 mm), at Krynica: 1045 Istebna (181 mm). (Data: Sabor 1997, Ujvári-Jármay & Ujvári unpublished)

Summing it up, the use of reproductive material from local seed collection for domestic forest regeneration in Hungary has been supported by the test results (Ujvári-Jármay – Ujvári, 1980; Ujvári 1986).

4 MODELING ADAPTIVE RESPONSE TO MIMICKED CLIMATIC CHANGE

The concept of response analysis is based on the hypothesis that phenotypic response to macroclimatic changes depends on the inherited adaptive potential of the population and on the magnitude and direction of experienced environmental change. *Response analysis stands for both reaction norms and transfer functions. Reaction norms are calculated for single provenances (or single provenance groups) tested at different locations, while transfer functions display the response of numerous provenances at one single test site.* In common garden experiments, the transfer to the planting site is interpreted as simulation or mimicking of environmental change (Mátyás – Yeatman 1992).

In response analysis, the climatic variable (E) selected to best describe macroclimatic adaptation serves as independent variable, expressed as difference between test site (X_t) and location of origin (X_0). The ecodistance (DE) is then calculated as (Mátyás et al. 2009)

$$DE = X_t – X_0$$

The application of ecodistance of transfer for evaluating common garden experiments provides much needed quantitative information about response of tree populations to predicted climatic changes (Mátyás 2004). The aim was to analyze provenance tests in order to develop a response model of adaptation and stability of populations on evolutionary-ecological basis, following sudden climatic changes as a result of transplanting. Modeling of height and diameter were performed with the help of ecodistance variables.

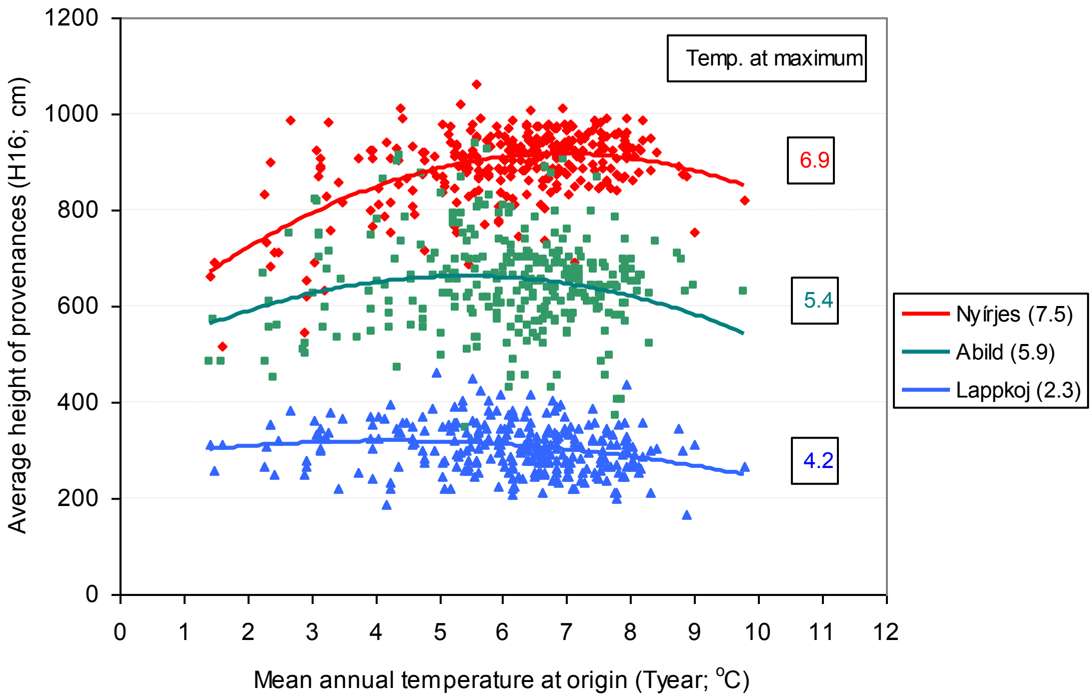
4.1 Response analysis at climatically distant sites: transfer functions

Climatic data for the sites of origin of the tested provenances, as well as for the test sites have been determined from monthly average precipitation and temperature maps for Eurasia, using the Worldclim database (see chapter 2.3). Transfer functions are calculated for individual tests, to describe the between-provenance variation of response in function of climatic variables. These models can then be used to predict the effects of climatic change on growth and survival (after Mátyás 1994). Provenance means measured in different blocks were *corrected with the calculated additive bock effect, termed "adjusted height"* (*H'*).

For the analysis, data of two parallel Swedish tests (Krutzsch 1974, Ujvári-Jármay and Ujvári 2006) Abild and Lappkojberget (63° 25´!) have been combined with data of Nyírjes. Data of Swedish experiments were published by A. Persson and B. Persson (1992). The three tests are climatically nearly equidistant, from the thermic (upper) to the xeric (lower) limits and the optimum for Norway spruce (*Figures 16* and *4*). Out of the 11 blocks planted, the adjusted mean heights at the age of 16 years (H'16) of provenances in block 7, 8 and 9 (i.e. theoretically 3x 100 = 300, in practice 291 populations) were analyzed (*Figure 16*). H'16 is a reliable criterion for productivity, because provenance-level age correlation between height at 16 and diameter at 44 years is strong: 0,794*** (*Table 12*). In order to confirm the results, further growth data (diameter at 25 years = D25 and diameter at 44 years = D44) were checked as well.

Table 16. Data of three selected experiments and provenances considered local (height measured at age 16)

Experimental site data				Local provenance data			
Test No. and name	mean height of test (cm)	mean annual temp. °C	mean annual precip. (mm)	Prov. No. and name	mean height of prov. (cm)	mean annual temp. °C	mean annual precip. (mm)
20 Nyírjes (HU)	892.5	7.5	782	0796 Bükksztkereszt	932.4	6.9	823
06 Abild (SE)	643.1	5.9	654	0980 Kinnared	693.9	5.6	651
08 Lappkojberg (SE)	305.4	2.3	456	0938 Geraasaag	323.3	3.2	441



Site	R^2	df	F	p
Nyírjes	0.2964	288	60.66	0.0000
Abild	0.0334	288	4.97	0.0075
Lappkojberget	0.0497	286	7.47	0.0007

Figure 29. Regression of 16-year average tree height (vertical axis) of identical Norway spruce provenances versus mean annual temperature (°C) at the origin (horizontal axis) in three IUFRO provenance tests. Mean temperatures (°C) of the test sites are shown in the legend. The attached table shows main statistical data of the polynomial regression computed with the GRM program

Transfer functions were calculated versus the mean annual temperature of the locations of origin of the populations for the three sites *(Figure 29).* In all 3 experiments local provenances were identified (*Table 16).* In case of Nyírjes, "local" means the ecologically nearest population, as no Hungarian provenance is native. Average heights and DBH of zone groups were also expressed in % of local population as relative values (see also *Figure 30,* chapter 4.2 and *Figure 39, Tables 21, 22;* chapter 4.5).

The climatically determined site potential difference is well reflected by the general decrease of production in the northern tests, as compared to Nyírjes. Comparing the three transfer functions, it seems that *genetic differentiation in height growth, or better: expression of utilization of length of growing season is enhanced in milder environments, where minimum temperature constraints and selection effects are not present*. This is a general observation of test series compared at different sites: with increasing length of the vegetation season, i.e. with improving conditions the growth differentiation between provenances is increasing (Mátyás et al. 2010, Kapeller et al. 2012).

At the northern test sites, against any expectation, populations originating from mild, warmer environments perform rather similar to the local provenances, as if these genotypes would equally tolerate the extreme boreal conditions. It has to be remembered however, that *only surviving trees contributed data for the regressions in the Figure 29*! For example in the Northern test of Lappkojberget a survival of approx. 30% for the southernmost populations with an annual average temperature of e.g. 8.5–9 °C means that only about one third of the genotypes in these populations were able to adjust their annual cycle to an annual average temperature of 2.3 °C (see *Figure 41,* chapter 4.7). At the same time, northern populations were unable to utilize the long vegetation season of Nyírjes in Hungary; their low height growth is however not connected with a heavy mortality, at least not until within-stand competition has set in. Majority of the genotypes survived the very different temperature cycles – it is another question that they lost their competitive potential after the closure of the stand.

The results confirm on the one hand the inherently high within-population genetic variation and phenotypic plasticity present in Norway spruce (and, in general: forest trees) which lends an unusual potential of adjustment even to instant extreme changes of weather/climate conditions.

On the other hand it draws the attention on the *significance of competitive power* in ecosystems with differently adapted species – vegetative fitness (first of all height growth and tolerance to extremes, pests) will decide about survival. In this respect the transfer function for Lappkojberget (*Figure 29*) shows a deceptive picture (compare to *Figure 41*).

4.2 Transfer functions by zone groups

The analysis has shown that phenotypic stability ("plasticity")[4] of populations from certain geographic regions display characteristic differences, which may be determined by regional adaptation/microevolution or by random effects (migration). As an example, the transfer function for height growth is shown for 10 zone groups of spruce provenances. For the

[4] plasticity is regularly used to describe this phenomenon, but the authors believe this is often an inappropriate interpretation of the original meaning of plasticity, which refers to changes in manifestation of traits. In the investigated cases, however, only the observed increment changes; therefore the term stability is preferred

Nyírjes site the most important and most promising populations belong to the following three zone groups: Eastern Carpathians (5), the Sudeten-Beskids (4), and Harz Mts-Böhmerwald (3).

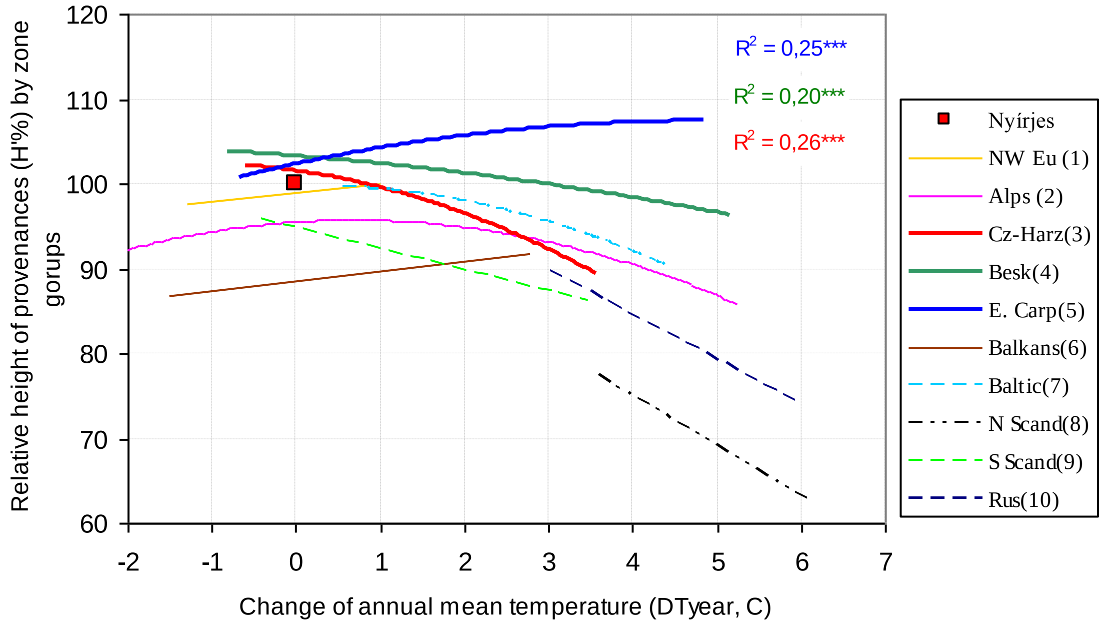


Figure 30. Effect of mean annual temperature change (°C) (horizontal axis, positive values stand for warming), on 16-year relative height (H %), measured in Nyírjes by zone groups. The 10 zone groups show different phenotypic stability characteristics

Figure 30 shows that an increase of average annual mean temperature of up to 4 °C has no significant effect on the 16-year height of eastern Carpathian provenances in the Nyírjes test. At the same time the population from the Harz-Böhmerwald (3) have reacted with a decline of roughly 15%. The Sudeten-Beskids group was in between. The transfer function values of relative heights for "local" values (= where the mean temperature of the test site Nyírjes was similar to the one at origin of the population, i.e. DTyear = 0) were similar for all the three zone groups (H'16 ~ 103%). The results support the higher stability of the Eastern Carpathian provenances (Mátyás et al. 2010). Similar experiences have been gained by Norway spruce breeders in northern Europe (A. Persson – B. Persson 1992). Contemplating all transfer functions together, a parallelism of certain functions is visible, first of all that of boreal zone groups 7, 8, 9 and 10. It has to be considered however, that the position and the slope of the function depend on the original mean temperature of tested provenances in relation to the conditions of the test site. A nonlinear extrapolation of functions would show a rather parallel run on all zone group functions.

The data have been analyzed by ANOVA, data are displayed in *Table 17*. Both the F value and the LSD test between zone groups were highly significant at $p < 0.001$ level.

Table 17. Analysis of variance of adjusted heights of zone group data

Source of variation	d. f.	Mean Squares	F value	*p*
Intercept	1	105 610 125	39 175.0***	0.000
Between zone groups	9	113 936	42.3***	0.000
Error	281	2 696		

4.3 Effect of climate variables on growth traits of provenances

According to the basic hypothesis, in provenance tests provenance heights are in correlation with the ecological (climatic) distance of transfer, i.e. with ecodistance. In order to apply the data for projection of performance under changed climatic conditions, the question: how much does height (or DBH) change for a given shift in climate variables. The response will determine about adaptability, survival or mortality of the population.

For detailed analysis of differences in adaptability first of all correlation coefficients and determination coefficients between height growth and climate variables were calculated, i.e. between adjusted mean height (*H'16*) of provenances and ecodistances of transfer. More than 130 climate variables were investigated. The main climatic parameters and their R values are listed in *Table 18.*

Table 18. Correlation coefficients between adjusted heights (H'16) and different ecodistances for Norway spruce. Sensitivity differentiation between groups is marked turquoise. Data: Nyírjes trial, 290 provenances in 3 blocks

Variables	Provenances pooled (n = 290)	Southern range (n = 236)	Northern range (n = 54)
Mean annual temperature, C° (*DT_{year}*)	***–0.444***	–0.107	***–0.811***
Continentality, average of $T_{max} – T_{min.}$ (*DT_{cont}*)	<u>*0.187*</u>	***–0.491***	<u>*0.328*</u>
Mean temp. of vegetation period, 04-10(*DT_{veg2}*)	***–0.408***	<u>*–0.255*</u>	***–0.830***
Mean winter temperature, 12, 01, 02 (*DT_{win}*)	***–0.381***	<u>*0.173*</u>	***–0.637***
Mean spring temp, 03-05 (*DT_{spr}*)	***–0.512***	<u>*–0.227*</u>	***–0.819***
Mean summer temp, 06-08 (*DT_{sum}*)	<u>*–0.264*</u>	***–0.289***	***–0.721***
Mean autumn temp, 09-11 (*DT_{aut}*)	***–0.434***	–0.066	***–0.780***
Number of months above 5 C° (*DT5+*)	***–0.490***	<u>*–0,223*</u>	***–0.731***
Mean precipitation sum per year, mm (*DP_{year}*)	0.079	***0.531***	–0.249
Mean precip. sum in veget. period, 04-10 (*DP_{veg2}*)	0.051	***0.496***	–0.252
Mean precip. sum in winter, 12, 01, 02 (*DP_{win}*)	<u>*0.118*</u>	***0.476***	–0.200
Mean precip. sum in spring, 03-05 (*DP_{spr}*)	0.001	***0.511***	<u>*–0.418*</u>
Mean precip. sum in summer, 06-08 (*DP_{sum}*)	0.004	***0.428***	–0.169
Mean precipitation in autumn, 09-11 (*DP_{aut}*)	<u>*0.234*</u>	***0.558***	–0.141

coefficients in underlined <u>*italics*</u> are significant at $p < 0.05$, in ***italic bold*** at < 0.001
variables highlighted in grey color have been analyzed further in detail

Instead of analyzing only pooled data, it is quite informative to split provenances into two parts, roughly along latitude 55: the southern group consisting of whole central and SE Europe, the northern one of Scandinavia, Baltics and N Russia. The most interesting phenomenon is the clear differentiation of the two groups: the northern group displaying a clearly higher sensitivity to temperature variables, while the southern group shows the same for precipitation (highlighted in *Table 18*). The differentiating selection pressure approaching to either the thermic or the xeric limit is well documented. It is also illustrative that the pooled analysis of all provenances covers up much of the zonal divergence of response, especially for precipitation.

Above and similar other correlations with climatic factors indicate a significant differentiation between Southern and Northern populations. In view of the basically dual migration origin of European Norway spruce as proven recently on material from Nyírjes by Sperisen et al. (1999) and Tollefsrud et al. (2008) with the analysis of maternally inherited mtDNA (see chapter 5.4 on analysis of genetic polymorphism), two alternative interpretations for explaining this dichotomy are possible: a pattern originating from either historic migration or from climatic selection. The contradiction might be solved considering the different adaptive background of the traits. Growth traits (e.g. length of active growth period, temperature sum needed for budbrake etc.) must be under permanent and direct selective pressure on a given site, resulting in a genetic variation pattern significantly correlated with climatic variables.

On the other hand, neutral molecular markers, such as mtDNA haplotypes are inherited independently from environmental effects and may maintain footprints of postglacial migration, as proven e.g. for oak species. In the case of Norway spruce, these two effects appear incidentally confounded across Central-Northern Europe. We may assume that *the within-species adaptive genetic variation reflects predominantly the selective effects of actual, recent climate, and these forces may overwrite historic and gene flow influences on adaptive traits, especially in the zones of severe selection.* The assumption is further supported by the observable difference of transfer functions of zone groups North and South Scandinavia, originating from the same refugial area, but displaying a weaker response towards the south (*Figure 30*). The dominant effect of climatic factors has been identified also in another unrelated species with different migration background, Scots pine (Mátyás 1981). This hypothesis may be maintained even in the light of some evidence that a number of isozyme and molecular markers display certain, although weak correlations with climatic factor patterns in Norway spruce (unpublished results of Vendramin and Kärkkäinen in 2015).

The two interpretations are not completely opposing, as spruce populations migrating from the East to Scandinavia and the Baltic had to adapt to boreal conditions already in NE Europe; therefore they most probably carried already adaptation to boreal conditions when immigrating to Scandinavia. In addition, clear, fine-tuned clinal variation may be also observed between spruce populations along the latitudinal (climatic) gradient within Scandinavia which cannot be considered as an effect of migration (Savolainen et al. 2004, Ericsson and Ekberg 2001). This is supported by the observed response of Northern populations to temperature change: the regression in *Figure 31* indicates a close, clinal climatic adaptation for Scandinavia.

Multiple regression modeling of height growth response with humidity and thermic variables

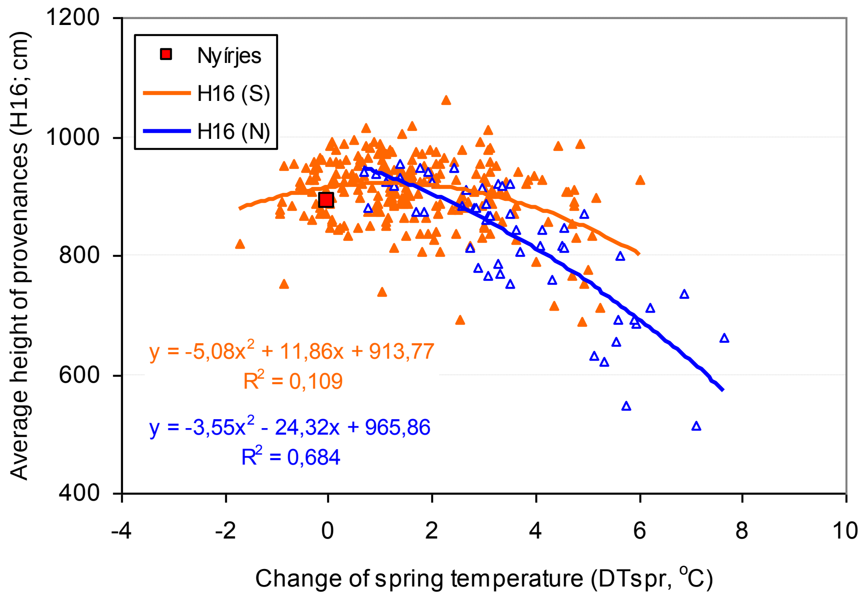
The comparison of reaction norms (chapter 4.4) proves that growth responses to (climatic) transfer are characteristically differentiated by regions of provenance. The analysis of main climate factors influencing growth response (see previous subchapter) indicates that climatic adaptation requires tolerance to different factors approaching the xeric (lower) limit or the thermic (upper) limit; in comparison to Southern populations, Northern ones have displayed a significantly stronger response to change of temperature being exposed to the selection effect of harsher cold spells, controlling their distribution at the thermic limit (*Table 18*). On the other hand, in the range part approaching the lower, drier and warmer limit (= xeric limit) increasing exposure to dry events is indicated by higher responsiveness to precipitation change. In our interpretation this differentiation is primarily caused by a different frequency of stressing and limiting climatic events – conceding that it may be confounded with the effects of different migration origin.

A multiple regression analysis of response containing both a precipitation and thermic factor to survey their effect on growth performance should be done therefore separately for the two range parts; a pooled analysis will underestimate the full effect of climatic variables on the adaptive pattern within the species.

In the followings the response of provenances is investigated against a temperature and a precipitation variable. The selection of the variables was based on the results displayed in *Table 18*. For selecting the variables which may describe best the climate effects for both groups, the correlation coefficients for the pooled data as well as for the ones of the northern and southern groups had been considered. From among thermic and humidity variables highly correlated with 16-year height, the ecodistances of spring and autumn temperature and precipitation display reliable correlations significant at least in two columns. Spring temperature and rainfall is certainly an adaptively decisive variable for all provenances (determining spring phenology), for autumn precipitation this seems to be less obvious, especially for the Northern group. Bearing in mind that in both variable groups the intercorrelation between variables is high, the *mean temperature ecodistance of spring months* (*DT_{spr}*)*, and mean spring precipitation ecodistance* (*DP_{spr}*) *were selected* for calculating second degree polynomial regressions for both selected climate factors.

During the processing of growth data the differences in growth rate has been investigated in order to identify outliers, most probably not autochthonous and therefore correlation breaking provenances. Very few populations with extreme data had been excluded, such as 0900 Timirjas (RU) and 0905 Nagykanizsa (HU), the latter being certainly a cultivated stand of unknown origin. Similarly 0927 Austagder (N), from the south coast of Norway, was excluded, which has been identified as originating probably from Lapland. After the exclusions, 290 provenances (236 southern and 54 northern ones) represented in the blocks 7, 8 and 9 were analyzed.

In the present analysis the reference "0 ecodistance" for the site Nyírjes had the following mean weather data: mean spring temperature 7.4 °C and mean spring precipitation 159 mm, calculated for the test period (since planting). In order to directly compare the mean heights of provenances measured in different blocks, the data were *corrected with the block effect, and termed "adjusted height"* (*H'*).

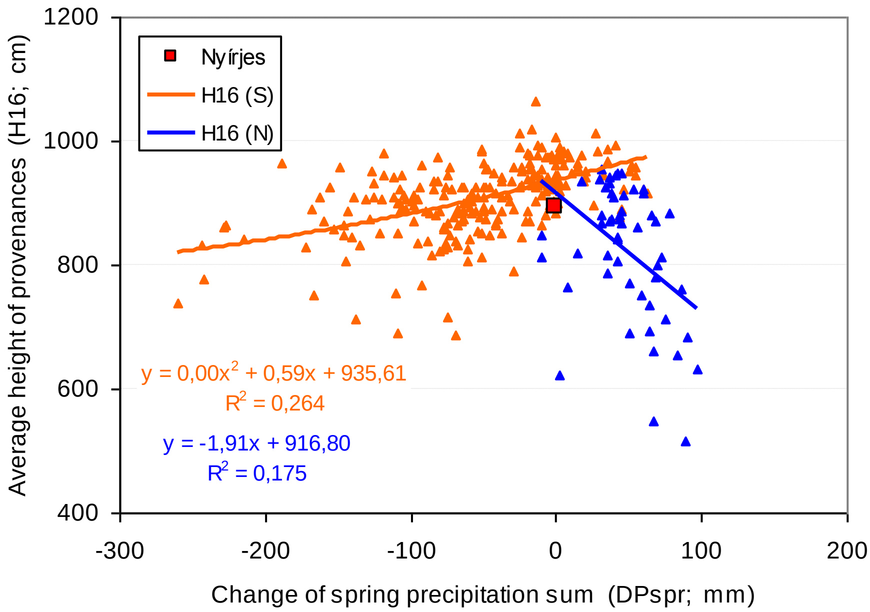


Dependent variable	n	R^2	F	p
H'16 (all)	290	0.4087	99.2	0.0000
H'16 (S)	236	0.1088	14.2	0.0000
H'16 (N)	54	0.6835	55.1	0.0000

Figure 31. Response of average height at age 16 (H'16, cm) to change of spring temperature (DT_{spr}, °C), separated for Southern and Northern range provenances. The attached table shows main statistical data of the polynomial regressions computed with the GRM program for the separated two groups and for the pooled data

In *Figure 31* a "cross-section" of the age 16 height data cloud of the two goups South and North versus the single variable mean spring temperature (DT_{spr}), indicates a rather differentiated growth response to change of thermic conditions. Southern provenances experiencing increasing spring temperatures did show a minor, although significant, response. Maximum value (H'_{max}) was calculated for +1.0 °C. At the same time the Northern group has shown a very significant, nearly extreme response (R^2 = 0.684) which is also observed at the individual reaction norm level and also for the transfer functions of the Northern zone groups. The sensitivity to temperature increase leads to low phenotypic stability of these populations (see chapter 4.2, *Figure 30* and chapter 4.4, *Figure 36b*).

It should be mentioned here that transfer functions are restricted in covering the possible response by the concrete range of encountered ecodistances of transfer: Northern provenances did not run into any spring temperature decrease in Nyírjes; on the contrary, the conditions at the test were for most a drastic change toward higher temperatures. Comparing the statistics of the two groups and of the pooled analysis (figure for "all" not shown), the higher predictive power of the separated analysis is obvious.



Dependent variable	n	R^2	F	p
H'16 (all)	290	0.0000	0.0	0.9841
H'16 (S)	236	0.2641	82.8	0.0000
H'16 (N)	54	0.1748	11.0	0.0017

Figure 32. Response of average height at age 16 (H'16, cm) to change of spring precipitation (DP_{spr}, mm), separated for Southern and Northern range provenances. The attached table shows main statistical data of the polynomial regressions computed with the GRM program for the separated two groups and for the pooled data

Figure 32 shows a very clear effect of spring precipitation change on height growth for the Southern provenance group (R^2 = 0.264***); they do not tolerate well declining precipitation and react with declining growth. As regards the Northern group, there were no sources which were exposed to considerably higher spring precipitation than at their original site, therefore it cannot be decided whether a maximum will appear as in case of temperature. On the other hand the response of the Northern provenance group is ambiguous. It seems that it contains a Baltic subgroup (above approx. 750 cm height) seemingly responding positively to more rainfall, and a slower growing subgroup originating from Lapland and Siberia which responds with a rather definite decline to more precipitation. For the proper interpretation of this decline, it is however necessary to consider the parallel change of precipitation and temperature; the drastic increase of spring temperatures to up to +8 °C, the longer vegetation period with more moisture is not utilized by these populations adapted to much cooler and drier springs.

The General Regression Model (GRM) has been applied for calculating multiple regression for the two independent regressor variables 'ecodistance of spring temperature'(DT_{spr}) and of 'spring rainfall'(DP_{spr}), versus the dependent variable *H'16,* the adjusted mean height.

For the pooled dataset, the simplified multiple regression equation (the insignificant, practically 0 value component of the equation, $(DP_{spr})^2$ is not included) for adjusted height of provenances, is as follows:

$$H'16 = 934.36 + 4.82(DT_{spr}) + 0.28(DP_{spr}) - 5.84(DT_{spr})^2 - 0.16(DT_{spr})(DP_{spr})$$

The response surface regression polynomial describes a paraboloid (*Figures 33, 34*) where temperature plays the decisive role determining growth response. The quadratic parameter for $(DP_{spr})^2$ is practically nil (see *Table 18 and 19*).

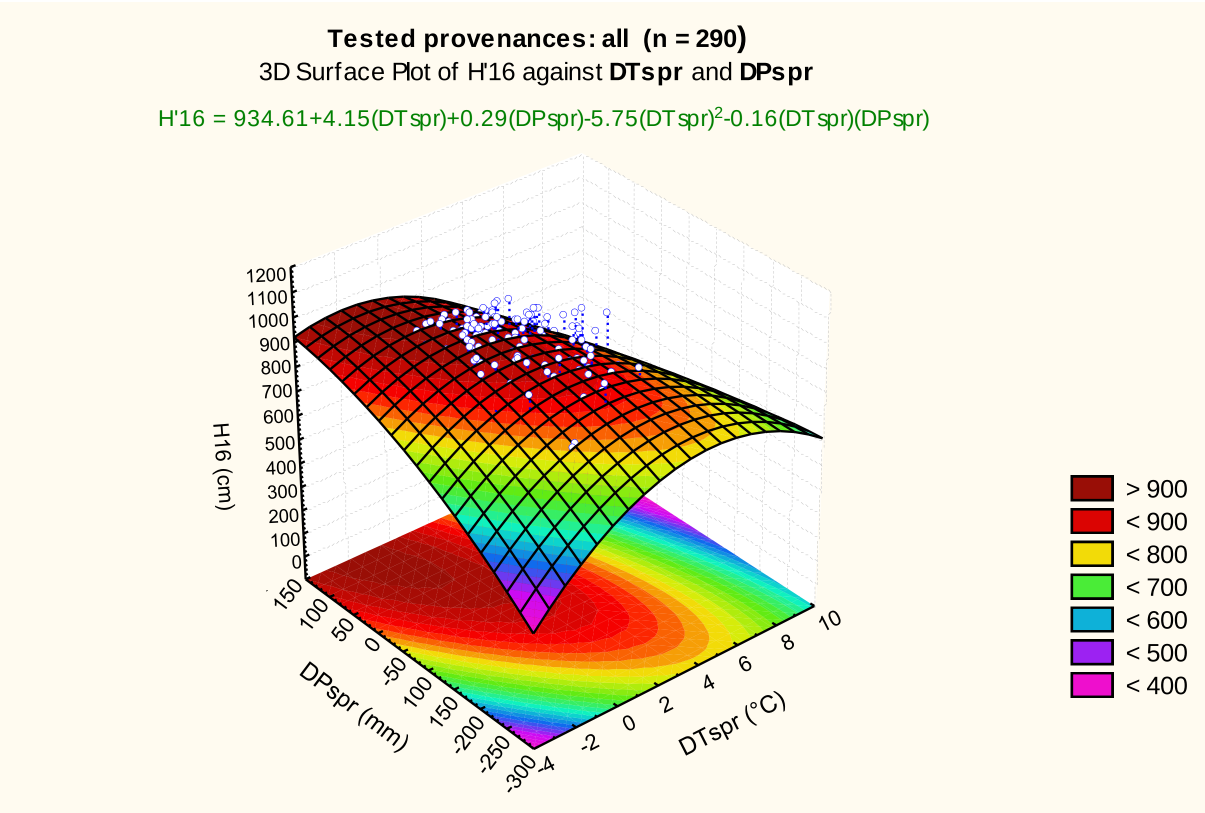
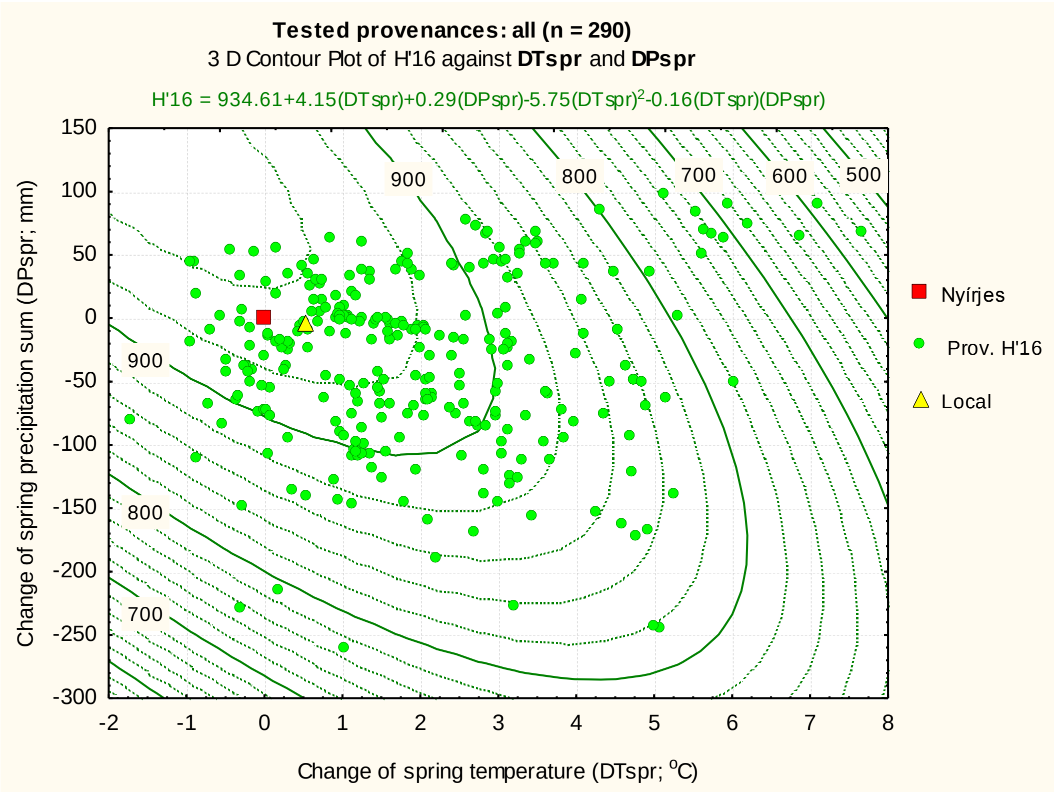


Figure 33. 3D surface plot of adjusted height growth of all provenances at age16 in Nyírjes as a function of ecological distance of transfer; left axis: spring precipitation change (DP_{spr}, mm) right axis: spring temperature change (DT_{spr}, °C)



Dependent variables	n	Prov. mean cm	Multiple R^2	F	p
H'16 (all)	290	892.1	0.5074	58.5	0.0000
H'16 (S)	236	908.0	0.3096	20.6	0.0000
H'16 (N)	54	823.9	0.7305	26.0	0.0000

Figure 34a. Contour plot of multiple regression of adjusted height at age16 (H'16; cm) of all investigated provenances in Nyírjes versus ecological distances of transfer [spring precipitation change (DP_{spr}) and spring temperature change (DT_{spr})]. The reference position of Nyírjes is marked with a red quadrate, that of the "local" provenance (0796 Bükkszentkereszt) with a yellow triangle. The attached table shows main statistical data of the response surface regressions computed with the GRM program for the pooled data and for the separated two groups (see Figures 34b and 34c)

The contour plot shows that the larger part of the analyzed provenances are transferred to a climatic environment in Nyírjes which is up to 6–7 °C warmer in spring and the spring precipitation is less, in few cases up to 300 mm less; i.e. majority of sources originate from cooler and wetter climates. On the other hand, 93 populations were transferred from drier sites than Nyírjes (< P_{spr} = 159 mm), half of them surpassed the height of "local" Bükkszentkereszt provenance. If the local or similar to local populations would be the most productive, the 0; 0 point marking the position of the experiment should be on the top of the „ridge". At Nyírjes, the theoretical maximum production is attained by provenances coming from 0.8 °C cooler climate in spring, where spring precipitation is somewhat less. In other words, provenances from climates 0.8 °C cooler in spring than Nyírjes attain theoretically maximum height, at least for age 16. Above 2 °C of warming height growth decreases rapidly in quadratic manner.

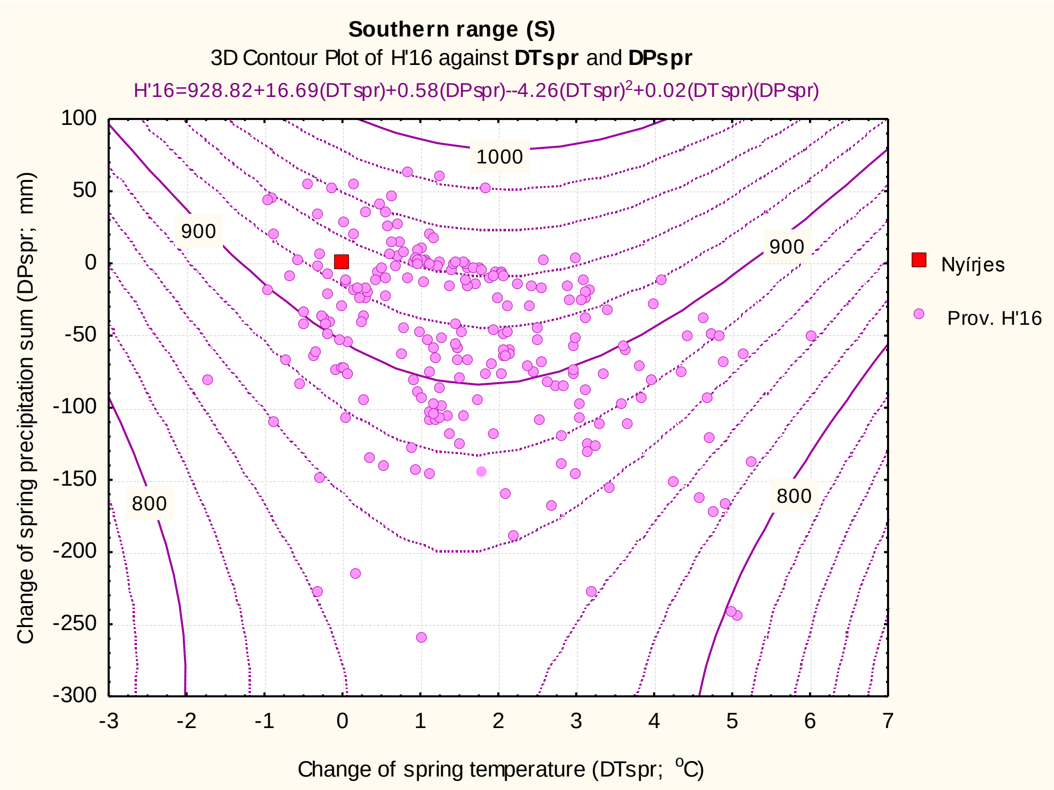


Figure 34b. Contour plot of multiple regression of adjusted height of Southern provenances at age16 (H'16; cm) in Nyírjes versus ecological distances of transfer [spring precipitation change (DP_{spr}) and spring temperature change (DT_{spr})]. The reference position of Nyírjes is marked with a red quadrate. For statistical data see table in Figure 34a

In *Figure 34b* the primary effect of (spring) precipitation change is confirmed for southern provenances, which is basically linear – the quadratic component is zero. Nearly all (!) provenances experiencing a precipitation increase reacted with increased height, confirming the results shown in *Figure 32*. On the other hand, provenances originating from sites with more precipitation, responded to lower rainfall generally with declining height. On the contrary, moderate spring temperature increase had little effect on growth. Populations suffering spring temperature increase above 3 °C responded however increasingly negatively.

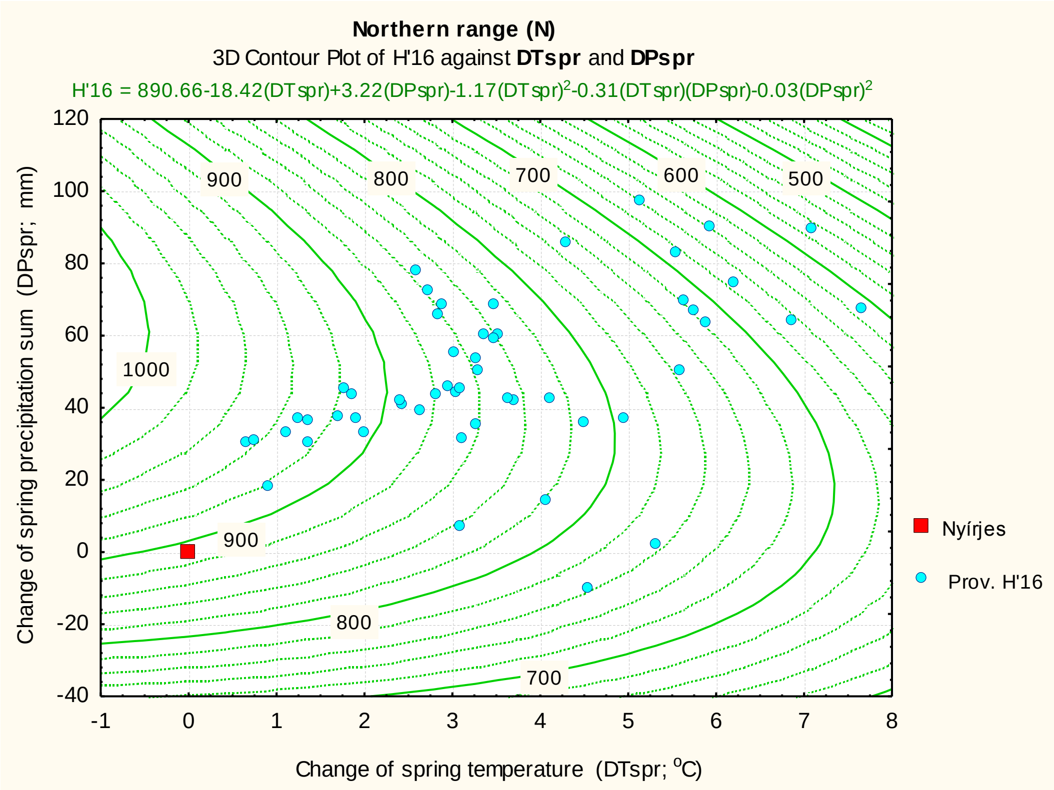


Figure 34c. Contour plot of multiple regression of adjusted height of Northern provenances at age16 (H'16; cm) in Nyírjes versus ecological distances of transfer [spring precipitation change (DP_{spr}) and spring temperature change (DT_{spr})]. The reference position of Nyírjes is marked with a red quadrate. For statistical data see table in Figure 34a

The contour plot of Northern provenances (*Figure 34c*) confirms the very significant effect of spring temperature, most probably connected (together with photoperiod) to the *regulation of spring phenology*. All provenances experienced rising spring temperatures in Nyírjes and responded with practically linear decline of height growth (see also *Figure 31*). Spring precipitation change had, compared to the Southern group, less effect (*Table 18 and 19*).

Table 19. Correlation coefficients[1,2] between adjusted heights (H'16) of provenances and selected climatic variables of the response regression surface

Effects (variables)	Provenances pooled (all) (n = 290)	Southern range (S) (n = 236)	Northern range (N) (n = 54)
(DT_{spr})	***–0.512***	*<u>–0.227</u>*	***–0.819***
(DT_{spr})^2	***–0.623***	***–0.305***	***–0.821***
(DP_{spr})	0.001	***0.511***	*<u>–0.418</u>*
(DP_{spr})^2	*<u>–0.255</u>*	***–0.415***	***–0.566***
(DT_{spr})(DP_{spr})	–0.132	***0.414***	***–0.722***

[1] coefficients in underlined *<u>italics</u>* are significant at $p < 0.05$, in ***italic bold*** at $p < 0.001$
[2] red numbers: decisive values

Table 19 shows in detail the correlation coefficients between height of provenance groups and climatic variables of the response regression surfaces (Correlations of "vectors in design matrix" were computed with the GRM program; see also *Table 18* and *Figures 34a, b* and *c*).

Comparing the statistical data of the *Figures 34a, b, c* and *Table 19* it may be concluded that the regressions improved through the partition of the distribution range, confirming different influences of climate factors in different parts of the Norway spruce range. The correlation coefficients are especially high for the Northern group (R=–0.819 and R=–0.821), indicating that more than 68% of the observed variation of mean heights is explained by spring temperature conditions (see statistics in *Figure 31*).

The shift of the maximum production away from locally adapted populations toward provenances adapted to cooler and wetter climates is characteristic for test sites closer to the xeric (low elevation, low latitude) limit of distribution. The phenomenon may be explained partly by "cultivation fitness", by gene flow from adjacent populations less adapted to the local conditions and partly by the simultaneous action of genetic adaptation and phenotypic stability (Mátyás et al. 2010).

The response models (*Figures 34a, b and c)* enable predictions of productivity changes in case temperature and rainfall conditions change. For instance, considering the pooled model, at the age of 16 a loss of about 5% in height growth is predicted if the mean spring temperature increases by 3 °C and the mean spring precipitation declines by 100 mm. Of course, *drying climate manifests itself much more in the extremes in individual years, and the effects of these extreme events are the really decisive factors deciding over vitality and survival.*

4.4 Reaction norm analysis of provenances

To calculate reaction norms requires more than three, but better as many as possible test locations. As the three experiments used for the report did not provide enough data, two additional tests were included: the South Swedish Lisjö and Krynica in South Poland (basic climatic data of the sites are listed in *Table 20*). Because of restrictions of data sets, only provenances of block 7 were used in the reaction norm comparison. 21 provenances were selected to represent characteristic ecologic regions grouped in overlapping subgroups for identifying general trends in reaction norms:

- Boreal (Nr. 0779, 0734, 0733, 0768, 0772) and high-elevation provenances of Central Europe (0770, 0790 0798, 0778),
- Central European low elevation (0711, 0721, 0746, 0723, 0794) and high elevation (0770, 0790 0798, 0778) populations, and
- Provenances of the Carpathians, from low (0755, 0773) and high elevation (0700, 0713, 0749).

Due to the low number of test sites, reaction norms were calculated as linear regressions.

Table 20. Basic geographic and climatic data of the Norway spruce provenances selected for reaction norm calculation and the respective data of the five test sites (in bold)

Nr.	Location name	E. Long.	N. Lat.	Elev. (m)	Region	Prec. annual	Temp. annual
0700	COSNA/CUCUREASA	25.18	47.32	1032	59	835	4.4
0708	TAVEJANNE	7.11	46.31	1563	2	1468	4.2
0711	ZWINGENBERG	8.68	49.73	465	12	761	8.1
0713	LIPTOVSKY HRADOK	19.84	48.93	1120	47	1048	3.3
0721	BURGHAUSEN	12.81	48.11	483	22	1088	8.2
0723	BADEN-BADEN	8.27	48.76	514	13	801	8.9
0733	OESTLANDSGARN	11.02	60.48	280	84	876	4.2
0734	BOGSTAD	10.65	59.97	420	83	1003	4.0
0746	WISMAR	11.33	53.83	51	8	625	8.2
0749	CUCUREASA	25.02	47.19	1311	59	955	2.7
0755	MARGINEA	25.76	47.75	663	59	710	6.1
0768	VALLEN	14.09	62.32	438	91	575	2.9
0770	VAL DI FIEMME	11.46	46.30	1090	29	1106	6.4
0772	UDMURTSK	53.00	58.00	149	79	551	1.5
0773	JASINA	24.33	48.25	766	60	738	6.1
0778	BOROVEC	23.58	42.25	1585	56	973	5.4
0779	URJALA HONKOLAN	23.50	61.10	108	94	583	3.9
0790	MALI LOM	14.94	44.74	1120	54	1408	6.6
0794	BAINDT	9.83	47.50	606	16	1362	7.7
0796	BUKKSZENTKERESZT	20.64	48.07	649	53	823	6.9
0798	GURKTAL	14.29	46.94	1233	31	1384	3.9
20	**NYIRJES (H)**	19.92	47.93	680	–	782	7.5
19	**KRYNICA (PL)**	21.01	49.45	728	–	867	6.1
6	**ABILD (S)**	12.73	56.95	105	–	654	5.9
7	**LISJÖ (S)**	16.08	59.72	60	–	520	6.4
8	**LAPPKOJBERGET (S)**	18.62	63.42	208	–	456	2.3

The problem of standardization of growth response

Applying the measured phenotypic values (here: height), reaction norms show first of all the site potential, i.e. “yield class” differences between test sites, which is tremendous in this analysis and cover up the finer genetic-adaptational differentiation. Therefore it is not uncommon to encounter the conclusion that genetic differentiation is only a marginal factor determining growth, compared to site potential.

As the main interest of reaction norm analysis lies in the ***changes*** of performance across sites (climates), and not in the usual characterisation of concrete ***growth differences*** such as in yield tables, a standardisation of data is necessary to exclude the effects of site potential differences. It seems obvious to use performance of the locally adapted population as standard. The presence of “locally adapted, autochthonous” provenance was however not among the requirements of the planners of the test series. This is understandable as Norway spruce is the typical example of a species planted widely off its ecological niche limits where “local” adaptation and “autochthony” are not meaningful terms.

Accordingly, even at test sites within the original distribution area, including provenances explicitly local is not the rule; one reason might be the awareness about widespread human interference which makes the decision about “locality” problematic. For understandable reasons a “local” provenance is missing in the Nyírjes experiment too. Instead, the general mean of the experiment had to be applied for standardization, expressing the (yield) potential of the site. The immediate drawback is the dependence on the representation of provenances; which may cause bias if the included provenances are not the same in all analysed experiments.

Comparison of reaction norms

Figures 36a and *36b* show the reaction norms for the same provenances in the first group (boreal and high-elevation Central European provenances), displayed as regressions of absolute (*Figure 36a*) and of relative heights (*Figure 36b*) versus transfer distance in mean annual temperature. Comparing the two graphs, it is discernible that although absolute height is increasing with higher temperatures in case of all provenances, the climate sensitivity differences among provenances are visible only when reaction norms are calculated with relative values (i.e. in percents of block mean).

Reaction norms of the group northern-boreal (Nr. 0779, 0734, 0733, 0768, 0772) and high-elevation provenances of Central Europe (0770, 0790, 0798, 0778) show decreasing relative heights with increasing annual mean temperatures at the test locations, except for the provenance 0790 (Mali Lom, Croatia). On the other hand, relative growth seems to improve toward cooler (and moister) than original conditions (*Figure 36b*). The populations from latitude 60 and further north (0733, 0734, 0768, 0779) show a higher sensitivity to increasing temperatures, the regressions are steeper. The populations from similarly cold, high-elevation sites in Central Europe (0770, 0778, 0790, 0798, 0794) display a high level of stability across test sites; although their height was less than that of the locals and of the block means in all 5 trials. The provenance from the coldest Russian site 0772 Udmurtsk (Ural region) surprises with similar stability (*Figure 36b*).

Figure 37a and *37b* displays provenances adapted to very different temperature conditions at various altitudes (*Table 20*) in Central Europe. The trend of the regressions clearly indicate the character of response to mimicked climate change across a spectrum of transfer to sites 6 degrees colder or to sites 4 degrees warmer than the original location. The orientation of regressions support the general rule of relatively highest productivity close to the original climatic conditions, with its maximum on the cooler/moister side of the curve. Low elevation Central European populations display higher sensitivity to colder temperatures than originally adapted to. On the warming side of the graph, Central European mountain provenances indicate a remarkable tolerance to increasing heat stress. Contrary to northern-boreal populations, these provenances display higher stability, most probably due to less vigorous selection by extreme cold (compare also with *Figure 36b*). No significant differentiation in stability is observable. The same picture is visible when spruce provenances of the Carpathians are separately displayed (*Figure 38a and 38b*). Judged on the very limited number of selected provenances, high phenotypic stability may be observed also among populations from regions outside of the East Carpathians (0713 Liptovsky Hrádok, Slovakia).

A more detailed analysis is needed to find reasons for unexpected correlation brakers of the general trend, such as 0772 Udmurtsk, Russia and 0790 Mali Lom, Croatia. For this, further retrospective data have to be found in up to now unpublished and not evaluated datasets of parallel experiments.

The reaction norms presented in *Figure* pairs *36, 37 and 38* explain the large and seemingly random *scatter of pooled provenance data observable in transfer analyses such as in Figure 29: responses are not parallel and are characteristically differentiated also by regions of provenance*, i.e. by the complexity of different climatic selection pressures and – perhaps to a smaller extent – by historic effects of migration. The regionally different responses were analysed in chapter 4.2 on the example of zone groups (see *Figure 30*).

Figure 35. Provenance trial in 2007 (age 40). To the right is corner of block 10, the first marked tree is provenance 1030 Rostock (DE)

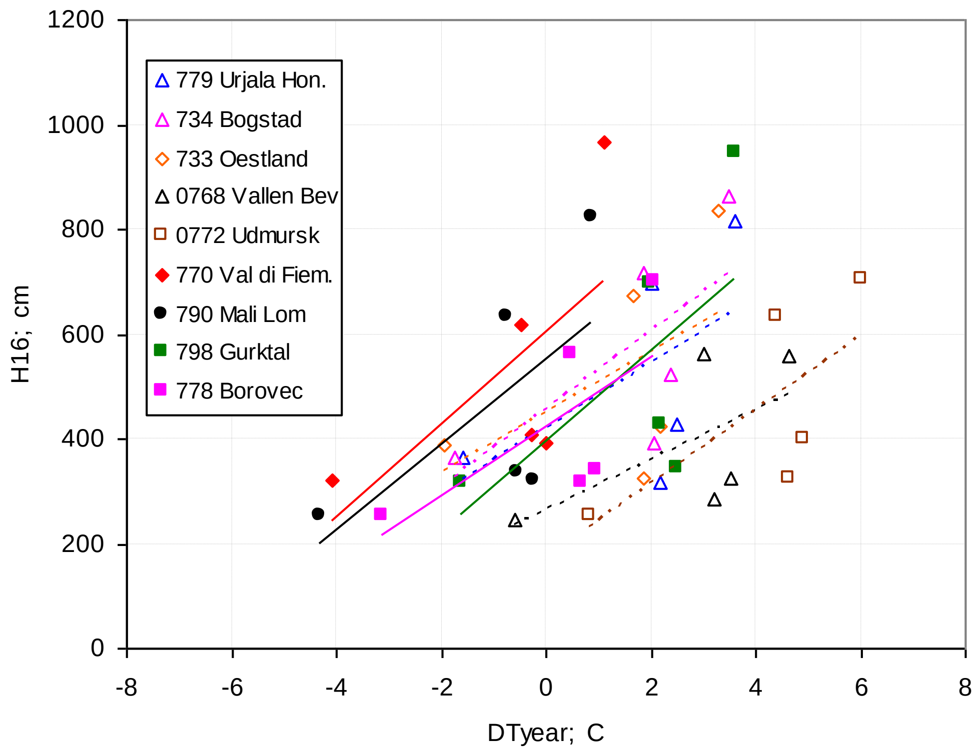


Figure 36a. Reaction norms for16-year height (cm) of northern-boreal provenances: Nr. 779, 734, 733, 768, 772 (empty symbols and dotted lines) and of high-elevation spruce provenances from Central Europe: 770, 790, 798, 778 (full symbols and full lines) set against transfer distance in mean annual temperature (DTyear in °C); from data of five tests

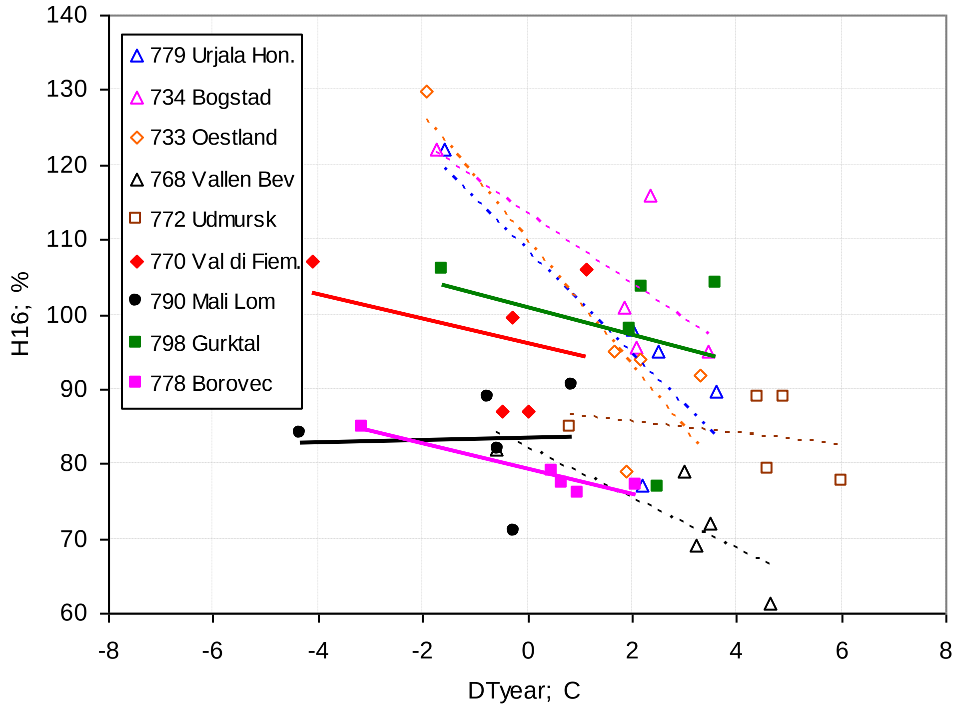


Figure 36b. Reaction norms for relative height (block mean = 100%) at age 16 of northern-boreal (Nr. 779, 734, 733, 768, 772) and of high-elevation spruce provenances from Central Europe (770, 790, 798, 778), set against transfer distance in mean annual temperature (DTyear in °C); from data of five tests. Provenances and symbols same as in Figure 36a

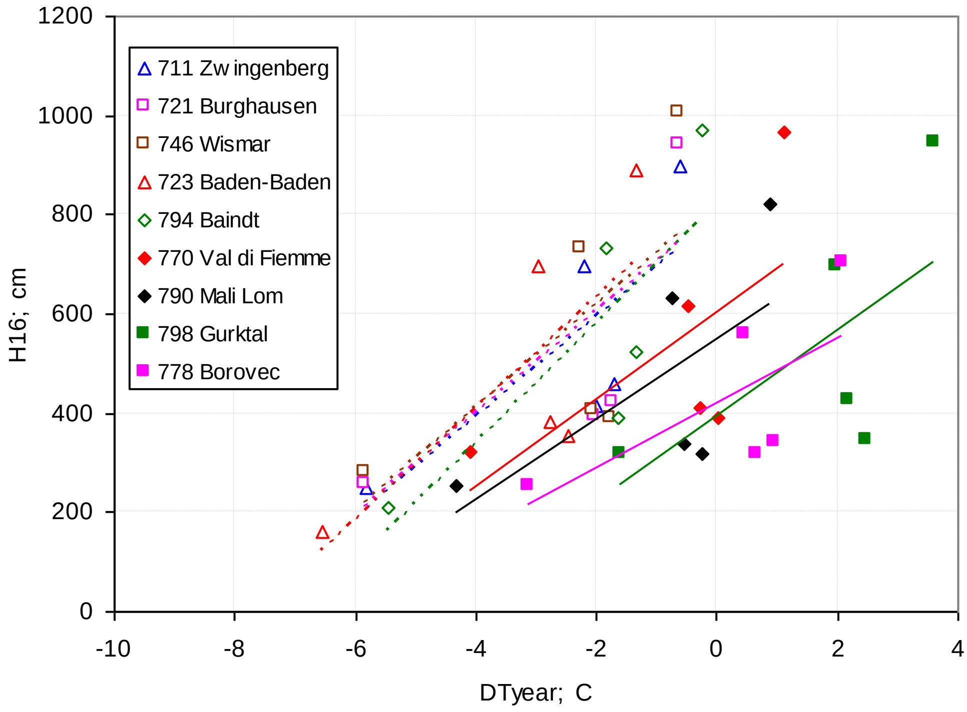


Figure 37a. Reaction norms for16-year height (cm) of low-elevation provenances: Nr. 711, 721, 723, 746, 794 (empty symbols and dotted lines) and high-elevation provenances: Nr. 770, 778, 790, 798 (full symbols and full lines) from Central Europe set against transfer distance in mean annual temperature (DTyear in °C); data of five tests

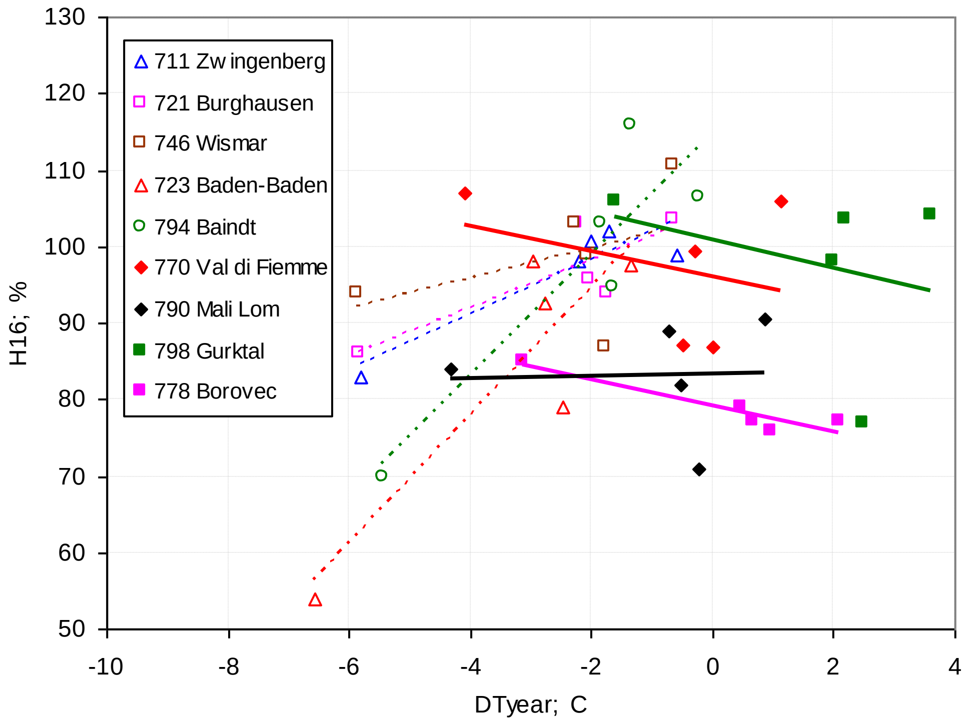


Figure 37b. Reaction norms for relative height (block mean = 100%) at age 16 of low (Nr. 711, 721, 723, 746, 794) and high-elevation (770, 778, 790, 798) spruce provenances from Central Europe, set against transfer distance in mean annual temperature (DTyear in °C); from data of five tests. Provenances and symbols same as in Figure 37a

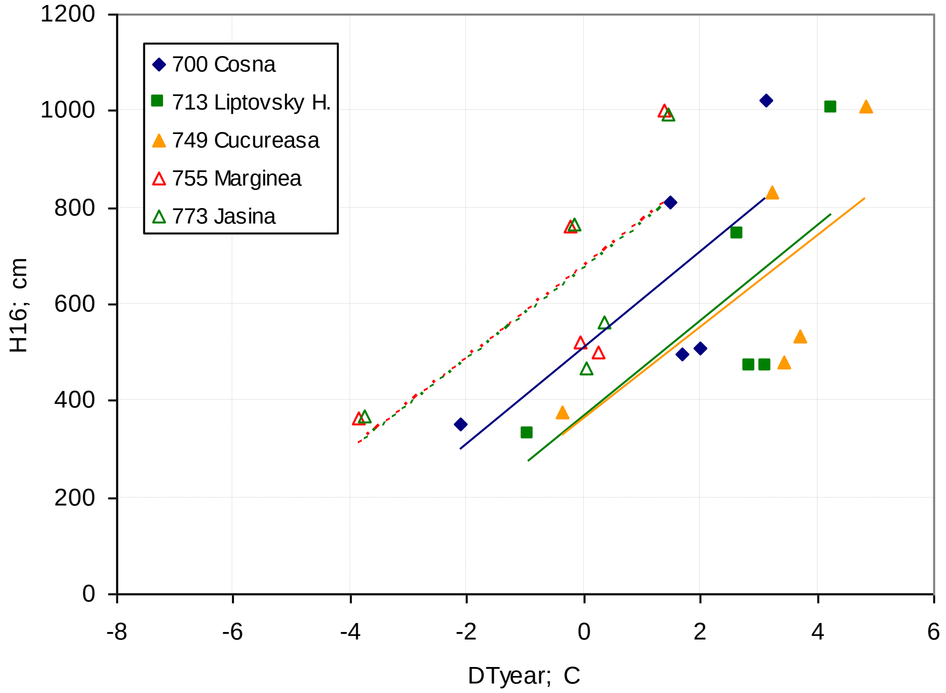


Figure 38a. Reaction norms for16-year height (cm) of low- (Nr. 755, 773;empty symbols and dotted lines) and high-elevation (700, 713, 749; full symbols and full lines) provenances from the Carpathians at age 16, set against transfer distance in mean annual temperature (DTyear in °C); from data of five tests.

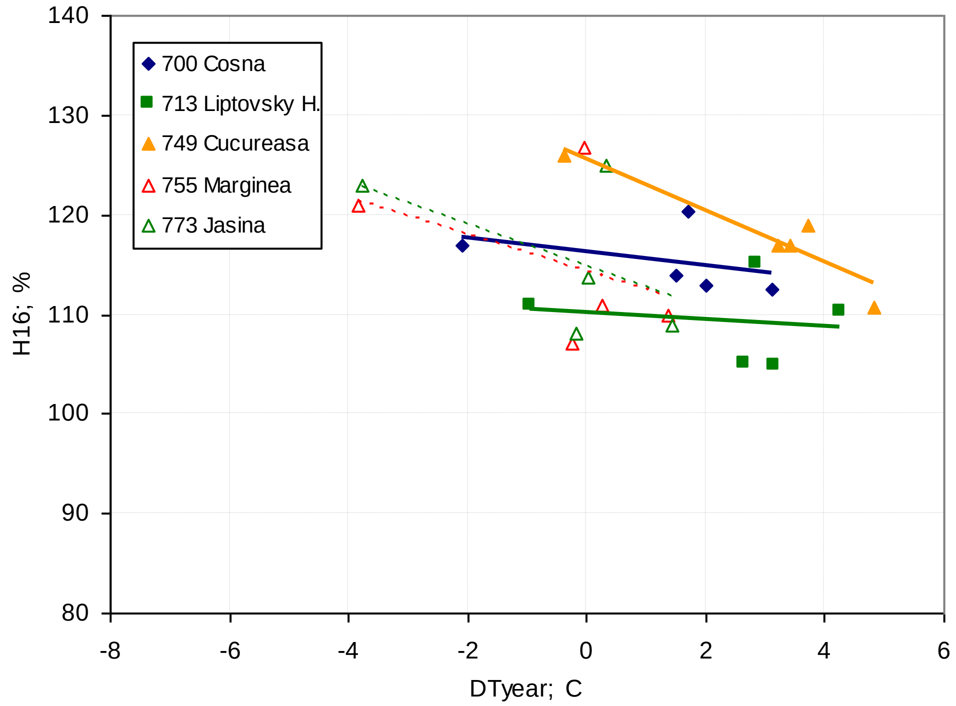


Figure 38b. Reaction norms for relative height (block mean = 100%) at age 16 of low (Nr. 755, 773) and high-elevation (Nr. 700, 713, 749) spruce provenances from the Carpathians, set against transfer distance in mean annual temperature (DTyear in °C); from data of five tests. Provenances and symbols same as in Figure 38a

4.5 Investigation of phenotypic stability by zone groups

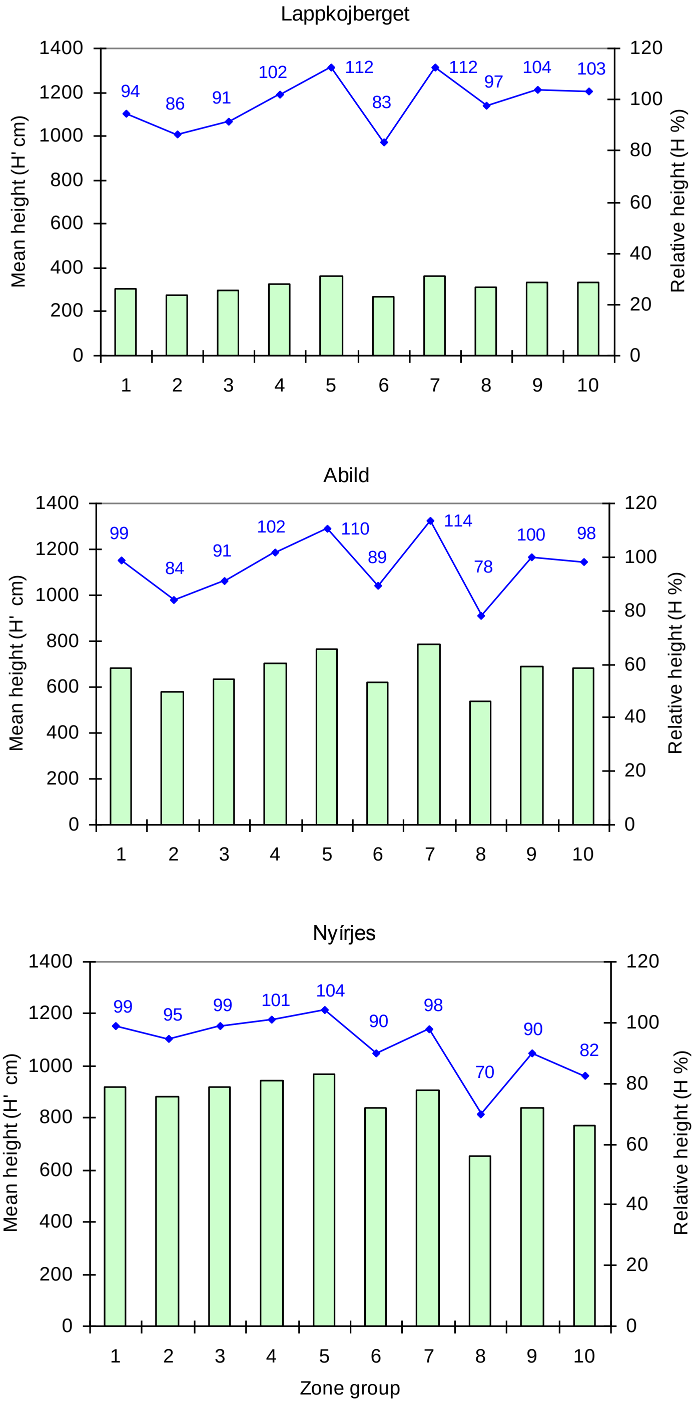


Figure 39. Comparison of average adjusted height (vertical axis left, H'16 cm) and average relative height (vertical axis right, H %) of 10 zone groups at 3 provenance experiments

In *Figure 39* absolute and relative mean heights of the ten zone groups are shown. Of special interest is the comparison of the performance of zone 5 and 8 across the three test sites; zone 5 showing exceptional stability, in contrast zone 8 is unstable. The shift of mean productivity may be compared both in space and time. Juvenile height data (age 16) of 3 European experiments (Lappkojberget, Abild and Nyírjes) and growth data of different assessments (age 16, 25 and 44) at Nyírjes test site are shown in *Tables 21*and *22*. Due to storm damages in 2007, both absolute and relative means in block 7 became unreliable. They were recalculated based on very tight correlations with 2003 data (D36), see *Table 12* (chapter 3.4).

Table 21. Comparison of adjusted and relative height[1] of tested provenances (block 7, 8 and 9) by zone groups at 3 experiments at age 16

Zone group	Localities of tested experiments and growth traits					
	Nyírjes (HU)		Abild (SE)		Lappkojberget (SE)	
	H'16 (cm)	rel H' (%)	H'16 (cm)	rel H' (%)	H'16 (cm)	rel H' (%)
1	919.5	99	684.8	99	304.7	94
2	883.7	95	581.6	84	278.6	86
3	922.5	99	632.3	91	295.4	91
4	943.5	101	706.6	102	328.8	102
5	971.3	**104**	766.2	**110**	363.1	**112**
6	835.9	90	618.9	89	269.1	83
7	910.4	98	788.7	114	363.6	112
8	650.7	**70**	541.0	**78**	315.1	**97**
9	838.0	90	691.6	100	335.2	104
10	769.1	82	682.3	98	334.3	103
Mean[2]	892.5	95.8	645.0	93.0	305.9	94.6
Local prov.	932.4	100.0	693.9	100.0	323.3	100.0

[1] Relative height: in % of local provenances (see *Table 16)*
[2] Mean of each tested provenances (not of 10 zone groups)

Table 22. Comparison of adjusted and relative growth traits[1] of tested provenances (block 7, 8 and 9) by zone groups at Nyírjes experiment at age 16, 25 and 44

Zone group	NYÍRJES					
	Growth traits and ages at different assessments					
	H'16 (cm)	rel H'16 (%)	D'25 (mm)	rel D'25 (%)	D'44 (mm)	rel D'44 (%)
1	919.5	99	179.7	107	272.6	**114**
2	883.7	95	164.5	98	248.6	104
3	922.5	99	176.1	105	262.8	109
4	943.5	101	181.5	108	264.8	110
5	971.3	104	186.1	111	272.0	113
6	835.9	90	162.3	97	237.2	99
7	910.4	98	163.6	98	232.4	97
8	650.7	70	115.1	69	164.0	**68**
9	838.0	90	148.7	89	218.4	91
10	769.1	82	132.0	79	190.7	79
Mean[3]	892.5	95.8	167.3	100.0	248.3	103.4
Local prov.	932.4	100.0	167.7	100.0	240.1	100.0

[1] Relative growth traits: % of "local" provenance (0796 Bükkszentkereszt)
[3] Mean of tested individual provenances (not of 10 zone groups)

The average of H'16 of tested provenances was below 100% at every experiment, i.e. the local provenances were everywhere higher than the means of tested 3 blocks (*Table 21*, *Figure 39*).

At the same time, provenances of zone group 4 and 5 exceeded the local provenances in every trial. Zone groups 4 and 5 proved to be the best in Nyírjes and zone groups 5 and 7 were the most vigorous in Scandinavian trials. Turning from zone groups to individual provenances, the superiority of zone 5 is even more convincing. The relative height performance of provenances from this zone group were superior in every trial, first of all 0935 Turda from the Bihor Mts. (Nyírjes 114%; Abild: 135%; Lappkojberget: 111%) and 0922 Cucureasa from the E. Carpathians (Nyírjes 109%; Abild: 131%; Lappkojberget: 104%).

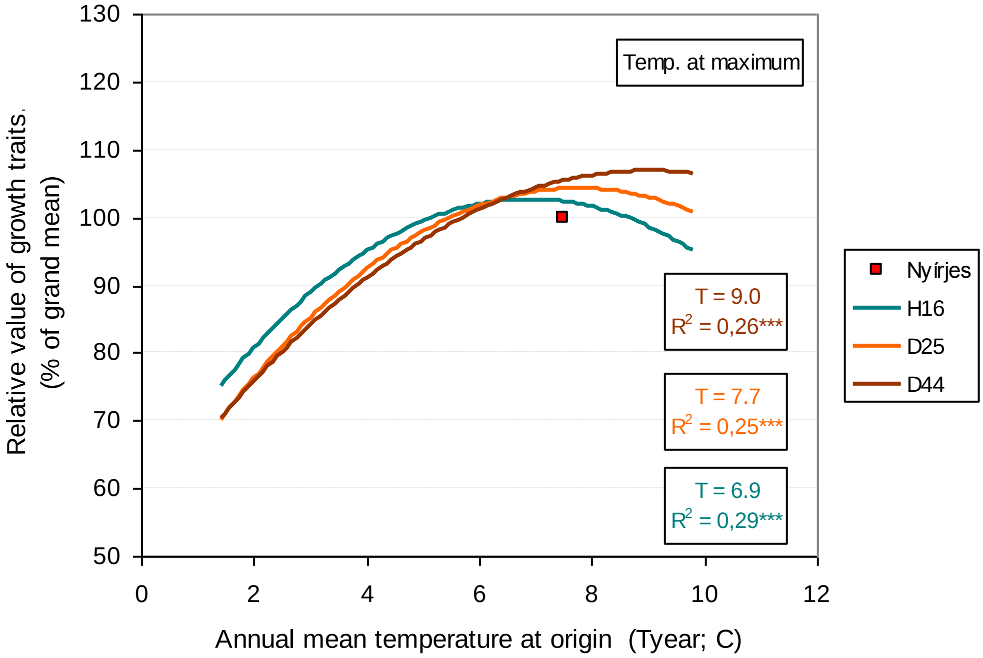
The lowest stability was found in zone group 8 provenances, which contains the northernmost provenances. Although their absolute height increased when transferred to Nyírjes, their relative height – related to the local population – declined strongly (in Lappkojberget 97%; in Abild 78% and in Nyírjes 70%) (*Table 21*, *Figure 39*)

4.6 Shift of transfer function with age: acclimation or climatic shift effect?

In the Nyírjes trial, transfer function of height at 16 years of age (H'16) was compared with similar functions for diameter at age 25 and 44. Between age 16 and 44 an *upward shift of maxima of transfer functions* (*Figure 40*) was observed which may have various reasons. Beside on-going selection, and epigenetic acclimation, the effect of climatic shift since the first measurements might be considered too; in the last 30 years summer temperatures increased by +2°C (Bartholy et al. 2011). The temperature shift might have played a role in the change of maxima. At least, it draws the attention *to use relevant, fitting climate reference periods* for climate response analysis.

Figure 40 indicates the shift of transfer functions in relative terms i.e. in percents of the experimental mean (H'16 data are the same as in *Figure 29*, here as relative values) for the sake of easier comparison. Although the superiority of phenotypically plastic populations, such as Carpathian provenances, is maintained until age 44 (DBH), provenances from warmer and drier sites than Nyírjes, originating from lower elevations and developing stems and crowns of larger dimensions got into the leading ranks at higher age (*Table 22*).

Between 16 and 44 years, largest changes happened in zone group 1; relative height of 99% at age 16 changed to 114% for relative DBH at age 44. Similar trends were observed among populations of zone groups 3 and 4 from lower elevations (see also *Figure 40*). Largest change, to highest relative DBH of 129% at age 44 was measured on 0910 Karlovice (CZ, zone group 4). The northernmost and northeastern zone groups 8 and 10 displayed an ever-decreasing relative diameter (*Table 22*).



Growth traits	n	R²	df	F	p
Relative height at 16 (H'16%)	291	0.293	288	59.6	0.0000
Relative DBH at 25 (D'25%)	291	0.247	288	47.2	0.0000
Relative DBH at 44 (D'44%)	291	0.262	288	51.2	0.0000

Figure 40. Regression of 16-year relative tree height (%) and 25-, 44-year relative DBH (%) (vertical axis) of identical Norway spruce provenances versus mean annual temperature (°C) at origin (horizontal axis) in three tested blocks (block 7, 8 and 9) of the Nyírjes experiment. 1950–2000 average annual mean temperature of test site (Nyírjes) was 7.5 °C. Traits in percents are expressed relative to the grand mean of the respective blocks. The attached table shows main statistical data of the polynomial regression computed with the GRM program

The shift of the functions has had only a mild effect on age correlation data: even the correlation between 10 years height and DBH at age 44 is highly significant, as described in the chapter on age correlation (see *Tables 12* and *13*).

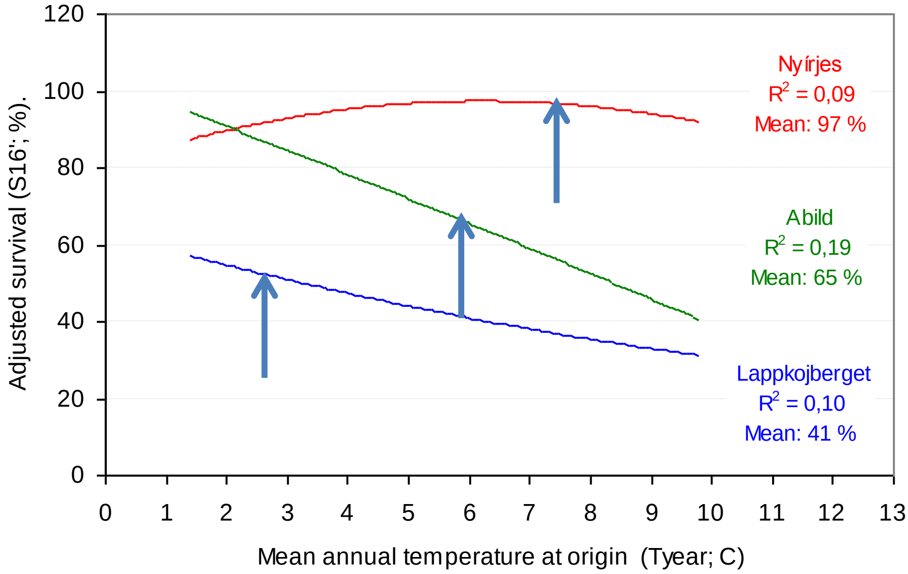
It has to be remarked, that the maximum for the function DBH 44 around 9 °C is rather imaginary as only few provenances originating from regions with an annual average above 8 °C were included in the analysis (compare *Figure 16*). In that sense the form of the function in the range >8 °C may be also an artifact.

4.7 Survival statistics indicating climate selection impact

Approaching the limits of tolerance, a decisive trait for biotic modeling should be survival. Although assessment of survival in tests is generally executed, these may, however, it is *often biased by early age biotic damages and technological faults.* Most early data are therefore of low reliability with regard of climatic selection effects. Survival measured at age 16 in three parallel tests of the IUFRO Norway spruce test network (two Swedish tests, Abild and

Lappkojberget, and Nyírjes) is an exception and suitable to illustrate the effect of sites of various exposure (*Figure 41*, see also chapter 4.1).

Ordered by the mean annual temperature of origin of provenances, survival indicates a strong differentiation by test conditions, not surprisingly the harshest site showing the highest losses, i.e. *the severest climate selection effect*. Provenances adapted to warmer sites proved to be less resistant in both Swedish tests (A. Persson – B. Persson 1992). In Lappkojberget, close to the thermal (upper, colonizing) limit[5], i.e. exposed to severe thermic selection, the resilience of distant, inappropriately adapted populations seem to be most uncertain. At the mild site Nyírjes, survival between the extremely diverse provenances did not show any clear trend (see also the discussion in chapter 4.1.: response on climatically distant sites).



Site	R^2	df	F	p
Nyírjes	0.0903	288	14.30	0.0000
Abild	0.1940	288	34.67	0.0000
Lappkojberget	0.0991	286	15.73	0.0000

Figure 41. Regression of survival (%, vertical axis) of 291 identic provenances at three test sites – Nyírjes (HU), Abild (SE) and Lappkojberget (SE) –, versus mean annual temperature (T_{year}; °C) at origin (horizontal axis) at age 16. Arrows show the mean temperature at the respective test site. The attached table shows main statistical data of the polynomial regression computed with the GRM program

[5] According to the terminology applied here, thermic limit is used for the upper limit of distribution where (negative) temperature extremes decide over the presence or absence of species. Alternatively, the lower border is termed xeric limit, being determined primarily by moisture stress (Mátyás et al. 2010)

5 FURTHER INVESTIGATIONS IN CONNECTION WITH THE NYIRJES PROVENANCE TRIAL

5.1 Vegetative propagation of selected clones

Preceding provenance testing, a government-supported program for Norway spruce breeding was initiated in Hungary by L. Szőnyi in 1963 to accelerate the supply with domestic grown conifer timber. As a part of the program phenotypically outstanding juvenile genotypes were selected for vegetative propagation (Ujvári-Jármay 1981).

Figure 42. Rooted cutting

The initial purposes of the research were:

- to investigate the rooting ability of different clones, the aging problem, etc.
- to create a synthetic, multiclonal variety of elite clones for mass propagation in a significantly shorter time as from seed.

Applying Kleinschmit's method (1972, 1977), propagation techniques were developed, rooting ability and different substrates were investigated. Both the costs and the expected genetic gain were calculated as well.

After the survey at 10 years, more than 400 genotypes were selected in the provenance trial, the selection intensity was 2.5–3.0. Rooting ability varied from clone to clone (55–95%). Cuttings taken from young trees have shown no effects on topophysis (Ujvári-Jármay – Ujvári 1980). After rooting and transplanting, the 1+2 year old cuttings were planted for clonal testing in three field experiments. The field trials have been assessed and evaluated after 6 years and 19 superior clones were selected for mass propagation (*Figures 43, 44*). In 1980's the assemblage of the 19 clones became the first state-registered synthetic variety 'Nyírjes'. Compared with commercial seedlings, the ramets have shown a superiority of 46% in height at age of 6 years from planting (Ujvári-Jármay 1981).

Figure 43. Large-scale cutting propagation. Transplantation in the nursery

Due to reasons already discussed before, at present forest managers do not apply vegetative propagation of Norway spruce any more. The use of conifers – in particular Norway spruce – has fallen back drastically over the last 30 years. Naturally regenerated native species and close-to-nature management have priority.

Figure 44. Superior clones selected for a "synthetical population": candidates for a multiclonal variety at the age of 6 years

5.2 Testing of progenies

Adaptability of open pollinated progenies of different Norway spruce provenances has been studied in a progeny test. 38 superior and 10 inferior mother trees were selected in the Nyírjes test. The mother trees originated from different European regions from different geographical distances. Local sources were introduced as control. Survival and height growth of 13 years old half-sib families were used for assessing the adaptability.

Survival of families has shown small differences, the average amounted to 91%. The family mean heights were more equalized than expected but significant differences could be shown among the families. Offsprings of the superior mother trees performed well, most of them exceeded the local control. The progenies of inferior mother trees showed reduced growth. A highly significant correlation (P = 0.01) was found between the height of mother trees and mean height of their progenies. The correlation between provenance mean of mother trees and the mean of their offsprings was also significant (Ujvári-Jármay – Ujvári 2006).

5.3 Assessment of tree height from aerial photos

After crown closure which occurred around age 18–20, the height of the trees was impossible to measure with terrestrial instruments. In 1993, at age 26 a digital surface model for the terrain of the test was produced and aerial photos were taken. The idea of conveniently measuring tree heights from this information could not be realized, due to interpretation and identification problems of trees. In 2015 a reanalysis of the database was initiated by K. Czimber, applying the photogrammetric program of own development, DigiTerra Stereo (Czimber et al. 2016). With the new interpretation technique identification of individual trees and determination of their heights (H26) in three blocks (7, 8 and 9) of the trial was successful.

Table 23. Summary of height measurements on aerial photos (1993) by blocks. Results of statistical analysis and growth trait correlations (source: K. Czimber)

No.	Characteristics	Number of block		
		7.	8.	9.
General characteristics				
1.	Identified and measured trees (No.)	1336	1099	1111
2.	Identified and measured trees (%)	93.4	91.2	88.9
3.	Block mean of provenance heights (**H26;** m)	16.1	15.9	15.2
4.	Range of provenance mean heights (**H26**; m)	13.3–17.3	12.8–17.9	11.5–17.3
5.	Standard deviation within provenances (m)	0.90–2.53	0.88–2.69	0.67–2.41
Correlations (R) of provenance growth traits[1]				
6.	H16 vs. DBH 16 (age 16, before thinning)	0.944	0.956	0.968
7.	H16 vs. **H26** (before and after thinning)	0.831	0.877	0.882
8.	DBH25 vs. **H26** (after thinning) (see *Fig. 45.)*	0.861	0.882	0.898

[1] every coefficient is significant at $p = 0.001$ level

It is probable that a similar technique of height measurement may be selected by other partners of the trial series, therefore details of the precision of the height determination is briefly described. The identity of 3 546 interpreted trees were compared to terrestrially determined identity. In 91.5 percent of the cases the identification was successful. Determined heights were compared blockwise to terrestrially measured diameter (age 25) and height (age 16) and statistically evaluated (provenance averages, standard deviation etc.). Data for the three blocks are found in *Table 23*.

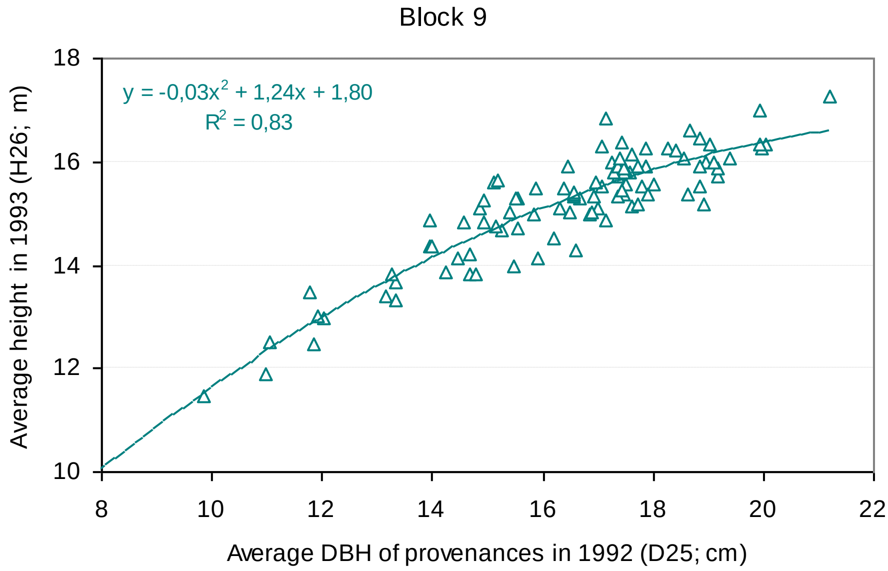


Figure 45. Polynomial regression (R^2) of average DBH (age 25) and average height at age 26, determined by photointerpretation of provenances in block 9 (source: K. Czimber)

Correlation, respectively regression (R^2) between mean tree heights of provenances determined by terrestrial and by aerial measurements was very strong (p = 0.001) (*Table 23, Figure 45*).

The application of digital photogrammetry, combining data of a terrestrial land surface model with aerial photo interpretation seems to be applicable on larger scale. The method offers advantages in mature, dense stands with closed crown cover where the assessment of height needs traditionally indirect methods and provides less precise results. Its further development is foreseen (Czimber et al. 2016).

5.4 The provenance trial as a reference basis

"... the experiment will continue to have a useful role as reference material, e.g. for wood properties or as a gene pool ..."

(R. Lines, 1979)

Reference basis for analysis of genetic polymorphism

It is a well-established fact that the postglacial decolonization of Europe by Norway spruce happened from two directions, from the refugia in Western Russia and from different mountain refugia of south-eastern Europe (Schmidt-Vogt 1977, Vendramin et al. 2000). Fossil pollen analyses have also proven that the division between the two disjunct colonization areas of spruce lies in NE Poland.

A molecular genetic confirmation of the colonization routes is provided by maternally inherited markers, in case of conifers: by mtDNA markers. For the molecular genetic reconstruction of migration pathways across the whole European distribution, the Nyírjes trial offered an excellent opportunity to sample at one location a wide range of provenances. On the initiative of C. Mátyás, 97 populations, (10 individuals per population) were sampled in the Hungarian provenance trial. Complemented with other population samples, the comprehensive investigation of mtDNA haplotypes were carried out by G. Mátyás, C. Sperisen and collaborators in the WSL Institute (Birmensdorf, Switzerland), in 1995–1998 (Sperisen et al.1999, Tollefsrud et al. 2008).

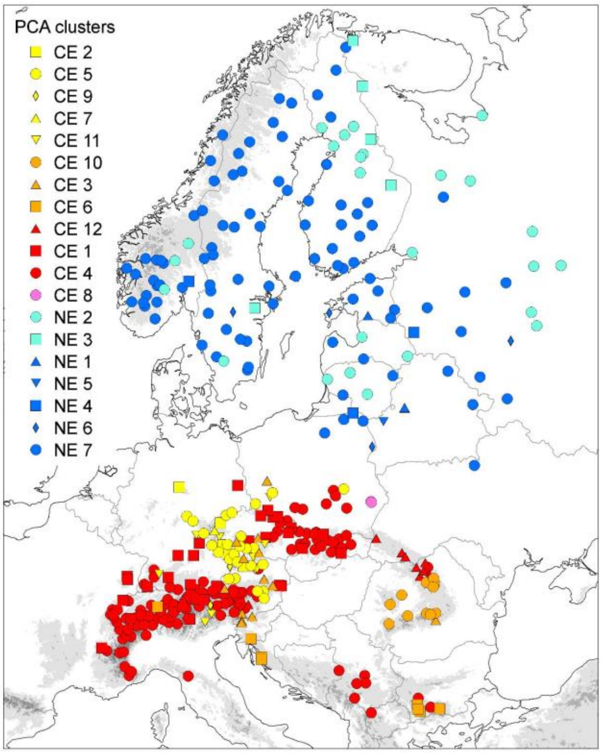


Figure 46. Geographic distribution of PCA clusters established from mtDNA marker data of Norway spruce populations, sampled in Nyírjes. The recolonisation from two separate refugia is easily discernible (Tollefsrud et al. 2008)

In the study of Tollefsrud et al. (2008) genetic data were combined with paleoecological data to analyze the consequences of past demographic events on genetic diversity and structuring in Norway spruce. To investigate patterns of genetic subdivision, spatial analysis of molecular variance (SAMOVA) and clustering based on principal component analysis were applied. Variation was assessed in the mitochondrial *nad*1 gene containing two minisatellite regions (*Figure 46*).

Combined molecular genetic and fossil pollen data suggest that during the last glaciation, Norway spruce survived in at least seven refugial areas from which it expanded during Holocene. The southern lineage expanded mainly out of refugia in the south-eastern Alps, in the southern Bohemian Massif including its southern foreland, in the northern Dinaric Alps, northern Carpathians, southern Carpathians, and southwest Bulgarian mountains. The Russian Plain represents the single, extensive refugium for the northern lineage.

Reference basis for reconstitution of genetic resources

Although not connected to the Nyírjes trial site, the example of reconstructing lost genetic resources from the IUFRO 1964/68 provenance experiment should be mentioned. In the Polish trial, the provenance 0293 Kolonowskie was found to display a great adaptive potential across many trial sites which raised interest in the provenance for reforestation and breeding (Giertych 1978). Unfortunately, the original population did not exist anymore. Thus, scions collected from trees of this provenance grown on the experimental plots of the IUFRO trials was used to *establish a reconstitution seed orchard* in the experimental forest of the Institute of Dendrology at Kórnik (Giertich 1993, Fober 2004).

5.5 Biomass and dry matter allocation investigation in the provenance trial

The study was carried out in the 27 years old provenance trial in Nyírjes. 12 sample trees from different zone groups were cut to study the fresh and air-dry biomass. Weighing was carried out compartment-wise (stem, branches, needles, and cones*)* (*Figures 47, 48*).

Figure 47. Biomass measurements in the provenance test (photo: ERTI archive)

There was a very strong positive correlation between DBH and air-dry weight (R=0.984***). Diameter-based aboveground biomass equations were developed (*Figure 48*). The biomass of each tree and provenance was determined in Block 7 and 11. Relative variation of biomass between and within provenances was studied. Harvest index (HI, the proportion of stem mass out of the total above-ground phytomass), and leaf area index (LAI) were also determined (Ujvári-Jármay et al. 2000/2001.). The results were in accordance with findings of international studies. In the published study provenances have been also evaluated.

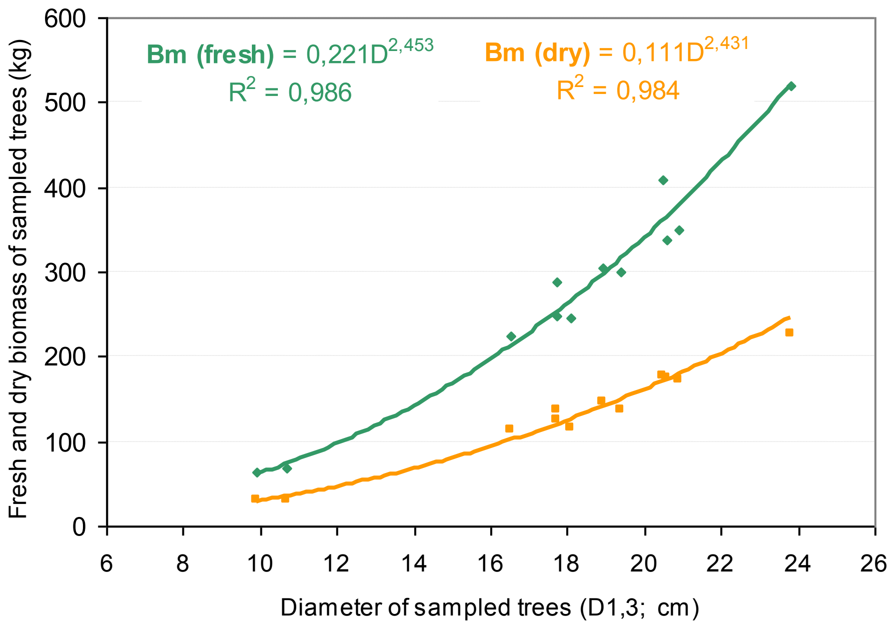


Figure 48. Regression of fresh and air-dry biomass (Bm; kg/tree) versus DBH of sampled trees (cm)

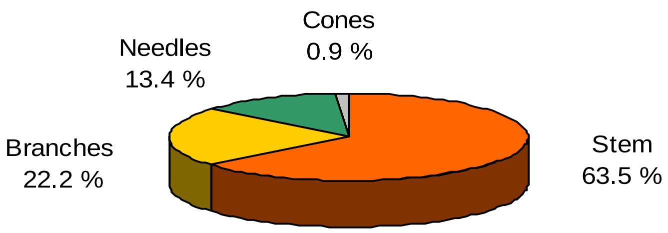


Figure 49. Allocation of dry biomass of block 7, at the age of 27 years (170 t/ha)

5.6 Wood quality studies

After the first thinning of provenance trial wood samples (discs, thickness ca. 5 cm) were collected from felled trees in 1985. The samples were investigated in Research Institute of Wood Industry by Babos (1986, 1987). Growth ring width of different years, proportion of early wood and late wood, fiber length and specific gravity were determined. The results provided information on trait variation between individuals and between provenances as well as about relations between investigated traits.

6 SHORT OVERVIEW OF INTERNATIONAL CO-OPERATION

IUFRO's international trial served primarily domestic interests. Forest managers of each country waited eagerly for practically applicable results of the expensive trial. No wonder that the analysis of data and evaluations of field experiments were carried out first separately in each country, providing information for the domestic silviculture. *Table 24* contains a selection of national publications which evaluated the experiences of the trials in their own country.

Figure 50. Visit of Prof. H. Schmidt-Vogt (on the right) and his students from Freiburg University (Germany) at the Nyírjes trial site in 1986. From left to right the local hosts: É. Ujvári-Jármay, F. Ujvári (Forest Res. Inst. ERTI) and E. Csesznák (Sopron University) (photo Freiburg Univ.)

The first joint evaluation was compiled by Dietrichson et al. in 1976. The conclusions from results at early age were summarized by Schmidt-Vogt (1980) and Krutzsch (1992). Three detailed, comprehensive reports were published so far, dealing with one or more trials:

1. A full set of data of 3 Swedish experiments giving mean values of growth traits up to age 16 (or 20 from seed) for each provenance has been published by A. Persson – B. Persson in 1992.
2. A comprehensive overview about the Polish experiment was compiled by S. Bałut and J. Sabor in 2001 and 2002.
3. In Germany a separate provenance experiment with Norway spruce was established in 1962, in which more than two hundred provenances are included, which are identic with the IUFRO set. Results of 30 years were reported by M. Liesebach et al. (2010).

Table 24. A selection of publications on the IUFRO (1964/68) Norway spruce inventory provenance tests

Field experiments No. and country		Authors of publications, reports or books
01	Canada	Coles (1976), Fowler (1979)
02	Ireland	Nieuwenhuis – Rostami (1993)
03	England	Lines (1973,1979)
04, 05	Norway	Dietrichson (1976), Magnesen (1976), Dietrichson (1979), Skrøppa – Dietrichson (1986), Fottland – Skrøppa (1989), Skrøppa (1993)
06, 07, 08	Sweden	Krutzsch (1975, 1976, 1979), A. Persson – B. Persson (1992, 1997)
09	Finland	
10	France	Christophe (1976), V. D. Sype (1997)
11, 12	Belgium	de Jamblinne (1976), Nanson (1976)
13, 14, 15	Germany	König (1976, 1981, 1989), Rau (1993), Kannenberg – Gross (1999), Liesebach et al. (2001)
16	Scotland	Lines (1973, 1976, 1979)
17	Czech Republic	Vins (1976, 1979)
18	Austria	Günzl (1979a, 1979b)
19	Poland	Bałut (1979), Sabor (1979,1997), Bałut – Sabor (2001, 2002), Masternak et al. (2009)
20	Hungary	Szőnyi – Ujvári (1970, 1975), Ujvári-Jármay & Ujvári (1979, 1980, 1992/93, 2006), Ujvári-Jármay et al. (2000/2001), Liesebach et al. (2001), Mátyás et al. (2009, 2010)
–	Germany, 1962[6]	Weisgerber (1976 a,b, 1977, 1984), Liesebach (2010)
General evaluations		Dietrichson et al. (1976), Giertych (1979), Krutzsch (1974, 1975, 1992, 1993), Schmidt-Vogt (1980)

The meetings of IUFRO WP 2.02.11 in Biri (Norway, 1973), in Bucharest (Romania, 1979), in Vienna (Austria, 1985), in Riga (Latvia, 1993) etc. and the IUFRO Centennial in Berlin (1992) were good occasions to discuss the actual tasks and results. At the Bucharest meeting M. Giertych was entrusted with the responsibility for preparing a report on the 1938 and 1939 IUFRO Norway spruce provenance experiment. He collected all the pertinent literature on the subject and gathered new information that has been never published before. His excellent report with a full set of data, maps, results and recommendations was issued in 1984. A similar compilation on the international test 1964/68 is still missing.

[6] This experiment does not belong to the IUFRO series, it contains, however, over 200 provenances identic with the international trial.

Figure 51. Visit of representatives of European Forest Research Institutes in the Nyírjes experiment in 1973. Hosts on far left: L. Szőnyi, the Hungarian coordinator and F. Ujvári who was responsible for establishment and surveys (photo: ERTI archive)

A common database was planned by T. Skrøppa (1993). He described the several possibilities for utilization of data, from this large series of trials. “A common database will make it possible to do multivariate analyses of several traits measured on trees of the same provenance grown under diverse climatic conditions. Another possibility is to study the variability in the performance of subset of provenances, and, if possible, identify regions of origin with high and stable performance”. The measurement data from 12 participating countries were sent to Garpenberg (Sweden), but unfortunately the effort for founding a common database was not successful.

It is very deplorable that, judged on published papers, only a few countries follow the trials with unchanged interest: Germany, Poland, Norway, Sweden and Hungary. The renewed interest in reanalysis of common garden results for projecting responses to expected climatic/environmental changes may bring new motivations to endeavour on drawing generalised conclusions of the still available data of IUFRO’s IPTNS trial network.

7 CONCLUSIONS

Is the analysis of phenotypic responses in common gardens still opportune?

The study deals with phenotypic (quantitative) responses of populations adapted to different macroclimatic conditions observed in common gardens of Norway spruce. The research aim was the study of the impact of climatic conditions experienced by numerous generations of local, autochthonous populations on their genetic makeup. The working hypothesis was that climatic conditions represent a clear selective force which will create a clear adaptive pattern across the range of the species.

The basic question to be answered is, whether within-species adaptation of forest trees to macroclimate and its fluctuations is narrow and site-specific, or phenotypic stability and/or selectively neutral genetic processes are so effective that they buffer the expected climatic shifts during the present century? Ultimately, the *future strategy of forest reproductive material deployment and of nature conservation depends on the answer: how much human assistance* is necessary when genetic adjustment to projected site (= climate) changes has to happen *within one generation of trees*.

The analysis of genetically regulated responses is hampered by numerous obstacles. The complex genetic regulation system of woody species is difficult to analyze. Research result interpretations are often prejudiced by contradictions and implicit assumptions. *Primarily, the weight of natural (climatic) selection against tradeoff effects and random events as gene flow, historic migration effects or appearance of new mutants is still unresolved.*

In spite of all shortcomings of the investigated tests, analysis of phenotypic behavior observed in common gardens (provenance tests) is still indispensable; they provide at present the *only realistic possibility* to estimate and validate quantitative responses to climatic changes. Therefore, these tests are worth to evaluate even if they do not satisfy all requirements of correct experimental design.

Within-species phenotypic variation pattern: connections with macroclimatic clines

Traces of within-species macroclimatic selection could be substantiated for growth and survival traits. Within-species adaptive genetic variation patterns reflect climate selection effects, which *may overwrite random historic and gene flow influences* especially in the zones of severe selection. With increasing selection pressure of extreme conditions, growth and survival is *declining*. This effect has been observed recurrently when comparing provenances and zone groups in parallel trials in different parts of the distribution range (e.g. Mátyás et al. 2009b).

The proof of *differentiated sensitivity* in different regions of the distribution area could be ascertained which corroborates *dichotomy of selection pressure directions* toward the thermic and xeric margins (Table 18, chapter 4.3). Variation of sensitivity to climate factors indifferent climate zones could be proven both for provenances and zone groups. The difference of factor weights is illustrative: the weight of precipitation factors prevails at the xeric limit and that of thermal factors is dominant at the colonizing, i.e. thermic limits. This phenomenon explains the low predicting efficiency of single variables to describe whole-range species distributions.

Factors deciding over vitality, presence or absence of the species are definitely different in the thermic and xeric zones of distribution. Further, it has to be underlined that – although the results on survival have indicated only the decisive force of climate selection for the northern limit only (*Figure 41*) – at the *southern, xeric limits climate selection becomes again severe* and, exhausting the genetic potential for adaptation, may lead to total local extinction. No experiment of Norway spruce has been located under such demanding conditions. *Forest management, interested in reliable, sustained production, has to consider these facts even more carefully*.

It has to be pointed out that with the presently ongoing climatic changes, the damage of antagonists actively benefiting from the increasing length of growing season, i.e. insects and pathogens, emerge as primary factors causing widespread mortality and an upward shift of the distribution limits. Considered by many as a forest protection problem, the underlying reason is the climate becoming more favorable for the life cycle of antagonists. For instance, in case of Norway spruce, growing temperatures are triggers for the increasing damage of bark beetles in Central Europe, first of all at lower altitudes, close to the xeric limit (e.g. Hlásny – Turcany 2009). Although there is no doubt about the limiting role of biotic interactions, this phenomenon could not be modeled in the analyzed test series due to the lack of data on dynamism of the process (see subchapter on health and mortality).

Differentiation of phenotypic stability in Norway spruce

If response regressions are calculated separately for groups of provenances from one region, it turns out that that *the response variation of populations from different geographic regions displays characteristic differences*, determined by local ecological/climatic selection, probably also by local microevolution. *This may provide hints for phenotypic stability differentiation.* In *Figure 30*, chapter 4.2 variability of phenotypic stability within and between spruce provenance regions is displayed, indicating the excellence of the “East Carpathian” zone group.

Significant within-species differences and geographic patterns in phenotypic stability could be identified in Norway spruce. It seems that certain *ecological/climatic conditions at the site of origin may enhance or diminish the stability* of populations. Stability *seems to interfere with climatic adaptation and may contribute to the observed asymmetry in growth response patterns. (For details see the following subchapter on adaptation lag.)*

The results indicate certain estimation possibilities of stability of provenance regions from transfer functions.

Asymmetry of transfer functions: “adaptation lag” due to buffering of stability?

Contemplating the three response functions of three provenance trials in *Figure 29*, chapter 4.1 the first conclusion is that in spite of large environmental differences represented by the tested populations, the responses do not indicate narrow (strictly local) adaptation. It seems also that fitness differentiation increases towards more favorable environments, i.e. southward. This phenomenon is attributable to the fact that manifestation of genetic differences is favored by better site conditions (Mátyás et al. 2010, Kappeller et al. 2012).

When comparing the calculated response regression maxima for annual means with the Norway spruce test sites, it turns out that the "fittest" (maximum production) populations at milder locations originate from somewhat cooler environments[7], while at the harsh northern location, populations from milder environments perform somewhat better (*Figure 29,* chapter 4.1 and *Table 25, chapter 7.*). According to *Table 25,* the difference between the annual mean temperature corresponding to the response regression maximum and the test site mean is negative at milder sites, indicating that populations from somewhat cooler climates perform better ($\Delta T = T_{max} - T_{exp}$). The opposite result appears at the harsh northern site, where populations from milder environments outperform local ones. This surprising phenomenon was reported from some other boreal tests as well (e.g. Andalo *et al*. 2005).

Table 25. Temperature and height data of Norway spruce experiments to Figure 29.

Experimental site data			Transfer function		Temperature difference $T_{max} - T_{exp}$
test name	mean annual temp. (T_{exp} °C)	mean height of test (cm)	temp. at maximum (T_{max} °C)	mean height at T_{max} (cm)	(°C)
Nyírjes (H)	7.5	890.3	6.9	916.1	–0.6
Abild (S)	5.9	643.1	5.4	661.7	–0.5
Lappkojberget (S)	2.3	305.4	4.2	319.1	+1.9

Similar asymmetry can be observed in most other transfer functions. The same effect is visible in a bivariate response surface calculated with two, locally decisive climate factors for the Nyírjes test (*Figure 34* chapter 4.3). *The shift of the maximum production towards provenances originally adapted to somewhat cooler climates (i.e. experiencing a temperature increase – e.g. Figure 34) is characteristic for tests located closer to the xeric (low elevation, low latitude) limit of distribution.*

The asymmetry may be explained by the interaction of different effects, such as suboptimal adaptation due to gene flow, by the "cultivation fitness" but *most probably by the simultaneous action of genetic adaptation and phenotypic stability.* It is improbable that the phenomenon is exclusively caused by ecological fitness constraints or by random migration effects. Although the "nonoptimality" of local provenances is a feature observed in other experiments and other species as well, pointing to an adaptive disequilibrium (Mátyás et al. 2010), the lag in the adaptation process is difficult to capture due to observed parallel shifts of both climate factors and of phenotypic responses (see chapter 4.2).

A glance on the adaptive genetic resources of marginal populations

The concept that central populations harbor most of the species' (adaptive) variation and that the lower margins contain most of the remaining (perhaps mostly non-adaptive) pre-migration variability, has been tested by comparing the within-population variance means for height.

[7] For clarification, this means that when illustrating transfer differences (ecodistances), origin from cooler environment means positive difference, i.e. warming, as experienced at the test, compare in *Figure 31*!

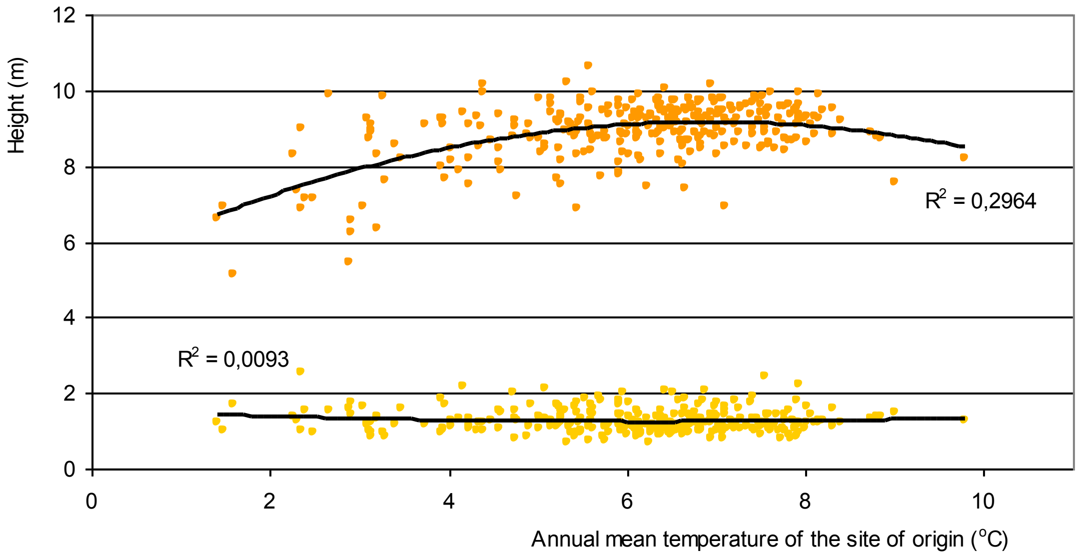


Figure 52. Average tree height (upper function) and within-population standard deviation of height (lower function) at age 16 of Norway spruce in the Nyírjes provenance test, versus annual mean temperature of the location of origin (horizontal axis)

Rather surprisingly, *no clear trend was detectable in within-population variation* in the Nyírjes test: there was no detectable differentiation across the range (*Figure 52*, lower function), i.e. the magnitude of quantitative/phenotypic variation in height between individuals remained roughly the same across the range. Neither the central ("optimum") nor the marginal ("edge") populations indicated excessive adaptive variation. Consequently, the data do not show either a specific loss of variability due to excessive selection at the lower margins (in spite of the fact that many of them are most probably artificially regenerated populations of unknown origin).

An important question is the adaptability and stability of marginal populations. This decides over their practical importance. The deplorable lack of properly positioned "stressing trials" does not allow a general assessment. Marginal populations are deplorably underrepresented. High selection intensity at the thermal (upper) limit, which may lead to loss of stability, is indicated by survival differentiation of Norway spruce provenances in the Lappland test Lappkojberget (*Figure 41*, chapter 4.7) and by the sensitivity of boreal populations to changing conditions (*Figure 36*, chapter 4.4). In summary, there are only indirect proofs that the hypothesis of generally high adaptive value of marginal populations may be questioned.

Test conditions interact: sampling pattern of sites and of provenances largely influence results

The comparison of responses shed the light on the role of testing conditions; a clear *interaction of test conditions and of involved populations on response variance* was observed which has to be taken into consideration when evaluating any result. Significant analytic results strongly depend not only on the proper selection of site, layout, measurement and treatment but also on the composition of provenances included in the experimental analysis and the proper set of tests for analysis. Available tests rarely provide at least partly ideal conditions. (The comparison of three test sites Nyírjes – Abild – Lappkojberget represent a seldom good example; see *Figures 16*, chapter 3.2 and *29*, chapter 4.1)

Expression of genetic differentiation in growth potential is enhanced in milder environments, while limits of tolerance (survival) is better observable under severe selection pressure (e.g. boreal sites for Norway spruce, xeric sites for beech etc.). In Norway spruce, changing response over time was observed, probably linked either to "acclimation" or climatic shift during the testing period. The experiences draw the attention to carefully check test conditions and to use relevant, fitting climate reference periods for climate response analysis.

Local is the best?

Although in most common garden tests the between-population variability of adaptive traits has reliably proven the existence of the effect of climate selection (e.g. Mátyás 1996, Rehfeldt et al 2003 etc.), transfer functions however show that, on the level of provenances, the adaptation to local climatic conditions is rather constrained ("adaptation lag": Mátyás 1990). As a corollary, the superiority of local populations cannot easily be proven.

As mentioned before, in the Nyírjes provenance test, although the sampled provenances cover most of the temperate-continental distribution of the species, the regression height at age 16 versus annual mean temperature at origin is rather flat (*Figure 52*). In spite of the wide range in annual temperatures between 1.5 and 10 °C at origin, the pooled transfer functions do not show the maxima at 0 ecodistance. This suggests a *remarkable width of adaptability and persistence* of Norway spruce populations (at least for the first half of the rotation) and supports the substantial conservatism in the climatic adaptation found in numerous other tree species. It has to be emphasized that this is *primarily valid for productive, mild sites such as the one in Nyírjes, Hungary.* The long-term effect of non-local superiority might be questioned by a gradually changing trend as observed in the Nyírjes after half rotation age (*Figure 40*, chapter 4.6), however, positive experiences with well selected non-local provenances over many decades do contradict, such as, for spruce, the provenances Istebna or E. Carpathians. The question provides one reason more to maintain the experiment further, until the end of rotation age, and to study climate selection effects more in detail.

Superiority of non-local, non-autochthonous provenances: the case of Hungarian sources

The true origin of Hungarian provenances is unknown, some might be second-generation progenies of locally cultivated stands, others descendants of imported lots (see chapter 3.4). The outstanding stability shown by some of these populations is, however, not exceptional. E.g. one of the most celebrated phenotypically stable population of Poland, 1045 Istebna, turned out to be non-autochthonous. It is known from investigations of J. Sabor (1997) that the one-time owner, a Habsburg prince, imported the seed lot from Austria, proving that careful selection of non-autochthonous sources may be a sensible solution.

Possibilities to improve reliability and precision of estimating climate factor effects

The provenance test Nyírjes – similar to other experiments of this kind – harbors numerous sources generating uncertainty to achieve proper results and interpretations. At this point we comment only on the *effect of composition of provenances* included in a trial. No result can be better than the data input provided by the set of investigated sources. In the present case the random selection of the investigated 290 provenances represent the whole set of 1100 entries. Considering the whole analyzed range of distribution, however, the selection is biased by basically two uncontrollable conditions: expert interest and accessibility of occurrences of the species (where did the samples come from) and – admittedly on a minor scale – possible human errors during transferring, planting and identification, i.e. bias caused by provenances of unknown or falsely identified origin.

No doubt that the reliability and precision of the results may be improved by further screening of the provenances. It was accepted already at the planning stage of the experiments that an unknown percentage of provenances is not autochthonous, and their climatic and other ecological data certainly impair the reliability of results. Part of the non-native populations might be singled out by routine molecular methods. For instance, Sperisen and collaborators (2001) have identified some Central- and Southeast European provenances in South Scandinavia. In a few cases even phenological appearance and growth rate may help in identification: the Norwegian provenance 0927 Austagder has been excluded on this basis. Also, reasons of exclusion could be overrepresentation (e.g. from the Alps) or “provenances” representing only individual trees, such as 0734, 0832, 0932 Bogstad from Norway. To study more precisely the functioning of environmental/climatic adaptation in nature, native populations should be selected and analysed, considering also the balanced representation of the standing genetic variation of the species.

Summary of conclusions

Analyses of field tests show remarkable range of adaptability and persistence (and, in consequence, an extended range of ‘local’ adaptation) in the face of even drastic changes in climatic environment. This phenomenon indicates the substantial conservatism in the climatic adaptation, which has an inherent genetic basis and may have been enhanced by evolution (Mátyás – Nagy 2005). The inherently high within- and between-population genetic variation present in all tested species lends an unusually *high potential of adjustment even to instant extreme changes of weather/climate conditions*.

Although seemingly having lost its justification and being obsolete for Hungary, the Nyírjes experiment provides extremely useful experiences also as a model species for answering silvicultural questions of the future. Among other things, the Norway spruce provenance test has demonstrated already in juvenile age

- the existence of climate-related clinal variation of major phenotypic traits (phenology, height and DBH growth);
- the value and adaptability of local, cultivated (non-autochthonous) sources in comparison with provenances from across Europe;
- the outstanding phenotypic stability (“plasticity”) and superiority of certain provenances, mostly from Southeastern Europe.

The results support the initial hypothesis that

- quantitative, adaptive responses (growth, phenology, health, survival) measured in comparative tests can be interpreted as mimicking of expected climatic changes, and may serve the further development of response models and projections;
- a significant part of the intraspecific genetic differentiation among populations is linked to macroclimatic adaptation and is the functional result of climatic selection;
- asymmetry of response indicated by response functions (both reaction norms and transfer functions) implies most probably the simultaneous action of phenotypic stability and selection, and maintains an adaptive non-equilibrium;
- it is probable that stability is enhanced by specific ecological/climatic conditions.

Further conclusions:

Adaptation to local environment cannot be considered as an implicitly sufficient basis for future adaption to projected climate shifts. Response to increasing temperatures shows remarkable differentiation in different parts of the distribution range. Opposing growth responses may be expected at the thermic versus the xeric limits;

In the northern-boreal zone, expected rise of temperature (with still sufficient precipitation) will lead to growth acceleration without significant genetic change. In the temperate-maritime zone, with increasing or at least unchanged rainfall growth will accelerate too. In the southeastern continental zone, relatively minor summer temperature increase will trigger higher susceptibility to diseases and increase of mortality. In semihumid climates at the lower forest limit extensive mortality may lead to local extinctions and shift of distribution area northward, or upward in altitude.

As expected rapid changes in the next decades will affect first of all the extant (already existing) forest stands, their adaptation potential will mainly depend on the level of their phenotypic stability. The importance of this trait should be recognized not only in breeding and improvement, but also in deployment of forest reproductive material.

The extremes in individual years are the really decisive factors deciding over vitality and survival. The frequency and severity of extremes has to be analysed further in detail, both for the recent past and for the projected future.

Observed survival results differing from growth trends caution from all too courageous selection of distant provenances, based on growth data. When deciding about the use of provenances, juvenile growth has to be considered together with criteria of tolerance and adaptability to expected, irregularly appearing climate extremes. Prudent provision for adaptability and stability increases the probability of success in the next generation.

Results may be adopted into functional growth models for predicting the behavior of forest stands under changing climatic conditions.

In summary, analysis of phenotypic behavior observed in common gardens (provenance tests) is still indispensable; the field tests provide the *only realistic possibility* to estimate and validate quantitative responses to projected climatic changes. To improve both response modeling and to support adaptive forest management, relevant information from common gardens, including retrospective data, should be further collected and evaluated as much as possible. One crucial aspect of evaluations is, however, the provision of exact climatic and other site information – both from the original sites and from the tests.

It is not expectable that large scale experiments such as the IUFRO test will be initiated in the foreseeable future; the need, however, of understanding both molecular and quantitative genetic consequences of adaptation justifies new tests, established with more sophistication, first of all with detailed, representative and exact sampling and documentation.

8 POST-SCRIPTUM

"Trees live longer than research concepts"
(D. Lindgren)

Nearly half a century, two human generations have seen in Hungary ups and downs in politics, economy and in science support. The provenance test had to survive priority changes, reorganizations and terminations – but it still attracts professional interest.

Phases of enthusiasm and oblivion changed from one into the other rapidly. Provenance tests, once initiators of international cooperation in forest science, were suddenly considered old-fashioned, of low scientific value and it was just lately that international interest could be directed again toward these experiments (Mátyás 1994). The comparatively short lifetime of supported research concepts tells also about the short-sightedness of human endeavor and the power of political and economic actualities.

Original intentions to utilize the experiment Nyírjes for practical forest management are gone – what remained is the growing interest in the functioning of living systems. There is an ever-renewing attempt of interpreting nature's grand play on the evolutionary stage and such a long monitoring period offers constantly new insights and explanations. The close follow-up over decades is fascinating and reveals continuously new facets of the evolution-trained life strategy of an important tree species which is among the ones with the largest distribution, successfully serving human needs.

The assertion that provenance tests represent possibly the most important contribution of forest science to general biology, not incidentally originating from Hungary (Mátyás 1996), reached many participants of the test series too late. Nevertheless, the obligation to evaluate these and other provenance tests from point of view of quantitative genetic background of adaptation to climate conditions is endorsed by the rapidly growing importance of preparing for the unresolved effects of projected severe climatic changes. The experiments – with all their shortcomings – provide a unique opportunity to glance into an uncertain future; the presentation of results of Nyírjes is aimed to contribute to this expectation.

The described results and experiences could not have reached the publication stage without the selfless enthusiasm of researchers and of forest managers, maintaining the experiment also in times of practically no support. Special thanks have to be expressed to László Szőnyi, the initiating spirit of the experiment and to Éva Ujvári-Jármay, her late husband Ferenc Ujvári and to László Nagy. We trust that their effort will find followers in the future as well.

Csaba Mátyás

Acknowledgements

Discussions and proposals in the international community of EUFORGEN and of the reviewers largely contributed to the improvement of the manuscript. The detailed and helpful comments of *S. Schüler* (BFW Vienna) have to be especially highlighted.

Scientific and financial support of the Hungarian Forest Research Institute (NARIC-ERTI), the Ministry of Agriculture, and of numerous research funds and projects, such as the Hungarian Scientific Research Fund (OTKA), as well as the TÁMOP "Agrárklíma" and VKSZ_12-1-2013-0034 „Agrárklíma.2" projects, jointly funded by the European Social Fund and by the Hungarian Research, Development and Innovation Agency (coordinated by Cs. Mátyás, Sopron); further the long-term support of the EU-7 projects FORGER (coordinated by K. Kramer, Wageningen) and EVOLTREE (coordinated by A. Kremer, Bordeaux) are gratefully acknowledged. The long-term monitoring and observation of the trial would have been impossible without the continuous, careful maintenance provided by the Egererdő State Forest Co., and its Mátrafüred Forest District. Thanks also to all mentioned and unmentioned co-workers and colleagues who contributed to the comprising of this paper. All unreferenced photos, figures and tables were provided by the authors.

REFERENCES[8]

Publications

ANDALO, C. – BEAULIEU, J. – BOUSQUET, J. (2005) : The impact of climate change on growth of local white spruce populations in Québec, Canada. For. Ecol. Manage 205: 169–182.

BAŁUT, S. – SABOR, J. (2001): Inventory provenance test of Norway Spruce (*Picea abies* (L.) Karst. IPTNS-IUFRO 1964/68 in Krynica. Part I. Description of the experimental area. Test material. IUFRO Working Party S 2.02.11 Norway Spruce Provenances and Breeding. Kraków. 87 p.

BAŁUT, S. – SABOR, J. (2002): Inventory provenance test of Norway Spruce (*Picea abies* (L.) Karst. IPTNS-IUFRO 1964/68 in Krynica. Part II. Test results of 1968–84. Geographical variability of traits in the whole range of the species. IUFRO Working Party S 2.02.11 Norway Spruce Provenances and Breeding. Kraków. 200 p.

BARTHOLY, J. – BOZÓ, L. – HASZPRA, L (eds., 2011): Klímaváltozás – 2011, Klímaszcenáriók a Kárpát-medence térségére. [Climate change – 2011, climate scenarios for the Carpathian Basin region] MTA – ELTE, Budapest, ISBN 978-963-284-232-5, 281 p (*in Hungarian*)

BEUKER, E. (1994): Long-term effects of temperature on the wood production of *Pinus sylvestris* L. *Pices abies* (L.) Karst. in old provenance experiments. Scand. J. For. Res. 9: 34–45.

CZIMBER, K. – MÁTYÁS, CS. – NAGY, L. – UJVÁRI-JÁRMAY, É. (2016): A fotogrammetriai famagasság-mérés módszere, eredményei, továbbá az eredmények hasznosítása a IUFRO lucfenyő származási kísérlet értékelésekor. [Method and results of photogrammetric tree height measurement and its application for the survey of the IUFRO provenance trial.] Erdészettudmányi Közlemények, 5: 2 submitted (in Hungarian with English summary)

DIETRICHSON, J. (1969): The geographic variation of springfrost resistance and growth cessation in Norway spruce (*Picea abies* (L.) Karst.). Meddr Norske Skogfors Ves. 27, 94–106.

DIETRICHSON, J. (1979): Norway spruce provenance trials in Nordic Countries. In: Proceedings of the IUFRO joint meeting of working parties on Norway spruce provenances and Norway spruce breeding. Bucharest, Romania 3–14.

DIETRICHSON, J. – SKRØPPA, T. (1977): Skadene på granskogen i vinter og valg av provenienser. [Winter damages in spruce forests and the selection of provenances.] Skogeieren 1977 (6–7): 10–12 (in Norwegian)

DIETRICHSON, J. – CHRISTOPHE, C. – COLES, J. F. – DE JAMBLINNE, A. – KRUTZSCH, P. – KÖNIG, A. – LINES, R. – MAGNESEN, S. – NANSON, A. – VINS, B. (1976): The IUFRO provenance experiment of 1964/68 on Norway spruce (*Picea abies* /L./ Karst). Voluntary paper the XVI. IUFRO Congress, Oslo. 14 p.

DIETRICHSON, J. – ROGNERUD, P.A. – HAVERAAEN, O. – SKRØPPA, T. (1985): Stem cracks in Norway spruce (*Picea abies* [L.] Karst.). Reports of the Norwegian Forest Research Institute 38.21

DIETZE, W. – RACZ, J. (1973): Phenological observations and height growth of the International Norway Spruce Provenance Trial from 1964/68 during the nursery stage. In: DIETRICHSON, J. (ed.): Abstracts of papers. IUFRO-meeting of the w.p. 2.02.11 on Norway spruce provenances, Biri / Norway, Aug. 14–20, 1973. The Norwegian For. Res. Inst., 18–19.

EBERHART, S. A. – RUSSEL, W. A. (1966): Stability parameters for comparing varieties. Crop Science, 1–2. 6: 36–40.

FOBER, H. (2004): An assessment of family variation of Norway spruce (Picea abies [L.] Karst.) of Kolonowskie provenance from reconstitution seed orchard. Silvae Genetica 53, 5/6: 249–253.

FOTTLAND, H. – SKRØPPA, T. (1989): The IUFRO 1964/68 provenance experiment with Norway spruce (*Picea abies*) in Norway. Variation in mortality and height growth. Communications of the Norwegian Forest Research Institute 43.1

[8] The list contains published papers related to the IUFRO Norway spruce trial 1964/68 (IPTNS) some of which are not cited in the text

FOWLER, D. P. (1979): Norway spruce provenance experiments in North America. In: Proceedings of the Joint Meeting of Working Parties on Norway Spruce Provenances and Norway Spruce Breeding. Bucharest, Rumania 1979. 28–40.

GÁLOS, B. – LORENZ, PH. – JACOB, D. (2007).Will dry events occur more often in Hungary in the future? Env. Res. Letters, 2:(034006) Paper 10.1088/1748-9326/2/3/034006. 9 p.

GIERTYCH, M. (1979): Norway spruce (Picea abies L. Karst.) provenance experiments in Eastern Europe. In: Proceedings of the Joint Meeting of Working Parties on Norway Spruce Provenances and Norway Spruce Breeding. Bucharest, Romania 1979. 15–27.

GIERTYCH, M. (1984): Report on the IUFRO 1938 and 1939 provenance experiments on Norway spruce (Picea abies /L./ Karst.). IUFRO WP S2.02.11. Polish Academy of Sciences, Inst. of Dendrology, Kórnik, Poland.

GIERTYCH, M. (1993): Breeding Norway spruce in Poland: from provenance tests to seed orchards. Norway spruce provenances and breeding. In: Proceedings of IUFRO (S2.2-11) Symposium, Latvia, 1993. 193–199.

GIERTYCH, M. (2001): The 1964/68 IUFRO inventory provenance test of Norway spruce IPTNS-IUFRO 1964/68 in Krynica. Part I. Description of the experimental area – test material. 1st ed. Widawnictwo Akademii Rolniczej w Krakowie, Krakow.

GÜNZL, L. (1979a): Internationale Fichten-Provenienzversuche der IUFRO 1938 und 1964/68 sowie Versuche mit österreichischen Herkunften. Allg. Forstztg. (Wien) 90 (7): 182–190.

GÜNZL, L. (1979b): International IUFRO Norway spruce provenance experiments of 1938 and 1964/68 and additional Austrian provenance experiments. In: Proceedings of the Joint Meeting of Working Parties on Norway Spruce Provenances and Norway Spruce Breeding. Bucharest, Rumania, 1979. 51–56.

HLÁSNY, T. – TURČÁNI, M., 2009: Insect pests as climate change driven disturbances in forest ecosystems. In: Střelcová, K., Mátyás, C., Kleidon, A., Lapin, M., Matejka, F., Blaženec, M. et al. (eds.): Bioclimatology and natural hazards. Springer, 165–176.

KANNENBERG, N. – GROSS, K. (1999): Allozymic variation in some Norway spruce populations of the International IUFRO Provenance-testing Programme of 1964/68. Silvae Genetica, 48. (5): 209–217.

KAPELLER, S. – LEXER, M.J. – GEBUREK, T. – HIEBL, J. – SCHUELER, S. (2012): Intraspecific variation in climate response of Norway spruce in the eastern Alpine range: Selecting appropriate provenances for future climate. Forest Ecology and Management 271, 46–57.

KLEINSCHMIT, J. – SCHMIDT, J. (1977):Expriences with *Picea abies* cutting propagation in Germany and problems connected with large scale application. Silvae Genetica, 26. 197–203.

KNABE, W. – URFER, W – VENNE, H. (1990): Die Variabilität der Immissionsresistenz von Fichten-herkünften – ein Beitrag zum IUFRO-Fichtenprovenienzversuch 1964/68. Silvae Genet. 39 (1): 8–17.

KÖNIG, A. (1981): Einige Ergebnisse aus dem IUFRO-Fichtenprovenienzversuch von 1964/68 in der Bundesrepublik Deutschland. Allg. Forstztg. (Wien) 92, 300–303.

KÖNIG, A. (1989): Correlations between growth data in the IUFRO 1964/68 Norway spruce provenance experiment. In: STENER, L-G. u. WERNER, M. (eds.) 1989: Norway Spruce; Provenances, Breeding and Genetic Conservation. In: Proc. IUFRO W.P. meeting, S2.02-11, in Tjornap, Sweden, Sept. 5–10, 1988, Inst. f. For. Improvement, Rep. 11, Uppsala, Sweden, 249–254.

KRUTOVSKII, K. V. – BERGMANN, F. (1993): Genetic variation of Norway and Siberian spruce species and their zone of introgressive hybridization studied by isozyme loci. In: Proceedings of the IUFRO S2.2-11 Symposium Riga, Latvia 93–99.

KRUTZSCH, P. (1973): The Inventory Provenance Test with Norway spruce of 1964/68. IUFRO Working Party S 2.02-11 Provenances, Norway spruce, Oslo, Norway, August 1973.

KRUTZSCH, P. (1974): The IUFRO 1964/68 provenance test with Norway spruce (Picea abies (L.) Karst.). Silvae Genetica, 23, (1–3): 58–62.

KRUTZSCH, P. (1975): Die Pflanzenschulergebnisse eines inventierenden Fichtenherkunftversuches (*Picea abies* (L.) Karst. und *Picea obovata* Ledeb.). Royal Coll. Forestry, Dept. For. Gen. Res. Notes. 14. 104.

KRUTZSCH, P. (1992): IUFRO’s role in coniferous tree improvement: Norway spruce (Picea abies (L.) Karst.). Silvae Genetica, 41, (3): 143–150.

LANGLET, O. (1971): Two hundred years of genecology. Taxon, 20: 653–722.

LANGNER, W. – STERN, K. (1964): Untersuchungen über den Austriebstermin von Fichten und dessen Beziehung zu anderen Merkmalen. Allg. Forst und J. Ztg., 135. 53–60.

LIESEBACH, M. – KÖNIG, A. O. – UJVÁRI-JÁRMAY, É. (2001): Provenance-environment interactions of Norway spruce (*Picea abies* [L.] Karst.) on German and Hungarian test sites. In: Müller-Starck, G. – Schubert, R. (eds.): Genetic Response of Forest Systems to Changing Environmental Conditions. 70. For. Sci. Kluwer Academic Publishers, Dordrecht, Boston, London. 353–363.

LIESEBACH, M. – RAU, H. M. - KÖNIG, A. O. (2010): Fichtenherkunftsversuch von 1962 und IUFRO-Fichtenherkunftsversuch von 1972. In: Beiträge aus der NW Deutschen Forstlichen Versuchsanstalt 5, Universitätsverlag Göttingen. 467 p.

LINES, R. (1973): Inventory provenance test with Norway spruce in Britain: First results. In: Forestry Commission Research and Development Paper, 11 p.

LINES, R. (1979): Results of the IUFRO 1964/68 experiments with Picea abies in Scotland after 11 years. In: Proceedings of the Joint Meeting of Working Parties on Norway Spruce Provenances and Norway Spruce Breeding. Bucharest, Rumania 1979. 44–46.

MASTERNAK, K. – SABOR, J. – MAJERCZYK, K. (2009): Effect of provenance the survival of *Picea abies* trees on the IPTNS- IUFRO 1964/68 site in Krynica (Poland). Dendrology 61. 53–61.

MÁTYÁS, CS. (1981): Kelet-európai erdeifenyő-származások fenológiai változékonysága. [Phenological diversity of East-European Scots pine provenances.] Erdészeti Kutatások 74: 71–80. (in Hungarian with English summary)

MÁTYÁS, CS. (1990): Adaptation lag: a general feature of natural populations. Invited lecture. Proc., WFGA-IUFRO Symp. Olympia, Wash. Paper no. 2.226, 10 p.

MÁTYÁS, CS. (1994): Modeling climate change effects with provenance test data. Tree Physiol. 14, 797–804.

MÁTYÁS, CS. (1996): Climatic adaptation of trees: Rediscovering provenance tests. Euphytica 92: 45–54.

MÁTYÁS, CS. (1999): Lessons from hundred years of international research in forest genetics and breeding. In: Mátyás, Cs. (ed.): Forest Genetics and sustainability. Kluwer, Dordrecht, 3–8.

MÁTYÁS, CS. (2006): Migratory, genetic and phenetic response potential of forest tree populations facing climate change. Acta Silvatica et Ligniaria Hung. 2: 33–46. (http://aslh.nyme.hu)

MÁTYÁS, CS. – YEATMAN, C.W. (1987): A magassági növekedés adaptív változatosságának vizsgálata *P. banksiana* populációkban. [Adaptive variation of height growth of *Pinus banksiana* populations] EFE Tud. Közl., (Scient. Proc. of Sopron Univ., Hungary), (1–2): 191–197. (in Hungarian with English summary).

MÁTYÁS, CS. – YEATMAN, C. W. (1992): Effect of geographical transfer on growth and survival of jack pine (*Pinus banksiana* Lamb.) populations, Silvae Genetica, 43, 6: 370–376.

MÁTYÁS, CS. – NAGY, L. (2005): Genetic potential of plastic response to climate change. In: Konnert M. (ed.) Tagungsberichte, Forum Genetik und Wald 2004. Bavarian Centre f. For. Repr. Material, Teisendorf, Germany, 2005. 55–69.

MÁTYÁS, CS. – NAGY, L. – UJVÁRI-JÁRMAY, É. (2009a): Genetic Background of response of trees to aridification at the xeric forest limit and consequences for bioclimatic modeling. In STRELCOVÁ, K. et al. (eds.): Bioclimatology and Natural Hazards. Springer. 179–196.

MÁTYÁS, CS. – BOŽIČ, G. – GÖMÖRY, D. – IVANKOVIĆ, M. – RASZTOVITS, E. (2009b): Transfer analysis of provenance trials reveals macroclimatic adaptedness of European Beech (*Fagus sylvatica)L.* Acta Silvatica et Ligniaria, 5. 47–62. (http://aslh.nyme.hu)

MÁTYÁS, CS. – NAGY, L. – UJVÁRI-JÁRMAY, É. (2010): Genetic background of response of trees to aridification at the xeric forest limit and consequences for bioclimatic modeling. Forstarchiv 81 (4): 130–140.

NIEWENHUIS, M. – ROSTAMI, T. (1993): The IUFRO Norway spruce provenance trial in Ireland – an update. In: Proceedings of the IUFRO S2.2-11 Symposium Riga, Latvia, 1993. 113–118.

PERSSON, A. (1994): Stem cracks in Norway spruce in southern Scandinavia: causes and consequences. Ann Sci For. 51. 315–327.

PERSSON, A. – PERSSON, B. (1992): Survival, growth and quality of Norway spruce (Picea abies (L.) Karst.) provenances at the three Swedish sites of the IUFRO 1964/68 provenance experiment. Report 29. Swedish University of Agricultural Sciences, Dep. of Forest Yield Research, Garpenberg. 87 p.

PERSSON, A. – PERSSON, B. (1997): Variation in stem properties in IUFRO 1964/68 Picea abies provenance experiment in southern Sweden. Silvae Genetica, 46, 94–101.

RAU, H. M. (1993): The IUFRO 1964/68 Norway spruce provenances trial in Germany after 25 years of observation. In: RONE, V. (ed.): Norway Spruce Provenances and Breeding. In: Proc. of the IUFRO S. 2.2-11 Symposium Riga, Latvia, 1993. Latvian For. Res. Inst. 'Silava', Riga 1993. 128–132.

REHFELDT, G.E. – TCHEBAKOVA, N.M. – MILYUTIN, L.I. – PARFENOVA, E.I. – WYKOFF, W.R. – KOUZMINA, N.A. (2003): Assessing population responses to climate in *Pinus sylvestris* and *Larix* spp. of Eurasia with climate transfer models. Eurasian J. For. Res., 6 (2): 83–98.

SABOR, J. (1979): The relation between the selection of early and late flushing provenances of Norway spruce at a IUFRO 1964/68 site in Krynica and observation dates in the annual growing cycle. In: Proceedings of the Joint Meeting of Working Parties on Norway Spruce Provenances and Norway Spruce Breeding. Bucharest. 455–463.

SABOR, J. (1997): *Picea abies* (L.) Karst. provenances and breeding. In: IUFRO Norway Spruce Symposium, Norway spruce breeding and genetic resources, Stara Lesna.

SAVOLAINEN, O. – BOKMA, F. – GARCÍA-GIL, R. – KOMULAINEN, P. – REPO, T. (2004): Genetic variation in cessation of growth and frost hardiness and consequences for adaptation of *Pinus sylvestris* to climatic changes. For. Ecol. Mange. 197: 79–89

SCHMIDT-VOGT, H. (1977): Die Fichte. Band I. Verlag Paul Parey, Hamburg und Berlin. 647 p.

SKRØPPA, T. – DIETRICHSON, J. (1986): Winter damage in the IUFRO 1964/68 provenance experiment with Norway spruce (Picea abies (L.) Karst.). Meddr Norsk Inst Skogforsk 39: 161–183.

SKRØPPA, T. – PERSSON, B. – PERSSON, A. (1993): A database for the IUFRO 1964/68 provenance experiment with Norway spruce. In: Proceedings of the IUFRO S. 2.2-11 Symposium Riga, Latvia. Latvian For. Res. Inst. 'Silava', Riga. 141–146.

SKRØPPA, T. – TOLLEFSRUD, M. M. – SPERISEN, C. – JOHNSEN, Ø. (2010): Rapid change in adaptive performance from one generation to the next in Picea abies – Central European trees in a Nordic environment. Tree Genetics & Genomes. (6): 93–99.

SPERISEN, C. – BÜCHLER, U. – MÁTYÁS, G. – ACKZELL, L. (1999): Mitochondrial DNA variation a tool for identifying introduced provenances: a case study in Norway spruce. In: GILLET, E. M. (ed): Molecular Tools for Biodiversity. Chapter 10. Wich DNA Marker for Wich Purpose.URL.

SPERISEN, C. – BÜCHLER, U. – GUGERLI, F. – MÁTYÁS, G. – GEBUREK, T. – VENDRAMIN, G. G. (2001): Tandem repeats in plant mitochondrial genomes: application to the analysis of population differentiation in the conifer Norway spruce. Molecular Ecology, (10): 257–263.

SZŐNYI, L. – UJVÁRI, F.(1970): International (IUFRO) Norway spruce provenance trial. Erdészeti Kutatások, 66. 47–59.

SZŐNYI, L. – UJVÁRI, F. (1975): First results of the international (IUFRO) Norway spruce provenance experiment. Erdészeti Kutatások. 71 (2): 139–147.

THORNTHWAITE, C. W. – MATHER , J. R. (1955): The water budget and its use in irrigation. In: Water, The Yearbook of Agriculture. US Department of Agriculture, Washington DC. 346–358.

TOLLEFSRUD, M. M. – KISSLING, R. – GUGERLI, F. – JOHNSEN, Ø. – SKRØPPA, T. – CHEDDADI, R. – VAN DER KNAAP, W. O. – LATAŁOWA, M. – TERHÜRNE-BERSON, R. – LITT, T. – GEBUREK, T. – BROCHMANN, C. – SPERISEN, C. (2008): Genetic consequences of glacial survival and postglacial colonization in Norway spruce: combined analysis of mitochondrial DNA and fossil pollen. Molecular Ecology, 17: 4134–4150.

TURESSON, G. (1925): The plant species in relation to habitat and climate. Hereditas, 6: 147–236

UJVÁRI, F. (1986): A IUFRO lucfenyő származási kísérlet gyakorlatban hasznosítható eredményei. [Practically useful results of IUFRO Provenance Trial Norway spruce] Erdészeti Kutatások, 78. 203–210. (in Hungarian with Engl. summary).

UJVÁRI-JÁRMAY, É. (1983): Gyökeres lucfenyő dugványok alakja és növekedése [Form and growth of rooted Norway spruce cuttings]. Erdészeti Kutatások, 74. 61–70. (in Hungarian with Engl. summary).

UJVÁRI-JÁRMAY, É. (1984): Lucfenyő dugványklónok növekedése terepi klónkisérletekben [Height growth of *Picea abies* cuttings in field trials]. Erdészeti Kutatások 75. 29 - 43. (in Hungarian with Engl. summary).

UJVÁRI-JÁRMAY, É. (2010): A környezetváltozás hatása az erdei fák növekedésére. [The effect of changing environment on height growth of forest trees]. Szemelvények az OTKA támogatásával készült alapkutatások újabb eredményeiből. Országos Tudományos Kutatási Alapprogramok (Programs of Hungarian Scientific Research Fund) Budapest. 35–37. (in Hungarian).

UJVÁRI-JÁRMAY, É. – UJVÁRI, F. (1979): Results of a 10 year old IUFRO international provenance trial Norway spruce /IPTNS 1964/68/ and their introduction in breeding and in practice. In: Proceedings of the Joint Meeting of Working Parties on Norway Spruce Provenances and Norway Spruce Breeding. Bucharest, Rumania 1979. 475–480.

UJVÁRI-JÁRMAY, É. – UJVÁRI, F. (1980a): Results of a 10-year old IUFRO International Provenance Trial of Norway spruce (IPTNS, 1964/68) and their application in breeding and practice. Erdészeti Kutatások 73. (2): 31–37.

UJVÁRI-JÁRMAY, É. – UJVÁRI, F. (1980b): Hazai lucfenyő állományaink genetikai értéke. [Genetic value of domestic Norway spruce stands.] Az Erdő, 29 (12): 539–541. (in Hungarian)

UJVÁRI-JÁRMAY, É. – UJVÁRI, F. (1992/93): Lucfenyő populációk génökológiai elemzése. [Genecological analysis of Norway spruce populations] Erdészeti és Faipari Tudományos Közlemények 38/39. 59–75 (in Hungarian with Engl. summary).

UJVÁRI-JÁRMAY, É. – UJVÁRI, F. (1993): Genecological investigation of Norway spruce provenances. In: Proceedings of the IUFRO S2.2-11 Symposium Riga, Latvia. 147–150.

UJVÁRI-JÁRMAY, É. – UJVÁRI, F. (2006): Adaptation of Progenies of a Norway Spruce Provenance Test (IUFRO 1964/68) to Local Environment. ASLH (2): 47–56.

UJVÁRI-JÁRMAY, É. – JÁRÓ Z. – UJVÁRI, F. (2000/2001): A biomassza mennyisége, megoszlása és változatossága a Nemzetközi Lucfenyő Származási Kísérletben (IUFRO 1964/68) [Biomass and dry matter allocation in the International Norway Spruce Provenance Trial (IUFRO 1964/68)] Erdészeti Kutatások 90. 49–64 (in Hungarian with Engl. summary).

VENDRAMIN, G. G. – ANZIDEI, M. – MADAGHIELE, A. – SPERISEN, C. – BUCCI, G. (2000): Chloroplast microsatellite analysis reveals the presence of population subdivision in Norway spruce (*Picea abies*). Genome 43. 68–78.

WEISGERBER, H. – DIETZE, W. – KLEINSCHMIT, J. – RACZ, J. – DIETERICH, H. – DIMPFLMEIER, R. (1976a): Der Internationale Fichten-Herkunftsversuch von 1962 in der Bundesrepublik Deutschland. Beobachtungen im Anzuchtstadium sowie nach drei- und achtjähriger Freilandpflanzung. Diskussionspapier, XVI IUFRO World-Congress, Oslo/Norwegen, WP S 2.02.11 – Norway spruce provenances. 7 p.

WEISGERBER, H. – DIETZE, W. – KLEINSCHMIT, J. – RACZ, J. – DIETERICH, H. – DIMPFLMEIER, R. (1976b): Ergebnisse des internationalen Fichten-Provenienzversuches 1962. Teil I: Phänologische Beobachtungen und Höhenwachstum bis zur ersten Freilandaufnahme. Allg. Forst- u. Jagdztg. 147 (12): 227–235.

WEISGERBER, H. – DIETZE, W. – KLEINSCHMIT, J. – RACZ, J. – DIETERICH, H. – DIMPFLMEIER, R. (1977): Ergebnisse des internationalen Fichten-Provenienzversuches 1962. Teil II: Weitere Entwicklung bis zum Alter 13. Allg. Forst- u. Jagdztg. 148 (12): 217–226.

WEISGERBER, H. – DIMPFLMEIER, R. – RUETZ, W. – KLEINSCHMIT, J. – WIDMAIER, T. (1984): Ergebnisse des internationalen Fichten-Provenienzversuches 1962. Entwicklung bis zum Alter 18. Allg. Forst- u. Jagdztg. 155 (4/5): 110–121.

Unpublished sources: PhD theses, studies, reports, correspondence

BABOS, K. (1986, 1987): Jelentés a lucfenyő származási kísérlet 2 féle gyérítési anyagának anatómiai vizsgálatáról. [Report on anatomical studies of provenances of thinned Norway spruce provenance trial] Research Institute of Wood Industry, Budapest. (in Hungarian)

KRUTZSCH, P. (1966 – 1975): Correspondence, circular letters

LIESEBACH, M. (1994): Untersuchungen an ausgewahlten Herkunften des internationalen Fichten-provenienzversuchs 1964/68 über den Zusammenhang zwischen Isoenzym-Merkmalen und morphologischen, phänologischen sowie Wachstums-Merkmalen. Dissertation, Universität Hamburg. 210 p.

MÁTYÁS, CS. (1996): Fontosabb hazai fafajok génökológiai elemzése. [Genecological investigation of forest tree species] 990. sz. OTKA témapályázat zárójelentése [Final report of theme 990, Hungarian Scientific Research Fund] (in Hungarian)

NAGY, L. (2010): Climatic adaptability and plastic response to climate change in Scots pine (*Pinus sylvestris* L.) populations. PhD thesis, University of West Hungary, Sopron. (in Hungarian)

SZŐNYI, L. (1966 – 1975): Correspondence, maps in manuscript

UJVÁRI, F. (1966 – 2007): Correspondence, maps, photo documentation and data records in manuscript

UJVÁRI-JÁRMAY, É. (1968 – 2014): Correspondence, maps, photo documentation and data records in manuscript

UJVÁRI-JÁRMAY, É. (1981): A lucfenyő nemesítése [Breeding of Norway spruce (*Picea abies* /L./ Karst).] PhD thesis, Hungarian Academy of Science, Budapest. (in Hungarian)

UJVÁRI-JÁRMAY, É. (2002): Az adaptáció szempontjából fontos tulajdonságok változatosságának értékelése, összefüggések feltárása lucfenyő származások, anyanövények és származáshibridek felhasználásával. Lucfenyő génmegőrzés. [Variation of phenotypical adaptive traits of Norway spruce. Conservation of genetic resources of Norway spruce] T 025 752 sz. OTKA témapályázat zárójelentése. [Final report T 025 752, Hungarian Scientific Research Fund] (in Hungarian)

UJVÁRI-JÁRMAY. É. (2006): Erdei fás növények válaszreakciója környezeti tényezők változására. [Response of forest trees to changing environmental conditions] T 37 194 sz. OTKA témapályázat zárójelentése.[Final report T 37 194. Hungarian Scientific Research Fund] (in Hungarian)

APPENDIX

Selection of data tables on the results of the experiment

Documentation edited by L. Nagy and É. Ujvári-Jármay

Text references to the tables in the Appendix are marked with the initial A before the table number

Contents

Appendix 1

Table A.1 IUFRO IPTNS 1964/68 provenance trial locations

Exp. no.	Locality	Country code	Lat.	Long.	Alt. m	Blocks										
						1	2	3	4	5	6	7	8	9	10	11
01	Bronson	CA	46° 11′	65° 47′ w	70	x	x	x	x	x	x	x	x	x	x	x
02	Castlemorris	IE	52° 28′	7° 17′ w	70	x	x	x	x	x	x	x	x	x	x	x
03	Salisbury	GB	50° 58′	1° 52′ w	170	x	x	x	x	x	x	x	x	x	x	x
04	Ilsvåg	NO	59° 31′	5° 49′ e	150	x	x	x		x		x	x	x	x	
05	Vats	NO	59° 29′	5° 45′ e	150				x		x					x
05	Overud	NO	60° 10′	11° 04′ e	200	x	x					x			x	x
05	Bjerkøy	NO	59° 12′	10° 28′ e	10			x	x	x	x		x	x		
06	Hjuleberg (Abild)	SE	56° 56′	12° 44′ e	60	x	x	x	x	x	x	x	x	x	x	x
07	Lisjö	SE	59° 43′	16° 05′ e	65	x	x	x	x	x	x	x	x	x	x	x
08	Lappkojberget	SE	63° 25′	18° 37′ e	190	x	x	x	x	x	x	x	x	x	x	x
09	Haapastansyrje*	FI	60° 36′	24° 25′ e	130	x	x	x	x	x	x	x	x	x	x	x
10	Amance	FR	48° 47′	6° 18′ e	240	x	x	x	x	x	x	x	x	x	x	x
11	Herbeumont	BE	49° 48′	5° 15′ e	410		x									
11	Fagne del Borne	BE	50° 02′	5° 27′ e	560				x							
11	Rocherath	BE	50° 28′	6° 20′ e	600						x					
12	Gendron-Celle	BE	50° 15′	5° 00′ e	250	x		x		x						
13	Deuselbach	DE	49° 45′	7° 06′ e	640	x	x									
13	Kell-Nord	DE	49° 38′	6° 50′ e	620					x						
13	Brandscheid	DE	50° 30′	6° 40′ e	620		x	x			x				x	
13	Ruppertsweiler	DE	49° 11′	7° 41′ e	305							x				
13	Kindsbach	DE	49° 04′	7° 07′ e	240								x			
13	Nister	DE	50° 40′	7° 51′ e	380									x		
13	Bellerhof	DE	50° 40′	7° 51′ e	440											x
14	Holzerode	DE	51° 40′	10° 07′ e	250	x					x	x	x			
14	Rüdershausen	DE	51° 34′	10° 16′ e	235		x								x	x
14	Schoningen	DE	51° 38′	9° 42′ e	305			x						x		
14	Delliehausen	DE	51° 40′	9° 42′ e	305				x							
14	Hörden	DE	51° 37′	10° 16′ e	235					x						
15	Heltorf	DE	51° 57′	7° 34′ e	400	x										
15	Brüggen	DE	51° 14′	6° 06′ e	40		x									
15	Letmathe	DE	51° 28′	7° 40′ e	250			x								
15	Gedern	DE	50° 25′	9° 08′ e	340				x							
15	Linz	DE	50° 36′	7° 20′ e	340					x	x					
15	Sassmannshausen	DE	51° 00′	8° 30′ e	400							x	x			
15	Herrnstein	DE	50° 49′	7° 30′ e	200									x		
15	Schleiden	DE	50° 28′	6° 21′ e	625										x	
15	Reggsdorf	DE	50° 34′	7° 29′ e	290											x
16	Minard Forest**	GB	56° 10′	5° 15′ w	170								x	x		
16	Drummond Hill**	GB	56° 35′	4° 05′ w	160										x	x
17	Zahradka	CZ	49° 37′	15° 15′ e	390	x	x	x	x	x	x					
17	Dolni Kralovice	CZ	49° 40′	15° 14′ e	390							x	x	x		
17	Borovsko	CZ	49° 41′	15° 14′ e	390										x	x
18	Klein-Mariazell	AT	48° 03′	15° 58′ e	450	x	x									
18	Stollberg	AT	48° 05′	15° 51′ e	500			x	x							
18	Ottenstein	AT	48° 37′	15° 17′ e	550					x	x					
18	Landsee	AT	47° 34′	16° 19′ e	600							x	x			
18	Klaus Pyhrnbahn	AT	47° 51′	14° 07′ e	600									x		
18	Eberstein	AT	46° 50′	14° 37′ e	1150										x	
18	Kelchsau	AT	47° 22′	12° 08′ e	1050											x
19	Krynica	PL	49° 21′	20° 59′ e	750		x				x				x	
19	Krynica	PL	49° 28′	21° 01′ e	750	x		x	x	x		x	x	x		x
20	Gyöngyössolymos (Nyírjes)	HU	47° 56′	19° 58′ e	600	x	x	x	x	x	x	x	x	x	x	x

* non experimental; **six-plant plots design was used
sources: Krutzsch (1992); *Lines* (1973); *Dietrichson* et al. (1976)

Appendix 2

Table A.2.1 Origin of the tested provenances, Block 01.
Serial numbers are blockwise planting codes of provenances.
Cyrillic names follow German transliteration. For seed class codes see A.15.

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
00	Oberhof	DE	50.7	10.7	900	3	11	7	3
01	Stryck, Sonderherkunft	DE	51.3	8.7	550	5	5	1	1
02	Gurker-Sirnitzwald	AT	46.8	14.1	900	4	31	5	2
03	Schussenried	DE	48.0	9.7	600	5	16	3	2
04	Froeschnitz	AT	47.6	15.8	900	4	34	5	2
05	Klingenbrunn	DE	48.9	13.3	1000	5	21	7	3
06	Ostrovsk	RU	57.0	28.5	200	4	74	15	7
07	Brjansk, Zukovsk	RU	53.3	33.7	150	4	78	.	10
08	Soell	AT	47.5	12.2	740	3	28	4	2
09	Njubsk	RU	61.3	47.0	50	4	77	.	10
10	Matrei	AT	47.0	12.5	1650	5	28	4	2
11	Bricalovic	BY	53.3	28.7	160	4	75	15	7
12	Bedretto, Airolo	CH	46.5	8.5	1500	1	15	2	2
13	Lichtenstein	DE	48.4	9.2	800	5	17	3	2
14	Blumberg	DE	47.8	8.5	800	5	14	3	2
15	Oberes Lechtal	AT	47.2	10.1	1400	6	27	4	2
16	Piana Selva, Faido	CH	46.5	8.8	980	1	15	2	2
17	Javorova Dolina	SK	49.3	20.2	1200	1	48	10	4
18	Bad Grund	DE	51.8	10.2	550	2	7	8	3
19	Esserval-Tartre	FR	46.8	6.1	820	3	3	2	2
20	Ramsaasa	SE	55.6	13.9	70	4	86	20	9
21	Taennesberg	DE	49.5	12.3	550	5	19	7	3
22	St. Veit/Pongau	AT	47.3	13.2	870	6	28	4	2
23	Mindelheim	DE	48.1	10.5	500	5	23	6	2
24	Riechenhall-Nord	DE	47.7	12.9	800	5	26	4	2
25	Reit im Winkel	DE	47.7	12.5	1130	4	26	4	2
26	Roan och Aafjord	NO	64.0	10.3	100	6	85	18	8
27	Garmisch	DE	47.5	11.1	1100	4	25	4	2
28	Bogstad, 1434	NO	60.0	10.7	160	1	83	19	9
29	Wasserburg	DE	48.1	12.2	800	5	22	6	2
30	Lessach, 132	AT	47.2	13.9	1600	5	30	5	2
31	Vlasim-Votice	CZ	49.6	14.7	600	4	41	7	3
32	Klodzko	PL	50.5	16.7	350	3	64	9	4
33	Murau	AT	47.1	14.1	740	6	31	5	2
34	Umeaa Oestra, Zon 1	SE	63.9	19.9	150	6	93	17	8
35	Grossarl	AT	47.2	13.2	1350	5	28	4	2
36	Rycerka	PL	49.5	19.1	700	4	63	9	4
37	Tamsweg/Salzburg	AT	47.1	13.8	1100	6	30	5	2
38	Goenenbach	DE	47.9	10.1	800	5	23	6	2
39	Sternberk, Hruba Voda	CZ	49.8	17.3	560	4	43	9	4
40	Leibnitz	AT	46.8	15.4	325	6	33	5	2
41	Kevele	SK	.	.	.	3	51	.	5
42	Oviken Bev.	SE	63.0	14.1	350	4	91	17	8
43	Nekla	PL	52.4	17.4	90	4	65	11	5
44	Rozmital pod Tremsinem	CZ	49.6	13.9	660	4	37	7	3
45	Luhacovice, Loucka	CZ	49.2	17.8	350	4	45	9	4
46	Puszcza Bialowieska	PL	52.6	23.6	130	4	70	14	7
47	Cervena Skala,	SK	48.9	20.2	1000	2	47	10	4
48	Parangalitza	BG	.	.	1500	1	56	13	6
49	Freudenstadt	DE	48.3	8.5	500	5	13	3	2

Table A.2.1 cont.

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
50	Svrcina Hrabusice	SK	49.0	20.2	900	4	47	10	4
51	Kuldiga Revier	LV	57.0	22.3	100	4	72	15	7
52	Luhacovice, Stary Hroz.	CZ	49.2	17.8	500	4	45	9	4
53	Seewiesen, Seeberg	AT	47.6	15.3	1200	3	32	5	2
54	Magyarlak 2 A	HU	47.0	16.4	270	2	52	5	2
55	Graasten	DK	54.9	9.4	60	5	82	20	9
56	Borki	PL	54.1	22.2	170	3	68	14	7
57	Buchberg, Flachwald	AT	47.5	15.2	1300	3	32	5	2
58	Borca, XV Sabasa Sting	RO	47.1	25.8	680	2	59	12	5
59	Froejered	SE	58.3	14.0	130	4	88	19	9
60	Obleze	PL	54.3	17.0	75	4	66	1	1
61	Horsovsky Tyn	CZ	49.5	13.0	700	4	37	7	3
62	Alby Bev.	SE	62.5	15.4	280	4	91	17	8
63	Saldus Revier	LV	56.8	22.3	100	4	72	15	7
64	Zamberk, Letohrad	CZ	50.2	16.5	550	4	64	9	4
65	St. Oswald	DE	48.9	13.4	1200	5	21	7	3
66	Udmurtsk, Glazov	RU	58.2	52.7	200	4	79	.	10
67	Laxaa	SE	59.0	14.6	75	4	90	19	9
68	Ljungsnaes KRP.	SE	57.5	13.4	180	4	87	19	9
69	Dorna Cindreni	RO	47.4	25.4	900	2	59	12	5
70	Lantosque	FR	44.0	7.3	1500	3	1	2	2
71	Cervena Recice-Lukavec	CZ	49.5	15.2	630	4	41	7	3
72	Valea Putnei, 60	RO	47.4	25.4	1290	1	59	12	5
73	Rabenstein	DE	49.1	13.2	1200	5	21	7	3
74	Wisla, 54 A	PL	49.7	18.9	620	3	63	9	4
75	Zwiesel-West	DE	49.1	13.2	1000	5	21	7	3
76	Liptovsky Hradok	SK	49.0	19.9	830	2	47	10	4
77	Sieber	DE	51.7	10.5	700	5	7	8	3
78	Jesenik-Zlate Hory	CZ	50.3	17.3	820	4	43	9	4
79	Walsrode	DE	52.9	9.6	50	5	5	1	1
80	Zwiesel-Ost	DE	49.1	13.3	670	2	21	7	3
81	Prachatice, Ceske Zleby	CZ	48.9	13.8	850	4	21	7	3
82	Jelak-Ceripasina	ME	42.0	20.9	1700	2	55	13	6
83	Zwiesel-Ost	DE	49.1	13.3	1000	5	21	7	3
84	Nepomuk	CZ	49.5	13.6	620	4	37	7	3
85	Donaueschingen	DE	48.0	8.5	750	5	13	3	2
86	Bilovec, Fulnek	CZ	49.8	18.0	410	4	44	9	4
87	Klastor pod Znievom	SK	49.0	18.9	700	3	46	10	4
88	Klingenbrunn	DE	48.9	13.3	1000	5	21	7	3
89	Kuernach	DE	47.7	10.2	800	5	24	4	2
90	Buergerwald	AT	47.4	15.2	1000	4	32	5	2
91	Prostejov, Dzbel	CZ	49.5	17.1	450	4	44	9	4
92	Crailsheim	DE	49.1	10.1	500	4	18	6	2
93	Hagenow	DE	53.3	11.0	100	5	8	1	1
94	Zdarske Vrchy	CZ	49.7	16.6	660	3	42	7	3
95	Memmingen	DE	48.0	10.2	500	5	23	6	2
96	Fladnitz-Schrems	AT	47.3	15.4	700	3	32	5	2
97	Balingen	DE	48.3	8.9	800	5	17	3	2
98	Groebming-Winkl	AT	47.5	13.9	800	3	30	5	2
99	Ramspau	DE	49.0	9.0	500	5	12	1	1

Table A.2.2 Origin of the tested provenances, Block 02

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
00	Tjumen, Uvat	RU	58.2	68.8	100	4	80	.	10
01	Kapfenberg	AT	47.5	15.4	1100	4	32	5	2
02	Ujsoly	PL	49.4	19.1	750	3	63	9	4
03	Steinheim	DE	48.3	9.5	500	5	17	3	2
04	Fall	DE	47.6	11.5	1100	5	25	4	2
05	Deggendorf	DE	48.8	13.0	1000	5	20	7	3
06	Hnojnik, Rovina	CZ	49.7	18.5	670	4	45	9	4
07	Kaluga	RU	54.8	36.3	100	4	78	.	10
08	Faido, Nante	CH	46.5	8.6	1490	1	15	2	2
09	Schluchsee, Eschenmoos	DE	47.8	8.2	1200	3	14	3	2
10	Albrechtice, Tisova	CZ	50.2	17.6	750	4	43	9	4
11	Neureichenau	DE	48.7	13.8	1200	4	21	7	3
12	Tegernsee	DE	47.7	11.8	1100	5	26	4	2
13	Trebon, Zamecky	CZ	49.0	14.8	430	4	36	7	3
14	Ebersberg	DE	48.1	12.0	500	5	22	6	2
15	Bogstad, 1422	NO	60.0	10.7	160	1	83	19	9
16	Altanca	CH	46.5	8.7	1400	1	15	2	2
17	Stryck, Sonderherkunft	DE	51.3	8.7	550	5	5	1	1
18	Helgum	SE	63.2	16.8	140	4	92	17	8
19	Vesijako Pajulahden L.	FI	61.3	25.3	110	4	94	16	8
20	Weingarten	DE	47.8	9.7	850	5	16	3	2
21	Groenbo	SE	59.6	15.5	110	4	90	19	9
22	Leutasch	AT	47.4	11.2	1150	3	27	4	2
23	Le Pertuis	FR	45.1	4.0	1100	6	1	2	2
24	Ramsau-Eisenerz	AT	47.5	14.9	1100	5	32	5	2
25	Tegernsee	DE	47.7	11.8	1100	5	26	4	2
26	Tatranska Lesna	SK	49.2	20.3	950	1	48	10	4
27	Ostravice, Stare Hamry	CZ	49.6	18.3	600	4	45	9	4
28	Schmiedefeld, Freibachtal	DE	50.8	10.8	525	3	11	7	3
29	Ostravice	CZ	49.6	18.3	800	4	45	9	4
30	Varakalani Revier	LV	56.7	26.7	90	4	74	15	7
31	Moldovita, Sacries	RO	47.7	25.6	825	3	59	12	5
32	Hurdal, B 400	NO	60.3	10.8	400	1	84	19	9
33	Umeaa Oestra, Zon 2	SE	64.0	19.1	250	6	93	17	8
34	Tellerhaeuser, 44	DE	50.4	12.9	980	2	10	7	3
35	Bechyne	CZ	49.3	14.5	450	4	40	7	3
36	Buchberg Flachwald	AT	47.5	15.2	1300	3	32	5	2
37	Witow	PL	49.3	19.8	1250	3	48	10	4
38	Smolnicka Huta	SK	48.7	20.8	600	4	50	10	4
39	Cimpeni, Nedei	RO	46.3	23.1	1400	2	58	12	5
40	Podolinec, Levocske P.	SK	49.3	20.5	900	4	49	10	4
41	Manderfeld, Gilbuschheek	BE	50.4	6.3	540	3	4	1	1
42	Pielenhofen	DE	49.1	12.0	500	5	22	6	2
43	Blumberg	DE	47.9	8.5	800	5	14	3	2
44	Sucha 139 A/L	SK	49.2	20.2	1190	1	48	10	4
45	Kroppefjaell	SE	58.7	12.2	50	4	87	19	9
46	Oberammergau	DE	47.6	11.0	1100	5	25	4	2
47	Zytkiejmy	PL	54.3	22.8	200	4	68	14	7
48	Freiland	AT	48.0	15.5	550	4	34	5	2
49	Peiting	DE	47.8	11.0	650	5	23	6	2

Table A.2.2 cont.

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
50	Dagdskin	LV	56.1	27.5	150	4	74	15	7
51	Smolno	PL	54.2	16.0	35	4	66	1	1
52	Szczecinek	PL	53.7	16.8	100	4	66	1	1
53	Serwy	PL	53.8	23.0	120	4	69	14	7
54	Partenkirchen	DE	47.5	11.1	800	6	25	4	2
55	Neustrelitz	DE	53.3	13.3	100	5	8	1	1
56	Le Reposoir	FR	46.0	6.6	1300	3	2	2	2
57	Habartice/Planice	CZ	49.4	13.4	550	3	37	7	3
58	Martei in Osttirol	AT	47.0	12.5	1000	6	28	4	2
59	Wunsiedel	DE	50.0	11.9	710	1	19	7	3
60	Siegenburg	DE	48.8	11.9	500	5	22	6	2
61	Zdirec nad Doubravou	CZ	49.7	15.8	600	4	42	7	3
62	Moldovita I Demacusa	RO	47.6	25.6	850	2	59	12	5
63	Moravsky Krumlov	CZ	49.1	16.3	380	4	44	7	3
64	Eglharting	DE	48.1	11.9	580	5	22	6	2
65	Knysperg nad Ohri	CZ	50.1	12.5	660	4	10	7	3
66	Karnieszewice	PL	53.3	15.8	175	4	66	1	1
67	Karlstad. Zon 0	SE	59.4	13.5	25	4	90	19	9
68	Razlog	BG	42.0	23.5	1450	4	56	13	6
69	Denklingen	DE	50.9	7.7	800	5	5	1	1
70	Cervena Recice	CZ	49.5	15.2	560	4	41	7	3
71	Sarospatak, Haromhuta	HU	48.3	21.4	400	3	53	.	5
72	Gallmannsegg	AT	47.2	15.1	1150	4	32	5	2
73	Trebic IV	CZ	49.3	15.8	550	4	42	7	3
74	Pfalzgrafenweiler	DE	48.5	8.6	500	4	13	3	2
75	Groebming-Winkel	AT	47.5	13.9	800	5	30	5	2
76	Rabenstein, Typengemisch	DE	49.1	13.2	1200	4	21	7	3
77	Bucovice, Nevojice	CZ	49.2	17.0	500	4	44	9	4
78	Cierny Vah, Ipeltica	SK	48.9	20.7	900	2	47	10	4
79	Wehingen	DE	48.1	8.8	800	5	17	3	2
80	Westerhof	DE	51.8	10.2	300	5	6	8	3
81	Smolnicka Huta	SK	48.8	20.8	700	2	50	10	4
82	Pfunds	AT	46.9	10.6	1225	5	27	4	2
83	Gsengegg	AT	47.3	13.6	1050	6	30	5	2
84	Seefeld	AT	47.3	11.2	1100	4	27	4	2
85	Altenhof, Attnang	AT	48.1	13.7	750	4	35	6	2
86	Gheorghieni, I Ditrau	RO	46.7	25.7	1280	2	59	12	5
87	Marquartstein-West	DE	47.8	12.5	1100	4	26	4	2
88	Starnberg	DE	48.0	11.4	800	5	22	6	2
89	Zwiesel-Ost VI/13	DE	49.1	13.3	630	3	21	7	3
90	Altshausen	DE	47.9	9.6	850	5	16	3	2
91	Hencov-Trest	CZ	49.3	15.5	600	4	42	7	3
92	Bystrzyca Klodzka	PL	50.3	16.6	700	4	64	9	4
93	Kolonowskie	PL	50.7	18.4	175	4	65	11	5
94	Anyksiu	LT	55.5	25.2	90	6	71	15	7
95	Bispgaarden, 1	SE	63.0	16.7	150	3	92	17	8
96	Gammertingen	DE	48.2	9.2	800	5	17	3	2
97	Moosburg	DE	48.5	12.0	500	5	22	6	2
98	Muehlheim	DE	48.0	8.9	800	5	17	3	2
99	Sandvik KRP	SE	57.2	13.3	170	4	87	19	9

Table A.2.3 Origin of the tested provenances, Block 03

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
00	Cemerjansk	BY	53.8	30.3	175	4	75	15	7
01	Utzmemmingen	DE	48.5	9.7	500	5	17	3	2
02	Eberbach	DE	49.5	9.0	150	5	12	1	1
03	Hoechenschwand Kurhaus	DE	47.7	8.2	1010	2	14	3	2
04	Bad Doberan	DE	54.1	11.9	50	1	8	1	1
05	Balingen	DE	48.3	8.9	800	4	17	3	2
06	Tatranska Lesna	SK	49.2	20.3	950	1	48	10	4
07	Werder 72	DE	54.6	13.7	90	3	8	1	1
08	Foerarp, Sk 1	SE	56.9	14.1	180	4	88	19	9
09	Jemielno	PL	51.5	16.5	90	4	65	11	5
10	Todtmoos	DE	47.7	8.0	850	5	14	3	2
11	Cham, Kugel-Gebiet	DE	49.2	12.7	480	2	20	7	3
12	Oberhofen	AT	47.3	11.1	1150	5	27	4	2
13	Karwice	PL	53.4	15.8	125	4	66	1	1
14	Glashuette	AT	47.5	16.0	1150	5	34	5	2
15	Starnberg	DE	48.0	11.4	650	5	22	6	2
16	Novgorod	RU	58.0	33.2	100	4	76	15	7
17	Diessen, ob. Spindler	DE	48.0	11.1	625	5	23	6	2
18	Foelz	AT	47.5	15.2	950	3	32	5	2
19	Mlada Boleslav-Zehrov	CZ	50.4	14.9	350	4	38	7	3
20	Knusk, 2	RU	.	.	.	4	81	.	.
21	Tailfingen	DE	48.3	9.0	800	5	17	3	2
22	Oeblarn	AT	47.4	14.0	1050	5	30	5	2
23	Eberbach	DE	49.5	9.0	500	5	12	1	1
24	Altenau 317	DE	51.8	10.6	725	3	7	8	3
25	Karlstift	AT	48.6	14.7	800	5	36	7	3
26	Knyszyn	PL	53.3	22.9	150	4	69	14	7
27	Jodlowno	PL	54.3	18.4	220	3	67	14	7
28	Pribram	CZ	49.8	14.0	520	4	38	7	3
29	Vrchlabi	CZ	50.6	15.6	800	4	39	9	4
30	Pyramis Koutra	GR	41.5	24.3	1630	1	56	13	6
31	Bialowieza	PL	52.7	23.8	130	4	70	14	7
32	Kydne, Babylon	CZ	49.4	13.0	600	4	37	7	3
33	Rantasalmi	FI	62.1	28.2	100	6	95	16	8
34	Cesky Rudolec, Lipnice	CZ	49.1	15.3	570	4	42	7	3
35	Mittenwald	DE	47.5	11.3	1100	4	25	4	2
36	Kaltwasser B. Stadl	AT	47.1	14.0	1200	4	31	5	2
37	Przysucha	PL	51.3	20.6	275	4	61	11	5
38	Skinnskatteberg	SE	59.8	15.6	140	4	90	19	9
39	Isen	DE	48.2	12.1	500	5	22	6	2
40	Cimpeni, XV Valea Mare	RO	46.3	23.0	1260	2	58	12	5
41	Sopron 203 D	HU	47.7	16.4	425	3	52	5	2
42	Klein Soelk/Steiermark	AT	47.4	13.9	1250	6	30	5	2
43	Piwniczna	PL	49.4	20.8	700	4	62	10	4
44	Brandenberg	AT	47.6	11.8	1400	3	28	4	2
45	Nedzinant	ME	42.7	20.1	1150	2	55	13	6
46	Steinheid, Kieferleskopf	DE	50.5	11.1	890	2	11	7	3
47	Hohenegg	AT	48.2	15.5	560	6	34	5	2
48	Nove Mesto na Morave	CZ	49.6	16.1	800	4	42	7	3
49	Zwiesel/West, Sandau	DE	49.1	13.2	650	3	21	7	3

Table A.2.3 cont.

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
50	Eisenkappel	AT	46.5	14.6	800	5	33	5	2
51	Ukmerges, Paschilsk Rev.	LT	55.3	24.7	75	6	71	15	7
52	Hohenschwangau	DE	47.6	10.8	1400	5	25	4	2
53	Snilfjord, Troendelag	NO	62.3	9.7	100	6	85	18	8
54	St. Oswald	DE	48.9	13.4	1000	5	21	7	3
55	Rycerka, Kiczora	PL	49.9	19.2	600	3	63	9	4
56	Svetla nad Sazavou	CZ	49.7	15.4	555	4	41	7	3
57	Kristinehamn	SE	59.5	14.1	130	4	90	19	9
58	Bogstad, 1426	NO	60.0	10.7	160	1	83	19	9
59	Rjasan, Pervmaisk	RU	54.3	41.0	150	4	78	.	10
60	Zwiesel-Ost, Dachshuette	DE	49.1	13.3	655	2	21	7	3
61	Sosnovsk	RU	60.5	29.7	75	4	95	16	8
62	Plan Bois	FR	46.3	6.5	500	3	2	2	2
63	Muesingen	DE	48.4	9.5	800	5	17	3	2
64	Chamrousse	FR	45.1	5.9	1100	3	1	2	2
65	Altoetting	DE	48.2	12.7	500	5	22	6	2
66	Edsleskog	SE	59.1	12.5	165	4	90	19	9
67	Spisska Nova Ves	SK	48.9	20.6	600	4	50	10	4
68	Klosters	CH	46.9	9.9	1500	2	15	2	2
69	Himmelberg-Mooswald	AT	46.8	14.0	1480	4	31	5	2
70	Altanca	CH	46.5	8.7	1140	1	15	2	2
71	Policka, Budislav	CZ	49.7	16.3	660	4	42	7	3
72	Kreuzen, Stockenboi	AT	46.7	13.5	1200	6	29	13	6
73	Rila-Gebirge Nr 1, Abt. 8	BG	.	.	1700	1	56	13	6
74	Cimpeni, Dara	RO	46.4	25.1	1260	3	58	12	5
75	Cierny Vah, Rovienky	SK	48.9	20.7	1100	2	47	10	4
76	Milevsko-Kostelec	CZ	49.4	14.3	450	4	40	7	3
77	Betzigaus	DE	47.7	10.4	800	5	24	4	2
78	Bispgaarden 2	SE	63.0	16.7	100	3	92	17	8
79	Nordmaling	SE	63.5	19.3	150	4	93	17	8
80	Plana u Marianskych Lazni	CZ	49.8	12.8	530	4	37	7	3
81	Sucha 139 A/L	SK	49.2	20.2	1190	1	48	10	4
82	Hinterhof West, Eibelkogel	AT	47.6	15.4	1200	3	32	5	2
83	Dobele Revier	LT	56.2	23.0	40	4	72	15	7
84	Baindt	DE	47.8	9.7	600	5	16	3	2
85	Gaischorn	AT	47.5	14.6	1200	6	31	5	2
86	Kdydne-Loucim	CZ	49.4	12.9	650	4	37	7	3
87	Berchtesgaden	DE	47.6	13.0	1100	4	26	4	2
88	Cimpeni, Valea Mare	RO	46.3	23.0	1375	2	58	12	5
89	Spiegelau	DE	48.9	13.4	1200	5	21	7	3
90	Kelheim-Nord	DE	49.0	11.8	400	5	22	6	2
91	Kezmarok, Vaj. Lesy	SK	49.1	20.5	800	4	48	10	4
92	Seiz	AT	47.4	14.9	765	6	32	5	2
93	Javorova Dolina 155 A	SK	49.3	20.2	1200	1	48	10	4
94	Vrchlabi	CZ	50.8	15.6	700	4	39	9	4
95	Buxabygd KRP	SE	56.8	14.2	170	4	88	19	9
96	Puus, I AVD 64-67	SE	55.8	13.8	180	3	86	20	9
97	Bogstad, 1435	NO	60.0	10.7	160	1	83	19	9
98	Javorova Dolina 155 A	SK	49.3	20.2	1200	1	48	10	4
99	Orawa	PL	49.6	19.6	950	2	62	9	4

Table A.2.4 Origin of the tested provenances, Block 04

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
00	Parchim	DE	53.3	12.0	100	5	8	1	1
01	Teljakov, Uzda	BY	53.5	8.0	200	4	75	15	7
02	Beglika	BG	41.8	24.2	1850	4	56	13	6
03	Pfullendorf	DE	47.9	9.3	600	5	16	3	2
04	Kitzbuehel	AT	47.4	12.4	1200	3	28	4	2
05	Gschwornrieser Bergwald	AT	47.3	12.8	1450	5	28	4	2
06	Rauris	AT	47.2	13.0	1100	4	28	4	2
07	Visoky Chlumec-Veletin	CZ	49.6	14.5	600	4	41	7	3
08	Boubin 1	CZ	49.0	13.9	1000	1	21	7	3
09	Vlasim	CZ	49.7	14.9	420	4	41	7	3
10	Lenzkirch	DE	47.8	8.2	1100	5	14	3	2
11	Moravska Trebova	CZ	49.8	16.7	550	4	42	9	4
12	Brosteni, VII Piriul Omului	RO	47.1	25.7	940	2	59	12	5
13	Hauzenstein	DE	19.2	12.2	550	6	20	7	3
14	Klodzko, 68 E	PL	50.5	16.7	340	3	64	9	4
15	Anzing	DE	48.2	11.9	500	5	22	6	2
16	Velfjord, Velvelstad	NO	65.4	12.5	100	6	85	18	8
17	Stanz-Kindtal-Allerheiligen	AT	47.5	15.5	750	6	32	5	2
18	Tuttlingen	DE	48.0	8.8	800	5	17	3	2
19	Viken och Turinge	SE	62.5	15.2	350	4	91	17	8
20	Ziegenberg	DE	51.3	8.0	700	5	5	1	1
21	Oberammergau	DE	47.6	11.0	1100	5	25	4	2
22	Vsetin, Pozdechov	CZ	49.3	18.0	560	4	45	9	4
23	St. Martin am Silberberg	AT	47.0	14.5	1300	5	31	5	2
24	Loendal F. 355	DK	56.1	9.6	100	3	82	20	9
25	Zwiesel-Ost	DE	49.1	13.5	1000	5	21	7	3
26	Vysoky Chlumec, Veletin	CZ	49.6	14.5	600	4	41	7	3
27	Moravska Trebova	CZ	49.8	16.7	460	4	42	9	4
28	Lessach, 146	AT	47.2	13.8	1360	5	30	5	2
29	Frenstat pod Radhostem	CZ	49.6	18.3	530	4	45	9	4
30	Blaubeuren	DE	48.4	9.8	500	5	23	6	2
31	Narewka	PL	52.8	23.7	130	4	70	14	7
32	Udmurtsk, Balezinsk 23	RU	58.0	53.0	200	4	79	.	10
33	Brunnerberg	AT	47.0	12.5	1600	5	28	4	2
34	Hronec	SK	48.8	19.9	900	4	47	10	4
35	Kysihybel	SK	48.5	19.0	540	1	51	.	5
36	Eisenerz	AT	47.6	14.9	1150	6	32	5	2
37	Hoting Bev.	SE	64.2	16.0	270	4	92	17	8
38	Muehldorf, Fors Puerten	DE	48.2	12.5	440	5	22	6	2
39	Dorna Cindreni, II Rosia	RO	47.4	25.4	975	2	59	12	5
40	Zwiesel-West, Schmalzau	DE	49.1	13.2	630	2	21	7	3
41	Deutschlandsberg	AT	46.8	15.2	700	6	33	5	2
42	Wegierska Gorka	PL	49.6	19.2	700	4	63	9	4
43	Prochowice	PL	51.3	16.3	125	4	65	11	5
44	Wloclawek	PL	52.7	19.0	70	4	67	14	7
45	Damnica	PL	54.5	17.3	65	4	66	1	1
46	Liptovsky Hradok	SK	49.1	19.9	875	2	47	10	4
47	Borki Knieja	PL	54.1	22.1	160	2	68	14	7
48	Kirchzarten	DE	47.9	8.0	750	2	14	3	2
49	Zwiesel-Ost, Typengemisch	DE	49.1	13.3	1200	4	21	7	3

Table A.2.4 cont.

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
50	Mindelheim	DE	48.1	10.5	500	5	23	6	2
51	Seewiesen, Seereith	AT	47.6	15.3	875	3	32	5	2
52	Saldus Revier	LV	56.7	22.3	70	4	72	15	7
53	Bayreuth-West	DE	49.9	11.5	380	5	19	7	3
54	Chlum u Trebone	CZ	48.9	14.9	460	4	36	7	3
55	Koeszeg 60 A	HU	46.4	16.6	420	2	52	5	2
56	Ceska Trebova	CZ	49.9	16.4	490	4	42	9	4
57	Schneegattern	AT	48.0	13.3	625	5	35	6	2
58	Amorbach-West	DE	49.6	9.2	280	2	12	1	1
59	Piana Selva, Faido	CH	46.5	8.8	980	1	15	2	2
60	Klingenbrunn	DE	48.9	13.3	1200	4	21	7	3
61	Mauth-Ost	DE	48.8	13.6	1000	5	21	7	3
62	Polanow	PL	54.2	16.7	125	4	66	1	1
63	Baden-Baden	DE	48.7	8.4	500	6	13	3	2
64	Virserum	SE	57.3	15.7	250	4	89	19	9
65	Chlum u Trebone	CZ	48.9	14.9	520	4	36	7	3
66	Konopiste, Dubsko	CZ	49.8	14.6	520	4	41	7	3
67	Plan Bois	FR	46.3	6.4	500	3	2	2	2
68	Oberes Lechtal	AT	47.2	10.1	1400	6	27	4	2
69	Reinberg/Vorau	AT	47.4	15.9	650	6	34	5	2
70	Bezcetsk	RU	57.8	36.5	200	4	77	.	10
71	Mechterstaedt	DE	50.9	10.6	200	3	11	7	3
72	Isny	DE	47.7	10.1	850	4	24	4	2
73	Foret de Risoud	CH	46.6	6.2	1100	2	3	2	2
74	Westerhof	DE	51.8	10.2	300	5	6	8	3
75	Babenhausen	DE	48.2	10.3	500	5	23	6	2
76	Aakakoep	SE	57.4	14.4	250	4	87	19	9
77	Vsetin, Hovezi	CZ	49.3	18.0	650	4	45	9	4
78	Eisenkappel 1.	AT	46.5	14.6	800	6	33	5	2
79	Bonetage	FR	47.2	6.7	875	3	3	2	2
80	Saaremaa Revier	EE	58.5	22.3	20	4	72	15	7
81	Reit im Winkel	DE	47.7	12.5	1100	5	26	4	2
82	Oerebro	SE	59.3	15.2	75	4	90	19	9
83	Schoenmuenzach	DE	48.6	8.4	700	5	13	3	2
84	Gradisch	AT	46.7	14.1	700	5	31	5	2
85	Njubsk	RU	61.3	47.0	50	4	77	.	10
86	Cervena Skala	SK	48.9	20.2	1000	2	47	10	4
87	Cucureasa, 65	RO	47.3	25.0	1260	1	59	12	5
88	Bad Grund 126	DE	51.8	10.3	450	2	7	8	3
89	Kuernach	DE	47.7	10.2	1000	5	24	4	2
90	Westerhof 48 A	DE	51.8	10.2	250	3	6	8	3
91	Klastor pod Znievom	SK	49.0	18.9	700	3	46	10	4
92	Janovice u Rymarova	CZ	49.9	17.2	790	4	43	9	4
93	Dietenheim	DE	48.2	10.1	600	5	23	6	2
94	Ruhpolding-West	DE	47.8	12.7	1100	4	26	4	2
95	Hohenaschau	DE	47.8	12.3	800	4	26	4	2
96	Murnau	DE	47.7	11.2	1350	4	25	4	2
97	Rabenstein	DE	49.1	13.2	1200	4	21	7	3
98	Boubin 4	CZ	49.0	13.9	1000	1	21	7	3
99	Stralsund	DE	53.3	13.2	100	5	8	1	1

Table A.2.5 Origin of the tested provenances, Block 05

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
00	Olecko	PL	54.2	22.0	175	4	68	14	7
01	Broczyno	PL	53.5	16.4	125	4	66	1	1
02	Sauerlach	DE	48.0	11.7	640	5	22	6	2
03	Ebersberg	DE	48.1	12.0	555	5	22	6	2
04	Ottobeuren	DE	48.0	10.3	800	5	23	6	2
05	Kaisheim	DE	48.8	10.0	500	5	18	6	2
06	Vlasim	CZ	49.7	14.9	680	4	41	7	3
07	Bruntal, Mezina	CZ	50.0	17.5	610	4	43	9	4
08	Vrchlabi	CZ	50.8	15.6	500	4	39	9	4
09	Lichtenstein	DE	48.4	9.2	800	5	17	3	2
10	Szentgotthard 1 C	HU	46.9	16.1	310	3	52	5	2
11	Zwiesel-Ost, Haselau	DE	49.1	13.3	625	3	21	7	3
12	Fuerstenberg/KRS B.	DE	51.5	8.7	200	5	5	1	1
13	Piberegg	AT	47.1	15.1	800	6	32	5	2
14	Donnersbach	AT	47.5	14.1	700	5	30	5	2
15	Neustadt	DE	47.9	8.2	850	4	14	3	2
16	Chlum u Trebone-Hamr	CZ	48.9	14.9	450	4	36	7	3
17	Poniki	PL	54.0	16.4	75	4	66	1	1
18	Cervena Recice, Rousinov	CZ	49.5	15.2	580	4	41	7	3
19	Oberkochen	DE	48.8	10.1	500	5	18	6	2
20	Cervena Skala	SK	48.8	20.1	800	4	47	10	4
21	Kappl-See	AT	47.0	10.4	1400	5	27	4	2
22	Schoenmuenzach	DE	48.6	8.4	500	5	13	3	2
23	Schladming, F. V. Coburg	AT	47.4	13.9	1250	6	30	5	2
24	Poprad	SK	49.1	20.3	900	4	49	10	4
25	Val Visdende	IT	46.6	12.7	1350	5	29	13	6
26	Frenstat p. Radhostem-Ob.	CZ	49.6	18.2	600	4	45	9	4
27	Javorova Dolina 155 A	SK	49.3	20.2	1200	1	48	10	4
28	Manderfeld, Gilbuschneek	BE	50.4	6.3	540	3	4	1	1
29	Wielgowo	PL	53.4	14.9	20	4	66	1	1
30	Frasin, X Ursoaia	RO	47.5	25.7	700	2	59	12	5
31	Passy	FR	46.0	6.8	1200	3	2	2	2
32	Comanesti, IV Bortea	RO	46.3	26.6	780	2	59	12	5
33	Liptovsky Mikulas	SK	49.6	19.4	920	4	63	9	4
34	Scheifling	AT	47.2	14.4	1450	6	31	5	2
35	Berwang	AT	47.4	10.7	1370	3	27	4	2
36	Neureichenau	DE	48.7	13.8	1000	5	21	7	3
37	Kaufbeuren	DE	47.9	10.6	800	5	23	6	2
38	Freiland	AT	48.0	15.6	1000	4	34	5	2
39	Pressath	DE	49.8	12.0	575	5	19	7	3
40	St. Veit/Pongau	AT	47.3	13.2	1000	5	28	4	2
41	Oberhof, Mittelberg	DE	50.7	10.7	700	3	11	7	3
42	Gundelsheim	DE	49.3	9.2	150	5	17	1	1
43	Wehingen	DE	48.1	8.8	800	5	17	3	2
44	Luzna	CZ	50.1	13.8	400	4	38	7	3
45	Ostravice	CZ	49.5	18.4	700	4	45	9	4
46	Maenttae, Kasvuala	FI	62.0	24.6	120	3	94	16	8
47	Cervena Skala, Martaluska	SK	48.9	20.2	1500	2	47	10	4
48	Massif Central, Mt. Megal	FR	45.1	4.0	900	4	1	2	2
49	Eglharting	DE	48.1	11.9	500	5	22	6	2

Table A.2.5 cont.

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
50	Westerhof, Elit	DE	51.8	10.2	200	3	6	8	3
51	Betzigau	DE	47.8	10.3	800	5	24	4	2
52	Ujsoly	PL	49.5	19.1	500	4	63	9	4
53	Stronie Slaskie	PL	50.2	16.8	820	3	64	9	4
54	Sibiu, Paltinis	RO	45.7	23.9	1500	3	57	12	6
55	Saldus Revier	LV	56.7	22.7	115	4	72	15	7
56	Viljandi Revier	EE	58.1	25.3	90	4	73	15	7
57	Partenkirchen	DE	47.5	11.1	800	5	25	4	2
58	Einsiedel	DE	48.5	12.0	500	5	22	6	2
59	Floning Kapfenberg	AT	47.5	15.2	825	6	32	5	2
60	Bogstad, 1421	NO	60.0	10.7	160	1	83	19	9
61	Crespato, Airolo	CH	46.5	8.6	1120	1	15	2	2
62	Carlsfeld, 275	DE	50.4	12.6	925	2	10	7	3
63	Cavagnago	CH	46.4	8.9	1180	1	15	2	2
64	Witow	PL	49.3	19.8	1100	3	48	10	4
65	Rezekne Revier	LV	56.5	27.3	100	4	74	15	7
66	Fuerstenfeld	AT	47.1	16.1	350	6	33	5	2
67	Ryssby	SE	56.9	14.1	175	4	88	19	9
68	Lilienfeld	AT	47.9	15.4	900	6	34	5	2
69	Marquarstein-West	DE	47.8	12.5	800	4	26	4	2
70	Bialobrzegi	PL	53.8	23.0	110	4	69	14	7
71	Sternwald/Leonfelden	AT	48.6	14.3	790	4	36	7	3
72	Salem	DE	47.8	9.3	600	5	16	3	2
73	Belogradtschik	BG	43.6	22.5	1400	4	56	13	6
74	Trieben	AT	47.5	14.5	850	5	31	5	2
75	Tepla	CZ	50.0	12.9	660	4	37	7	3
76	Sinaia-Gurguiata	RO	45.2	25.6	1115	2	57	12	6
77	Dagdskin	LV	56.1	27.5	150	4	74	15	7
78	Kuernach	DE	47.7	10.2	1000	5	24	4	2
79	Westerhof	DE	51.8	10.2	300	5	6	8	3
80	Litovel, Lostice	CZ	49.7	17.1	360	4	44	9	4
81	Cizova u Pisku	CZ	49.4	14.1	400	4	40	7	3
82	Glashuette	AT	47.5	16.0	1100	5	34	5	2
83	Kup, Murow	PL	50.8	17.9	170	3	65	11	5
84	Gessertshausen	DE	48.3	10.5	500	5	23	6	2
85	Sverdlovskoje Oblast	RU	58.0	65.3	100	4	80	.	10
86	Riksstens KRP	SE	59.2	17.9	50	4	89	19	9
87	Bottnaryd	SE	57.8	13.8	240	4	88	19	9
88	Boskovice, Kunstat	CZ	49.5	16.7	600	4	42	7	3
89	Hurdal, B 300	NO	60.3	10.8	300	1	84	19	9
90	Ukmerges	LT	55.3	24.7	75	6	71	15	7
91	Illertissen	DE	48.2	10.1	500	6	23	6	2
92	Bodum	SE	63.9	16.3	350	4	92	17	8
93	Tatranska Lesna	SK	49.2	20.3	950	1	48	10	4
94	Olomouc, Hranice	CZ	49.6	17.7	430	4	44	9	4
95	Groenbo	SE	59.6	15.5	90	4	90	19	9
96	Jasina	UA	48.3	24.3	1100	4	60	12	5
97	Kraslice-Nancy	CZ	50.3	12.5	920	2	10	7	3
98	Rajnochovice	CZ	49.4	17.8	560	4	45	9	4
99	Koenigseggwald	DE	47.9	9.4	550	5	16	3	2

Table A.2.6 Origin of the tested provenances, Block 06

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
00	Trebic	CZ	43.9	15.8	550	4	42	7	3
01	Kaludjerske Bare	RS	43.9	19.5	1000	2	55	13	6
02	Bogstad 1432	NO	60.0	10.7	160	1	83	19	9
03	Teisendorf, Lebenau	DE	47.9	12.8	420	5	26	4	2
04	Lenzkirch, Feldsee	DE	47.9	8.0	1200	2	14	3	2
05	St. Oswald	DE	48.9	13.4	1000	5	21	7	3
06	Wolozin	BY	54.1	26.5	225	4	75	15	7
07	Zjeimeny	LT	55.4	26.3	200	6	71	15	7
08	Disentis	CH	46.7	8.8	1600	2	15	2	2
09	Satakunta	FI	61.5	22.5	75	6	94	16	8
10	Zelezna Ruda	CZ	49.1	13.3	1015	4	21	7	3
11	Melnik, Semanovice	CZ	50.4	14.5	300	4	38	7	3
12	Brasov, Piatra Mare	RO	45.7	25.6	1050	2	57	12	6
13	Remeti, Zerna	RO	46.8	22.7	900	3	58	12	5
14	Rycerka	PL	49.4	19.1	700	4	63	9	4
15	Murau	AT	47.2	14.2	1000	5	31	5	2
16	Rjasan, Moshary	RU	53.8	41.0	150	4	78	.	10
17	Sandvik KRP	SE	57.2	13.3	170	4	87	19	9
18	Rajnochovice	CZ	49.4	17.8	580	4	45	9	4
19	Leoben-Leising	AT	47.3	14.9	650	6	32	5	2
20	Prasily	CZ	49.1	13.2	900	4	21	7	3
21	Cesky Krumlov	CZ	48.9	14.3	860	4	40	7	3
22	Justingen	DE	48.3	9.5	800	5	17	3	2
23	Nyboda	SE	65.3	21.5	170	4	93	17	8
24	Kalwang	AT	47.4	14.8	1025	6	32	5	2
25	Jaidhof	AT	48.6	15.5	550	3	36	7	3
26	Fladnitz-Passail	AT	47.3	15.5	825	6	32	5	2
27	Fussingoe, Udskovene	DK	56.5	9.9	45	5	82	20	9
28	Cervena Skala	SK	48.9	20.2	1325	2	47	10	4
29	Ottobeuren	DE	47.9	10.3	800	5	23	6	2
30	Sichow	PL	50.5	21.3	175	4	61	11	5
31	Kreisbach	AT	48.1	15.6	350	6	34	5	2
32	Sierpc	PL	52.9	19.6	110	4	67	14	7
33	Kercaszomor 20 A	HU	46.8	16.3	220	2	52	5	2
34	Krynica	PL	49.4	21.0	700	4	62	10	4
35	Toplita	RO	46.9	25.4	1135	2	59	12	5
36	Partenkirchen	DE	47.5	11.1	1100	4	25	4	2
37	Niederndorferberg	AT	47.7	12.2	900	3	28	4	2
38	Weidenberg	DE	50.0	11.8	745	2	19	7	3
39	Aelvdalen	SE	61.3	14.1	530	4	91	17	8
40	Jundola	BG	.	.	1600	1	56	13	6
41	Wunsiedel	DE	50.0	11.9	735	2	19	7	3
42	Flachslanden	DE	49.4	10.5	425	5	18	6	2
43	Knusk, 19	RU	.	.	.	4	81	.	.
44	Karlsdal	SE	59.5	14.7	75	4	90	19	9
45	Dieburg	DE	49.9	8.9	200	5	12	1	1
46	Tatranska Lesna	SK	49.2	20.3	950	1	48	10	4
47	Altanca	CH	46.5	8.7	1140	1	15	2	2
48	Westerhof 50, 58	DE	51.8	10.2	300	5	6	8	3
49	Rauris	AT	47.2	13.1	1550	5	28	4	2

Table A.2.6 cont.

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
50	Sobowidze	PL	54.2	18.5	120	3	67	14	7
51	Selbu, Klaebu	NO	63.3	10.5	300	6	85	18	8
52	Illertissen	DE	48.3	10.1	500	5	23	6	2
53	Naes	SE	63.0	14.6	340	4	91	17	8
54	Kumialka	PL	53.4	23.3	160	4	69	14	7
55	Javorova Dolina	SK	49.3	20.2	1200	1	48	10	4
56	Zwierzyniec	PL	52.7	23.8	150	3	70	14	7
57	Spiegelau	DE	48.9	13.4	740	3	21	7	3
58	Muenchen-Sued	DE	48.1	11.6	500	5	22	6	2
59	Ventspils Revier	LV	57.5	21.8	40	4	72	15	7
60	Diessen	DE	47.7	10.3	800	5	24	4	2
61	Jablunkov, Girova	CZ	49.6	18.8	490	4	63	9	4
62	Hnusta	SK	48.5	19.9	550	4	50	.	5
63	Krivoklat	CZ	50.0	13.9	470	4	38	7	3
64	Plana nad Luznici	CZ	49.3	14.7	650	4	41	7	3
65	Aich	AT	47.4	13.8	700	5	30	5	2
66	Foelz, Greith	AT	47.5	15.2	825	3	32	5	2
67	Cierny Vah, Rovienky	SK	48.9	20.7	950	2	47	10	4
68	Ed, Dalsland	SE	59.9	11.9	20	4	90	19	9
69	Passail-Teichalpe	AT	47.3	15.5	825	6	32	5	2
70	Pyramis Koutra	GR	41.5	24.3	1620	1	56	13	6
71	Rottweil	DE	48.2	8.6	500	4	13	3	2
72	Sternberk, Mutkov	CZ	49.8	17.3	560	4	43	9	4
73	Diessen	DE	47.7	10.3	800	5	24	4	2
74	Groenenbach	DE	47.9	10.2	800	5	23	6	2
75	Zwiesel-Ost	DE	49.1	13.3	610	2	21	7	3
76	Kohlstetten	DE	48.3	8.5	800	5	13	3	2
77	Bischofswiesen	DE	47.7	13.0	1100	5	26	4	2
78	Pirin	BG	41.5	23.5	1400	6	56	13	6
79	Memmingen	DE	48.0	10.2	500	5	23	6	2
80	Suedharz	DE	51.7	10.5	400	5	7	8	3
81	Bischofswiesen	DE	47.7	13.0	800	4	26	4	2
82	Spiegelau	DE	48.9	13.4	1200	5	21	7	3
83	Horni-Marsov	CZ	50.6	15.9	650	4	39	9	4
84	Riedlingen	DE	48.2	9.5	600	5	16	3	2
85	St. Laurent-du-Jura	FR	46.6	6.0	980	3	3	2	2
86	Raitis	AT	47.2	11.4	1100	5	27	4	2
87	Hinterhof-West	AT	47.6	15.4	1000	4	32	5	2
88	Untertal, St. Kathrein	AT	47.5	15.2	800	4	32	5	2
89	Passy	FR	45.9	6.7	1200	3	2	2	2
90	Bausskij	LV	56.4	24.3	75	4	73	15	7
91	Gorowo Ilaw.	PL	54.3	20.5	150	2	67	14	7
92	Hnojnik, Kosariska	CZ	49.7	18.5	800	4	45	9	4
93	Ottobeuren	DE	47.9	10.3	800	5	23	6	2
94	Pappenheim	DE	48.9	11.0	500	5	18	6	2
95	Elgersburg	DE	50.7	10.8	800	5	11	7	3
96	Poitschach	AT	46.8	14.1	750	5	31	5	2
97	Bad Doberan	DE	54.1	11.9	50	1	8	1	1
98	Bolkow	PL	50.8	16.1	450	4	65	9	4
99	Chatel	FR	46.3	6.9	1250	3	2	2	2

Table A.2.7 Origin of the tested provenances, Block 07

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
00	Cosna, Cucureasa	RO	47.3	25.2	1025	2	59	12	5
01	Koenigsbronn	DE	48.7	10.1	500	5	18	6	2
02	Nove Hrady-Dolni Hvozd	CZ	48.8	14.8	500	4	36	7	3
03	Ringamaala KRP	SE	56.3	14.8	175	4	88	19	9
04	Eckersholm	SE	57.6	14.2	240	4	88	19	9
05	Floda	SE	59.1	16.4	65	4	89	19	9
06	Stary Krakow	PL	54.4	16.6	35	4	66	1	1
07	Babki	PL	52.3	17.1	65	3	65	11	5
08	Tavejanne, Bex	CH	46.3	7.1	1600	1	2	2	2
09	Broczyno	PL	54.2	17.0	140	4	66	1	1
10	Zlota Wies	PL	53.3	23.3	175	4	69	14	7
11	Zwingenberg	DE	49.7	8.6	500	5	12	1	1
12	Luhacovice, Strani	CZ	49.2	17.8	600	4	45	9	4
13	Liptovsky Hradok	SK	48.9	19.9	1125	2	47	10	4
14	Moravska Trebova	CZ	49.8	16.7	570	4	42	9	4
15	Tussenhausen	DE	48.1	10.6	500	5	23	6	2
16	Reutte	AT	47.5	10.7	1000	6	27	4	2
17	Crespato, Airolo	CH	46.5	8.6	1120	1	15	2	2
18	Javorova Dolina	SK	49.3	20.2	1200	1	48	10	4
19	Cavagnago	CH	46.4	8.9	1180	1	15	2	2
20	Nove Hrady-Horni Hvozd	CZ	48.7	14.7	850	4	36	7	3
21	Burghausen	DE	48.2	12.8	500	5	22	6	2
22	Mengen	DE	48.0	9.3	600	5	16	3	2
23	Baden-Baden	DE	48.8	8.3	500	5	13	3	2
24	Pfronstetten	DE	48.3	9.5	800	5	17	3	2
25	St. Salvator	AT	47.0	14.4	900	4	31	5	2
26	Boubin 2	CZ	49.0	13.9	1000	1	21	7	3
27	Thiersee	AT	47.6	12.1	800	5	28	4	2
28	Lindenborg	DK	56.8	10.0	60	3	82	20	9
29	Nove Hrady, Horni Hvozd	CZ	48.7	14.7	790	4	36	7	3
30	Klastor pod Znievom	SV	49.0	18.9	700	3	46	10	4
31	Frantiskovy Lazne	CZ	50.1	12.3	550	4	10	7	3
32	Vitkov-Budisov	CZ	49.8	17.5	610	4	43	9	4
33	Oestlandsgarn	NO	60.5	11.0	275	6	84	19	9
34	Bogstad, 1440	NO	60.0	10.7	160	1	83	19	9
35	Knittelfeld	AT	47.2	14.8	1300	6	32	5	2
36	Velke Karlowice, Vranca	CZ	49.3	18.3	800	4	45	9	4
37	Lessach	AT	47.2	13.8	1250	5	30	5	2
38	Zeltschach	AT	47.0	14.5	950	5	31	5	2
39	Altoetting	DE	48.6	8.4	850	6	13	3	2
40	Rungstock	DE	50.7	13.3	560	2	10	7	3
41	Betzigau, Boerwang	DE	47.7	10.4	1000	5	24	4	2
42	Mauth-Ost	DE	48.9	13.6	1000	5	21	7	3
43	Witebsk	BY	55.1	30.2	150	4	76	15	7
44	Terepetsk	RU	56.5	32.0	200	4	76	15	7
45	Ruzomberok	SK	49.1	19.3	850	4	46	10	4
46	Wismar	DE	53.8	11.3	100	5	8	1	1
47	Kuernach	DE	47.7	10.2	1000	5	24	4	2
48	Policka, Pusta Kamenice	CZ	49.7	16.3	720	4	42	7	3
49	Cucureasa	RO	47.3	25.0	1410	1	59	12	5

Table A.2.7 cont.

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
50	Eisenkappel	AT	46.5	14.6	1000	6	33	5	2
51	Vrchlabi	CZ	50.6	15.6	750	4	39	9	4
52	Cervena Skala	SK	48.9	20.2	1000	2	47	10	4
53	Tegernsee	DE	47.7	11.8	1100	5	26	4	2
54	Hrabusice	SK	49.0	20.2	900	4	47	10	4
55	Marginea	RO	47.8	25.8	670	2	59	12	5
56	Verior Revier	EE	58.1	27.4	30	4	74	15	7
57	Horni Marsov, Velka Upa	CZ	50.6	15.9	940	4	39	9	4
58	Vorau	AT	47.4	15.9	1200	6	34	5	2
59	Veitsch-Neuberg	AT	47.7	15.6	1000	6	32	5	2
60	Siessen	DE	48.0	9.2	600	5	17	3	2
61	Liembergwald/Zell am See	AT	47.3	12.8	875	5	28	4	2
62	Mitterberg I. Ennstal	AT	47.5	13.9	800	5	30	5	2
63	Kloten, Zon 1	SE	59.9	15.3	150	4	90	19	9
64	Przerwanki	PL	54.2	22.0	150	2	68	14	7
65	Stuebing/Gamskogel	AT	47.3	15.6	640	6	32	5	2
66	Dobris, Obora	CZ	49.8	14.2	420	4	38	7	3
67	Blankenburg	DE	51.8	10.8	550	5	7	8	3
68	Vallen Bev.	SE	62.3	14.1	450	4	91	17	8
69	Hohenaschau	DE	47.8	12.3	1100	4	26	4	2
70	Val di Fiemme	IT	46.3	11.5	1100	5	29	13	6
71	Ipsheim	DE	49.5	10.5	400	5	18	6	2
72	Udmurtsk, Balezinsk	RU	58.0	53.0	200	4	79	.	10
73	Jasina	UA	48.3	24.3	700	4	60	12	5
74	Fjaellsjoe Bev.	SE	63.9	16.3	220	4	92	17	8
75	Clausthal-Zellerfeld	DE	51.6	10.4	560	2	7	8	3
76	Rabenstein	DE	49.1	13.2	600	2	21	7	3
77	Zwiesel-Ost, Plattenfichte	DE	49.1	13.3	1200	4	21	7	3
78	Borovec	BG	42.3	23.6	1300	4	56	13	6
79	Urjala Honkolan	FI	61.1	23.5	100	3	94	16	8
80	Landsberg	DE	48.1	10.9	800	5	23	6	2
81	Klodzko	PL	50.5	16.7	400	3	64	9	4
82	Muenchen-Sued	DE	48.1	11.6	500	5	22	6	2
83	Joenstorp, Galthult	SE	55.8	13.9	170	3	86	20	9
84	Kramersdorf	AT	47.3	15.5	700	3	32	5	2
85	Zakopane	PL	49.2	20.1	1100	4	48	10	4
86	Wegierska Gorka	PL	49.6	19.1	700	4	63	9	4
87	Tegernsee	DE	47.7	11.8	1150	4	26	4	2
88	Neustadt	DE	47.9	8.2	850	5	14	3	2
89	Herrenwies	DE	48.6	8.3	850	5	13	3	2
90	Mali Lom	HR	44.8	15.0	1150	2	54	13	6
91	Dobris, Chouzava	CZ	49.8	14.2	450	4	38	7	3
92	Judenburg	AT	47.2	14.7	850	6	32	5	2
93	Passau-Sued	DE	48.6	13.4	500	5	20	7	3
94	Baindt	DE	47.8	9.6	600	4	16	3	2
95	Schluchsee	DE	47.8	8.2	1050	5	14	3	2
96	Buekkszentkereszt	HU	48.1	20.6	615	2	53	.	5
97	Gerardmer	FR	48.2	6.9	750	3	4	1	1
98	Gurktal	AT	46.9	14.3	1300	6	31	5	2
99	Liezen	AT	47.6	14.3	750	6	30	5	2

Table A.2.8 Origin of the tested provenances, Block 08

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
00	Kirchzarten	DE	47.9	8.0	1100	2	14	3	2
01	Hinterhof Ost, Brenner	AT	47.6	15.5	1000	4	32	5	2
02	Burladingen	DE	48.3	9.1	800	5	17	3	2
03	Mochenwangen	DE	47.9	9.6	600	5	16	3	2
04	Traunstein	DE	47.9	12.7	800	5	26	4	2
05	Mitterdorf	AT	47.2	15.6	900	6	32	5	2
06	Peitz/Tannenwald	DE	51.9	14.3	60	3	9	1	1
07	Prionegsk	RU	62.0	34.0	75	4	77	.	10
08	Cazis	CH	46.7	9.4	750	2	15	2	2
09	Klingenbrunn	DE	48.9	13.3	1000	5	21	7	3
10	Ramsau	AT	47.6	12.9	1100	4	26	4	2
11	Stammham	DE	48.9	11.5	500	5	22	6	2
12	Grossarl	AT	47.2	13.2	1150	5	28	4	2
13	Cervene Porici Kaliste	CZ	49.5	13.3	480	4	37	7	3
14	Bruntal, Siroka Niva	CZ	50.0	17.5	450	4	43	9	4
15	Emmach/Murau	AT	47.1	14.2	1200	5	31	5	2
16	Nove Hrady, Dolni Hvozd	CZ	48.8	14.8	550	4	36	7	3
17	Passau-Nord	DE	48.7	13.6	1000	5	21	7	3
18	Weissenstadt	DE	50.1	11.9	750	5	19	7	3
19	Wolfach	DE	48.3	8.2	500	5	13	3	2
20	Villingsberg	SE	59.3	14.7	50	4	90	19	9
21	Javorova Dolina	SK	49.3	20.2	1200	1	48	10	4
22	Bebenhausen	DE	48.6	9.0	500	4	17	3	2
23	Bialowieza	PL	52.7	23.9	150	3	70	14	7
24	Muehldorf	DE	48.3	12.6	500	5	22	6	2
25	Ruciane	PL	53.7	21.6	150	3	68	14	7
26	Znojmo	CZ	48.8	16.1	450	4	44	7	3
27	Hrabusice	SK	49.0	20.2	900	4	47	10	4
28	Sucha	SK	49.2	20.2	1190	1	48	10	4
29	Zwiesel-Ost	DE	49.1	13.3	1200	5	21	7	3
30	Emmach/Murau	AT	47.1	14.2	1150	5	31	5	2
31	Tyldal, Aalen	NO	62.8	11.3	400	6	85	18	8
32	Bogstad, 1433	NO	60.0	10.7	160	1	83	19	9
33	Wasserburg	DE	48.1	12.3	800	5	22	6	2
34	Molvotitsk	RU	57.5	32.5	200	4	76	15	7
35	Graasten	DK	54.8	9.3	60	3	82	20	9
36	Nasswald	AT	47.7	15.6	1000	6	32	5	2
37	Wronki	PL	52.8	16.3	60	4	65	11	5
38	Hillet	SE	58.2	12.9	90	4	87	19	9
39	Turinge Bev.	SE	62.5	15.1	480	4	91	17	8
40	Soboljansk Revier	BY	53.7	24.8	150	4	71	15	7
41	Ignalino	LT	55.3	26.2	185	6	71	15	7
42	Weidenberg	DE	50.0	11.8	590	3	19	7	3
43	Wundelsiedel-Weissenstadt	DE	50.1	11.8	720	5	19	7	3
44	Klastor pod Znievom	SK	49.0	18.9	700	3	46	10	4
45	Kuernach	DE	47.7	10.2	800	5	24	4	2
46	Garmisch	DE	47.5	11.1	750	5	25	4	2
47	Galu	RO	47.0	25.9	650	2	59	12	5
48	Rycerka	PL	49.4	19.1	560	4	63	9	4
49	Diktschanska	BG	.	.	1550	1	56	13	6

Table A.2.8 cont.

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
50	Sonkajaervi	FI	63.7	27.4	200	6	95	16	8
51	Zwierzyniec Lubelski	PL	50.6	22.8	315	4	61	11	5
52	Luban Slaski	PL	51.1	15.3	275	4	65	11	5
53	Moosburg	DE	48.5	11.9	500	5	22	6	2
54	Jilove u Prahy	CZ	49.9	14.5	480	4	41	7	3
55	Cervena Skala	SK	48.9	20.2	1400	2	47	10	4
56	Roslavl	RU	54.0	33.0	270	4	78	.	10
57	Lukov u Holesova	CZ	49.3	17.7	550	4	45	9	4
58	Bischofswiessen	DE	47.7	13.0	1100	4	26	4	2
59	Nove Mesto na Morave	CZ	49.6	16.1	580	4	42	7	3
60	Altenburg/Horn	AT	48.7	15.6	485	5	36	7	3
61	Lipowa	PL	49.7	19.1	700	4	62	9	4
62	Voitsberg	AT	47.1	15.2	700	6	32	5	2
63	Stirovaca	HR	44.7	15.0	1080	2	54	13	6
64	Bauska Revier	LV	56.7	24.3	100	4	73	15	7
65	Lobming-Obertal	AT	47.3	15.0	800	4	32	5	2
66	Vsetin, Hovezi	CZ	49.3	18.0	600	4	45	9	4
67	Zwiesel-Ost	DE	49.1	13.3	655	2	21	7	3
68	Suchdol	CZ	48.9	14.9	460	4	36	7	3
69	Bad Doberan	DE	54.1	11.9	50	1	8	1	1
70	Kaufbeuren	DE	47.9	10.6	800	5	23	6	2
71	Grand-Cote	FR	46.8	6.4	950	3	3	2	2
72	Trieben	AT	47.5	14.5	750	6	31	5	2
73	St. Johann	DE	48.5	9.3	800	5	17	3	2
74	St. Veit/Glan	AT	46.8	14.3	1150	5	31	5	2
75	Berg Bev.	SE	62.8	14.4	350	4	91	17	8
76	Bjoerlida KRP	SE	57.4	13.2	175	4	87	19	9
77	Zamberk-Zajeciny	CZ	50.5	16.2	550	4	39	9	4
78	Mestwinowo	PL	54.0	18.3	100	2	67	14	7
79	Pyramis Koutra	GR	41.5	24.3	1620	1	56	13	6
80	St. Oswald	DE	48.9	13.4	1200	4	21	7	3
81	Vimperk-Prameny	CZ	49.1	13.7	850	4	21	7	3
82	Braunlage	DE	51.7	10.6	450	5	7	8	3
83	Gfoellwald	AT	47.5	15.2	1150	3	32	5	2
84	Strimbu-Baiut	RO	47.6	25.0	700	3	59	12	5
85	Toplita, Voivodeasa	RO	46.9	25.4	880	2	59	12	5
86	Magland	FR	46.0	6.6	700	3	2	2	2
87	Cizova u Pisku	CZ	49.4	14.1	450	4	40	7	3
88	Bayr. Eisenstein	DE	49.1	13.2	1000	5	21	7	3
89	Piana Selva, Faido	CH	46.5	8.8	980	1	15	2	2
90	Mengen	DE	48.0	9.3	600	5	16	3	2
91	Spiegelau	DE	48.9	13.4	730	3	21	7	3
92	Cesky Rudolec	CZ	49.1	15.3	680	4	42	7	3
93	Niederndorferberg	AT	47.7	12.2	900	3	28	4	2
94	Beerfelden	DE	49.6	9.0	450	5	12	1	1
95	Liptovsky Hradok	SK	49.0	19.9	825	2	47	10	4
96	Kromeriz, Halenkovice	CZ	49.3	17.4	300	4	44	9	4
97	Jaroslawl Oblast	RU	58.0	39.0	100	4	77	.	10
98	Degerfors	SE	64.2	19.7	175	4	93	17	8
99	Berchtesgaden	DE	47.6	13.0	800	4	26	4	2

Table A.2.9. Origin of the tested provenances, Block 09

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
00	Timirjas	RU	56.5	85.0	120	4	80	.	10
01	Ennstal	AT	47.5	14.2	750	6	30	5	2
02	Triberg	DE	48.1	8.2	500	5	13	3	2
03	Moskva	RU	56.3	37.5	200	4	78	.	10
04	Mpoukowaki	EL	41.5	24.3	1490	1	56	13	6
05	Nagykanizsa, Iharos	HU	46.3	16.9	200	3	52	5	2
06	Lantschbauern	AT	47.2	15.4	1100	5	32	5	2
07	Ravensburg	DE	47.8	9.7	800	5	16	3	2
08	Cervene Porici	CZ	49.5	13.3	430	4	10	7	3
09	Konopiste	CZ	49.8	14.6	360	4	41	7	3
10	Karlovice, Ludvikov	CZ	50.1	17.5	840	4	43	9	4
11	Schernfeld	DE	49.1	11.1	500	5	18	6	2
12	Knusk, Tunopol	RU	.	.	.	4	81	.	.
13	Incukalns Revier	LV	57.3	24.5	30	4	73	15	7
14	Zwiesel-West, Schmalzau	DE	49.1	13.2	630	3	21	7	3
15	Tuttlingen	DE	48.0	8.9	500	4	17	3	2
16	Mochy	PL	52.0	16.2	60	4	65	11	5
17	Mikaszowka	PL	53.9	23.4	120	4	69	14	7
18	Ukmerges	LT	55.3	24.7	73	6	71	15	7
19	Hoechendschwand	DE	47.7	8.2	950	2	14	3	2
20	Knittelfeld	AT	47.2	14.8	1300	6	32	5	2
21	Milevsko, Klucenice	CZ	49.4	14.3	430	4	40	7	3
22	Cucureasa, 65	RO	47.3	25.0	1100	1	59	12	5
23	Liptovsky Mikulas	SK	49.1	19.6	750	4	47	10	4
24	Rossfeld	DE	49.0	11.0	500	5	18	6	2
25	Tarnawa	PL	49.1	22.8	700	2	60	12	5
26	Hanefors	SE	59.0	12.6	75	4	90	19	9
27	Austagder	NO	58.3	8.3	100	6	84	19	9
28	Istebna	PL	49.6	18.9	650	4	63	9	4
29	Sucha 139 A/L	SK	49.2	20.2	1190	1	48	10	4
30	Szczytna Slaska, 292 B	PL	50.5	16.4	700	3	64	9	4
31	Javorova Dolina 155 A	SK	49.3	20.2	1200	1	48	10	4
32	Bogstad, 1425	NO	60.0	10.7	160	1	83	19	9
33	Telc, Horni Dubenky	CZ	49.2	15.5	700	4	42	7	3
34	Hauzenstein	DE	49.0	12.8	1000	5	20	7	3
35	Turda, v Virtopeni 34 A	RO	46.6	23.8	1110	2	58	12	5
36	Vilaka Revier	LV	57.3	27.7	120	4	74	15	7
37	Christinehovs Fideikommiss	SE	55.7	14.0	175	3	86	20	9
38	Geraasaag, Bispgaarden	SE	63.0	16.7	180	3	92	17	8
39	Minsk	BY	53.8	28.0	150	6	75	15	7
40	Bialowieza	PL	52.8	23.7	150	3	70	14	7
41	Stalin, Poiana	RO	45.6	25.3	1100	3	57	12	6
42	Bjurfors KRP	SE	60.1	16.1	140	4	90	19	9
43	Jilove u Prahy	CZ	49.9	14.5	430	4	41	7	3
44	Elbigenalp	AT	47.3	10.4	1200	3	27	4	2
45	Oberammergau	DE	47.6	11.1	1210	5	25	4	2
46	Seeshaupt	DE	47.8	11.3	650	5	23	6	2
47	Zwiesel-Ost, Rannenau	DE	49.1	13.5	655	2	21	7	3
48	Zwiesel-West	DE	49.1	13.2	750	2	21	7	3
49	Radom	PL	51.3	21.3	175	4	61	11	5

Table A.2.9. cont.

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
50	Torgelow	DE	53.5	14.0	100	5	8	1	1
51	Isen	DE	48.2	12.1	500	5	22	6	2
52	Weitra	AT	48.7	14.8	800	5	36	7	3
53	Unken, Salzburg	AT	47.7	12.7	1050	6	26	4	2
54	Himmelberg-Maitrattenw.	AT	46.8	14.0	1475	4	31	5	2
55	Cervena Recice	CZ	49.5	15.2	650	4	41	7	3
56	Breitenau-Mixnitz	AT	47.3	15.4	970	6	32	5	2
57	Cizova u Pisku	CZ	49.4	14.1	420	4	40	7	3
58	Stauffenburg	DE	51.7	10.5	450	5	7	8	3
59	Hohenaltheim	DE	48.3	9.5	500	5	17	3	2
60	Marischka 2	BG	.	.	1360	3	56	13	6
61	Dygowo	PL	54.2	15.8	30	4	66	1	1
62	Sternberk, Ridec	CZ	49.8	17.3	650	4	43	9	4
63	Rehefeld, 146	DE	50.8	13.7	810	2	10	7	3
64	Altenau 316	DE	51.8	10.6	660	3	7	8	3
65	Haus/ im Ennstal	AT	47.4	13.6	800	5	30	5	2
66	Eichstaett	DE	48.9	11.2	500	5	18	6	2
67	Tepla I	CZ	49.8	12.9	750	4	37	7	3
68	Sachsenried	DE	47.9	10.9	800	5	23	6	2
69	Daun-Ost	DE	50.2	6.8	450	5	4	1	1
70	Laintal Hafning	AT	47.4	15.0	1000	4	32	5	2
71	Kynsperk n. Ohri	CZ	50.1	12.5	650	4	10	7	3
72	Policka-Milovy	CZ	49.7	16.1	640	4	42	7	3
73	Freising V/6B, 7AB	DE	48.4	11.8	480	5	22	6	2
74	Gsengegg	AT	47.3	13.6	1100	3	30	5	2
75	Klingenbrunn	DE	48.9	13.3	1200	5	21	7	3
76	Podolinec	SK	49.1	20.5	800	4	48	10	4
77	Raitis	AT	47.2	11.4	1500	5	27	4	2
78	Montriond*	FR	46.2	6.7	1100	3	2	2	2
79	Karlstad, Zon 2	SE	59.6	13.3	125	4	90	19	9
80	Kinnared, Kult	SE	57.0	13.1	110	4	87	19	9
81	Mikkelin Mlk.	FI	61.7	27.3	100	4	95	16	8
82	Cottbus, Tannenwald	DE	51.9	14.2	80	3	9	1	1
83	Spiegelau	DE	48.9	13.4	1000	5	21	7	3
84	Offenburg	DE	48.5	8.0	850	5	13	3	2
85	Altanca	CH	46.5	8.7	1140	1	15	2	2
86	Foelz, Mayerberg	AT	47.5	15.2	950	3	32	5	2
87	Denklingen	DE	47.9	10.9	800	5	23	6	2
88	Kartuzy	PL	54.3	18.2	200	2	67	14	7
89	Ledec nad Sazavou	CZ	49.7	15.3	500	4	41	7	3
90	Sulzschneid	DE	47.7	10.3	800	5	24	4	2
91	Tatranska Lesna 559 C	SK	49.2	20.3	950	1	48	10	4
92	Buchberg Bodenwald	AT	47.6	15.1	900	3	32	5	2
93	Brandenberg/Tirol	AT	47.5	11.9	650	6	28	4	2
94	Jihlava-Hencov	CZ	49.4	15.7	600	4	42	7	3
95	Autrans	FR	45.2	5.6	1250	3	1	2	2
96	Cierny Vah, Kolesarky	SK	48.9	20.7	800	2	47	10	4
97	Unterliezheim	DE	48.3	9.5	500	5	17	3	2
98	Obernberg-Gries	AT	47.0	11.4	1650	2	27	4	2
99	Anyksiu	LT	55.5	25.2	90	6	71	15	7

* missing provenance

Table A.2.10 Origin of the tested provenances, Block 10

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
00	Sigmaringen	DE	48.1	9.2	600	5	17	3	2
01	Veliz	RU	55.6	31.2	200	4	76	15	7
02	Brumov, Navojna	CZ	49.1	18.1	600	4	45	9	4
03	Czerwony Dwor	PL	54.1	22.2	175	3	68	14	7
04	Liptovsky Mikulas	SK	49.0	19.4	800	2	47	10	4
05	Ergoldsbach	DE	48.7	12.2	500	5	22	6	2
06	Zalesie	PL	54.3	16.6	35	4	66	1	1
07	Valea Putnei	RO	47.4	25.4	1190	1	59	12	5
08	Stronie Slaskie	PL	50.2	16.8	800	3	64	9	4
09	Ledec nad Sazavou	CZ	49.7	15.3	400	4	41	7	3
10	Stuebing/Peggau	AT	47.2	15.3	640	6	32	5	2
11	Soboth	AT	46.7	15.1	1200	5	33	5	2
12	Cesky Krumlov-Borova	CZ	48.9	14.3	800	4	40	7	3
13	Bodenmais, Plattenfichten	DE	49.1	13.1	1225	4	21	7	3
14	Mauth-Ost, Plattenfichten	DE	48.9	13.6	1200	4	21	7	3
15	Oberzeiring	AT	47.3	14.5	1200	6	31	5	2
16	Cervena Skala	SK	48.9	20.2	1150	2	47	10	4
17	Presov	SK	49.0	21.2	500	4	49	10	4
18	Foresta di Paneveggio	IT	46.3	11.8	1700	5	29	13	6
19	Oberndorf	AT	47.5	12.4	750	3	28	4	2
20	Frohnleiten	AT	47.3	15.4	750	4	32	5	2
21	Hudson s Place, Ont. CA	DK	.	.	.	2	96	.	.
22	Dorna Cindreni	RO	47.2	25.1	975	2	59	12	5
23	Kraubath	AT	47.3	14.9	1050	6	32	5	2
24	Nove Hrady-Dolni Hvozd	CZ	48.8	14.8	500	4	36	7	3
25	Milevsko, Chysky	CZ	49.4	14.3	635	4	40	7	3
26	Taxenbach/Salzburg	AT	47.3	13.0	1500	6	28	4	2
27	Westerhof 51 B	DE	51.8	10.2	200	3	6	8	3
28	Muran	SK	48.7	20.1	800	4	50	10	4
29	Jaromerice, Lazany	CZ	49.1	15.9	550	4	42	7	3
30	Rostock	DE	54.2	12.5	100	5	8	1	1
31	Sinaia-Paduchiosul	RO	45.3	25.5	1345	2	57	12	6
32	Trebon	CZ	49.0	14.8	450	4	36	7	3
33	Kindberg, Veitsch	AT	47.6	15.5	1000	6	32	5	2
34	Tettnang	DE	47.7	9.6	600	5	16	3	2
35	Gsengegg	AT	47.3	13.6	1050	6	30	5	2
36	Trieben	AT	47.5	14.5	1100	5	31	5	2
37	Augustow	PL	53.9	23.0	120	3	69	14	7
38	Seeshaupt	DE	47.8	11.3	800	5	23	6	2
39	Enzkloesterle	DE	48.7	8.5	850	5	13	3	2
40	Dillingen	DE	48.6	10.5	500	5	23	6	2
41	Laerchschachen	AT	47.4	13.8	700	5	30	5	2
42	Lenzkirch	DE	47.9	8.2	1100	4	14	3	2
43	Aich-Althofen	AT	46.9	14.5	900	5	31	5	2
44	Malyinka 49 F	HU	48.2	20.5	700	2	53	.	5
45	Istebna, 148-149	PL	49.6	18.9	540	3	63	9	4
46	Bystra	PL	49.7	19.7	700	4	62	9	4
47	Lanskroun	CZ	49.9	16.6	490	4	42	9	4
48	Landsberg	DE	48.1	10.9	620	5	23	6	2
49	Sauerlach	DE	48.0	11.7	500	5	22	6	2

Table A.2.10 cont.

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
50	Trebic	CZ	49.3	15.8	590	4	42	7	3
51	Velke Karlovice	CZ	49.3	18.2	800	4	45	9	4
52	Leogang	DE	47.5	12.8	800	4	26	4	2
53	Velden	DE	49.6	11.5	500	5	19	7	3
54	Krumbach	DE	48.2	10.4	500	5	23	6	2
55	Glindfeld	DE	51.3	8.0	700	5	5	1	1
56	Bicaz, II Floarea Ivanesii	RO	46.8	25.9	1150	2	59	12	5
57	Laeaenema Revier	EE	58.9	24.4	40	4	73	15	7
58	Hammerdal Bev.	SE	63.5	15.5	330	4	92	17	8
59	Aasnes	NO	60.6	11.9	200	6	84	19	9
60	St. Oswald, Huettensch.	DE	48.9	13.4	720	3	21	7	3
61	Neuwirtshaus	DE	49.9	11.3	500	5	19	7	3
62	Jasina	UA	48.3	24.3	900	4	60	12	5
63	Walchensee	DE	47.6	11.3	1100	4	25	4	2
64	Bischofsreuth	DE	48.9	13.8	1000	5	21	7	3
65	Neukirchen	AT	47.3	12.3	870	5	28	4	2
66	Rohr im Geb.	AT	47.9	15.8	825	4	34	5	2
67	.	DE	47.5	12.8	1200	5	26	4	2
68	Tavejanne, Bex	CH	46.3	7.1	1600	1	2	2	2
69	Crespato, Airolo	CH	46.5	8.6	1120	1	15	2	2
70	Boubin	CZ	49.0	13.9	1000	1	21	7	3
71	Javorova Dolina	SK	49.3	20.2	1200	1	48	10	4
72	Traunstein	DE	47.9	12.7	800	5	26	4	2
73	Untertal/Schladming	AT	47.4	13.9	1075	6	30	5	2
74	Melnik, Semanovice	CZ	50.4	14.5	300	4	38	7	3
75	Mellier, Bois Bayai	BE	49.8	5.5	400	3	4	1	1
76	Chamonix	FR	45.9	6.9	1080	3	2	2	2
77	Muensingen	DE	48.4	9.5	700	5	17	3	2
78	Hnojnik, Tyra	CZ	49.7	18.5	600	4	45	9	4
79	Hranice	CZ	49.6	17.7	500	4	44	9	4
80	Ochsenhausen	DE	48.1	9.9	600	5	23	6	2
81	Passau-Sued	DE	48.6	13.4	400	5	20	7	3
82	Dalby KRP, Soedra	SE	55.7	13.4	40	4	86	20	9
83	Floda	SE	59.1	16.4	75	4	89	19	9
84	Oberhof, Schlossbergkopf	DE	50.7	10.7	840	2	11	7	3
85	Burghausen	DE	48.2	12.8	400	5	22	6	2
86	Lohja+Laakspohjan Kart.	FI	60.2	24.1	50	3	94	16	8
87	Cavagnago	CH	46.4	8.9	1180	1	15	2	2
88	Oberhof, Kanzlersgrund	DE	50.7	10.7	700	3	11	7	3
89	Cadca, Makov	SK	49.4	18.4	850	3	45	9	4
90	Koeszeg 1 C	HU	47.3	16.4	870	3	52	5	2
91	Bad Teinach	DE	48.7	8.7	500	5	13	3	2
92	Mo Haerad Bev.	SE	57.6	13.8	250	4	88	19	9
93	Kloevsjoe Bev.	SE	62.6	14.2	475	4	91	17	8
94	Wolfach	DE	48.4	8.3	500	5	13	3	2
95	Tatyschlinsk	RU	55.0	58.0	300	4	79	.	10
96	Kloten, Zon 2	SE	59.9	15.3	250	4	90	19	9
97	Polczyn-Zdroj	PL	53.8	16.1	170	4	66	1	1
98	Wolfstein	DE	48.8	13.5	1000	5	21	7	3
99	Westdeutsches Bergland	DE	51.3	8.0	450	5	5	1	1

Table A.2.11 Origin of the tested provenances, Block 11

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
00	Brumov nad Vlarou	CZ	49.1	18.1	760	4	45	9	4
01	Himmelberg-Hochwald	AT	46.8	14.0	1435	4	31	5	2
02	Zdar nad Sazavou	CZ	49.6	15.9	650	4	42	7	3
03	Markt Biberbach	DE	48.6	10.8	500	5	23	6	2
04	Wloszczowa	PL	50.8	20.0	200	4	61	11	5
05	Ronov nad Doubravou	CZ	49.9	15.5	500	4	41	7	3
06	Zlutice	CZ	50.1	13.2	600	4	10	7	3
07	Kraslice	CZ	50.3	12.6	530	4	37	7	3
08	Karlstad, Zon 1	SE	59.5	13.4	75	4	90	19	9
09	Wolfstein	DE	48.8	13.5	1000	5	21	7	3
10	Freising	DE	48.4	11.8	500	5	22	6	2
11	Teisendorf	DE	47.9	12.8	800	5	26	4	2
12	Mpoukowaki	GR	41.5	24.3	1480	1	56	13	6
13	Kulmbach	DE	50.1	11.5	400	5	19	7	3
14	Bogstad 1424	NO	60.0	10.7	160	1	83	19	9
15	Rabino	PL	53.9	15.9	125	4	66	1	1
16	Urszulewo	PL	53.0	19.5	125	4	67	14	7
17	Kroppelfjaell	SE	58.7	12.2	100	4	87	19	9
18	Tepla-Touzim	CZ	50.1	12.9	640	4	37	7	3
19	Schneegattern	AT	48.0	13.3	750	6	35	6	2
20	Passau-Nord	DE	48.7	13.6	1000	5	21	7	3
21	Peiting	DE	47.8	10.9	800	5	23	6	2
22	Gzatsk	RU	55.5	35.3	195	4	78	.	10
23	Altensteig	DE	48.6	8.7	500	5	13	3	2
24	Velke Mezirici-Rudolec	CZ	49.5	15.9	630	4	42	7	3
25	Saarijaervi och Karstula	FI	62.8	25.0	140	4	94	16	8
26	Siessen	DE	48.0	9.2	600	5	17	3	2
27	Fuerstenberg	DE	51.5	8.8	350	4	5	1	1
28	Hechingen	DE	48.3	9.0	500	5	17	3	2
29	Wildalpen	AT	47.6	15.0	850	6	32	5	2
30	Bodenmais	DE	49.1	13.1	1000	5	21	7	3
31	Bialowieza	PL	52.8	23.7	150	3	70	14	7
32	Reichanhall	DE	47.7	12.9	800	5	26	4	2
33	Gammlia	SE	63.8	20.3	60	4	93	17	8
34	Osterode	DE	51.8	10.3	450	5	7	8	3
35	Tamsweg	AT	47.1	13.8	1350	6	30	5	2
36	Dobersberg	AT	48.9	15.3	550	5	36	7	3
37	Roznava	SK	48.7	20.5	800	4	50	10	4
38	Soelktal	AT	47.4	13.9	1250	5	30	5	2
39	Rottweil	DE	48.2	8.6	500	5	13	3	2
40	Altanca	CH	46.5	8.7	1400	1	15	2	2
41	Karlsholm Gods	SE	56.1	14.3	20	4	86	20	9
42	Seestetten	DE	48.7	13.0	500	5	20	7	3
43	Isny	DE	47.7	10.1	850	5	24	4	2
44	Oberes Gailtal	AT	46.6	13.1	1100	6	29	13	6
45	Barsebaeck	SE	56.1	13.4	80	4	86	20	9
46	Ochsenhausen	DE	48.1	9.9	600	5	23	6	2
47	Mogilevskoje Oblast	BY	53.7	30.0	150	6	75	15	7
48	Zwiefalten	DE	48.2	9.5	800	4	16	3	2
49	Wipptal/Tirol	AT	47.2	11.5	1250	6	27	4	2

Table A.2.11 cont.

Provenance			Geographical coordinates (°)		Alt. (m)	Seed class	Krutzsch region	Skrøppa zone	Zone group
No.	Name and country code		Lat.	Long.					
50	Szczytna Slaska	PL	50.5	16.4	750	3	64	9	4
51	Nowy Dwor	PL	53.4	16.3	175	4	66	1	1
52	Ergoldsbach	DE	48.7	12.2	500	5	22	6	2
53	Lanskroun, Albrechtice	CZ	49.9	16.6	480	4	42	9	4
54	Obsteig/Gruenberg	AT	47.3	10.9	1350	3	27	4	2
55	Kaisheim	DE	48.8	10.8	500	5	18	6	2
56	Nancy sur Cluses	FR	46.0	6.6	1000	3	2	2	2
57	Peisey-Nancroix	FR	45.6	6.8	1400	3	2	2	2
58	Oberammergau	DE	47.6	11.1	800	4	25	4	2
59	Turnau-Aflenz	AT	47.6	15.4	1000	6	32	5	2
60	Tellerhaeuser	DE	50.4	12.9	980	2	10	7	3
61	Zwiesel-Ost	DE	49.1	13.3	670	3	21	7	3
62	Ulm-Soeflingen	DE	48.4	10.0	500	5	23	6	2
63	Miskolc, Lillafuered	HU	48.1	20.7	730	3	53	.	5
64	Tatranska Lesna	SK	49.2	20.3	950	1	48	10	4
65	Jablunkov-Girova	CZ	49.6	18.8	670	4	63	9	4
66	Vizovice, Bratrejov	CZ	49.3	17.8	650	4	45	9	4
67	Foelz, Greith	AT	47.5	15.2	825	4	32	5	2
68	Todtnauberg	DE	47.9	8.0	1200	2	14	3	2
69	Stixenstein	AT	47.7	16.0	1200	4	34	5	2
70	Frenstat pod Radhostem	CZ	49.6	18.2	560	4	45	9	4
71	TANAP, Podspady	SK	49.3	20.2	920	2	48	10	4
72	Donnersbach	AT	47.5	14.1	700	3	30	5	2
73	Templin	DE	53.2	13.5	150	5	8	1	1
74	Buchlovice-Koryzany	CZ	49.1	17.4	480	4	44	9	4
75	Unterliezheim	DE	48.3	9.5	500	5	17	3	2
76	Brosteni, Bradu	RO	47.2	25.7	1475	3	59	12	5
77	Buchberg Aegidiwald	AT	47.5	15.2	925	3	32	5	2
78	Bystra	PL	49.7	19.7	700	4	62	9	4
79	Denklingen	DE	47.9	10.9	800	5	23	6	2
80	Crucea	RO	47.3	25.7	740	2	59	12	5
81	Sachsenried	DE	47.9	10.9	775	5	23	6	2
82	Aasan, Bispgaarden	SE	63.0	16.7	270	3	92	17	8
83	Avramov, Jundola	BG	.	.	.	3	56	13	6
84	Voeru Revier	EE	57.8	27.0	90	4	74	15	7
85	Friedstein	AT	47.6	14.1	700	3	30	5	2
86	Malingsbo	SE	59.9	15.4	150	4	90	19	9
87	Kamenice nad Lipou	CZ	49.3	15.0	660	4	41	7	3
88	Gheorghieni	RO	46.7	25.7	1180	2	59	12	5
89	Schluchsee	DE	47.8	8.2	1100	5	14	3	2
90	Ugale Revier	LV	57.3	22.2	50	4	72	15	7
91	Cierny Vah	SK	48.9	20.7	800	2	47	10	4
92	Plaska	PL	53.9	23.2	120	2	69	14	7
93	Hnusta	SK	48.5	19.9	550	4	50	.	5
94	Gries	AT	47.0	11.5	1400	5	27	4	2
95	Oderhaus	DE	51.7	10.6	700	5	7	8	3
96	Olomouc, Olsovec	CZ	49.6	17.3	400	4	44	9	4
97	Ignalino	LT	55.3	26.2	185	6	71	15	7
98	Istebna	PL	49.6	18.9	500	4	63	9	4
99	Crawinkel	DE	50.8	10.7	650	3	11	7	3

Table A.2.12 Deviations from the planned layout in Nyírjes

The 0978 Montriond provenance is missing from block 09 and provenance 0916 Mochy is represented with 50 replications in the same block.

The Hungarian provenance list of block 02 differs from Polish and Swedish lists in two cases. The correct IUFRO numbers and names are:
0208 Faido Nante (CH)
0259 Wundsiedel (DE)

Appendix 3

Table A.3 Index of locations in alphabetical order

The list of population samples contains also the IUFRO provenance number. Broad geographic regions (e.g. Rila Mountains, Prionezhskiy rayon) and dubious cases have been excluded. The location names follow the original orthography, and may differ from the simplified versions used elsewhere.

Åfjord NO 126, **Aflenz** AT 1159, **Aich** AT 665, 1043, **Airolo** CH 112, 561, 717, 1069, **Åkaköp** SE 476, **Albrechtice** CZ 1153, **Alby** SE 162, **Ålen** NO 831, **Allerheiligen im Mürztal** AT 417, **Altanca** CH 216, 370, 647, 1140, **Altenau** DE 324, 964, **Altenburg** AT 860, **Altenhof am Hausruck** AT 285, **Altensteig** DE 1123, **Althausen** DE 290, **Althofen** AT 1043, **Altötting** DE 365, 739, **Älvdalen** SE 639, **Amorbach** DE 458, **Anzing** DE 415, **Anykščių** LT 294, 999, **Artmanov** CZ 210, **Åsan** SE 1182, **Åsnes** NO 1059, **Atanca** CH 985, **Attnang** AT 285, **Augustów** PL 1037, **Aust-Agder** NO 927, **Autrans** FR 995, **Avramovo** BG 1183

Babenhausen DE 475, **Babki** PL 707, **Babylon** CZ 332, **Bad Doberan** DE 304, 697, 869, **Bad Grönenbach** DE 138, 674, **Bad Grund** DE 118, 488, **Bad Leonfelden** AT 571, **Bad Reichenhall** DE 124, 1132, **Bad Rippoldsau** DE 1094, **Bad Schussenried** DE 103, **Bad Teinach** DE 1091, **Baden-Baden** DE 463, 723, **Baindt** DE 384, 794, **Balezino** RU 432, 772, **Balingen** DE 197, 305, **Bârnărel** RO 1180, **Barsebäck** SE 1145, **Bauska** LV 690, 864, **Bayerisch Eisenstein** DE 888, **Bayreuth** DE 453, **Bebenhausen** DE 822, **Bechyně** CZ 235, **Bedretto** CH 112, **Beerfelden** DE 894, **Beglika** BG 402, **Belogradchik** BG 573, **Berchtesgaden** DE 387, 899, **Berg** SE 875, **Berwang** AT 535, **Betzigau** DE 377, 551, 741, **Bex** CH 708, 1068, **Bezděkov** CZ 1187, **Bezhetsk** RU 470, **Białobrzegi** PL 570, **Białowieża** PL 331, 823, 940, 1131, **Biberach an der Riß** DE 1146, **Biberbach** DE 1103, **Bicaz** RO 1056, **Bílovec** CZ 186, **Bindal** NO 416, **Bischofsreuth** DE 1064, **Bischofswiesen** DE 677, 681, 858, **Bispgården** SE 295, 378, 1182, **Björlida** SE 876, **Bjurfors** SE 942, **Blankenburg** DE 767, **Blaubeuren** DE 430, **Blumberg** DE 114, 243, **Bodenmais** DE 1013, 1130, **Bodum** SE 592, **Bogstad** NO 128, 215, 358, 397, 560, 602, 734, 832, 932, 1114, **Bolków** PL 698, **Bonnétage** FR 479, **Borca** RO 158, **Borki** PL 156, 447, **Borovets** BG 778, **Boskovice** CZ 588, **Bottnaryd** SE 587, **Boubín** CZ 408, 498, 726, 1070, **Börwang** DE 741, **Bradu** RO 1176, **Brandenberg** AT 344, 993, **Braşov** RO 612, 941, **Braunlage** DE 882, **Breitenau** AT 956, **Bricalovic** BY 111, **Broczyno** PL 501, 709, **Broşteni** RO 412, 1176, **Brumov-Bylnice** CZ 1002, 1100, **Brunnerberg** AT 433, **Bruntal** CZ 507, 814, **Bryansk** RU 107, **Buchberg** AT 157, 236, 992, 1177, **Buchlovice** CZ 1174, **Bučovice** CZ 277, **Budislav** CZ 371, **Budišov nad Budišovkou** CZ 732, **Burghausen** DE 721, 1085, **Burladingen** DE 802, **Buxabygd** SE 395, **Bükkszentkereszt** HU 796, **Bürgerwald** AT 190, **Bystra** PL 1046, 1178, **Bystrzyca Kłodzka** PL 292

Čadca SK 1089, **Câmpeni** RO RO 239, RO 340, 374, RO 388, **Carlsfeld** DE 562, **Cavagnago** CH 563, 719, 1087, **Cazis** CH 808, **Ceripasina** ME 182, **Červená Řečice** CZ 270, 955, 518, 171, **Červená Skala** SK 147, 486, 520, 547, 628, 855, 752, 1016, **Červené Poříčí** CZ 813,908, **Česká Třebová** CZ 456, **České Žleby** CZ 181, **Český Krumlov** CZ 621, 1012, **Český Rudolec** CZ 334, 892, **Cham** DE 311, **Chamonix** FR 1076, **Chamrousse** FR 364, **Châtel** FR 699, **Chlum u Třeboně** CZ 454, 465, 516, **Chouzavá** CZ 791, **Christinehof** SE 937, **Chuprene** BG 573, **Chyšky** CZ 1025, **Čierny Váh** SK 278, 375, 667, 996, 1191, **Čížová u Pisku** CZ 581, 887, 957, **Clausthal-Zellerfeld** DE 775, **Comăneşti** RO 532, **Coşna** RO 700, **Cottbus** DE 982, **Crailsheim** DE 192, **Crawinkel** DE 1199, **Crucea** RO 1180, **Cucureasa** RO 487, 700, 749, 922, **Czerwony Dwór** PL 1003

Appendix 4

Table A.4 Provenances by countries (Cyrillic names follow German transliteration)

Provenance IUFRO No.	and name	Provenance IUFRO No.	and name	Provenance IUFRO No.	and name
	Austria (AT)	0457	Schneegattern	0830	Emmach/Murau
		0468	Oberes Lechtal	0836	Nasswald
0102	Gurker-Sirnitzwald	0469	Reinberg/Vorau	0860	Altenburg/Horn
0104	Froeschnitz	0478	Eisenkappel	0862	Voitsberg
0108	Soell	0484	Gradisch	0865	Lobming-Obertal
0110	Matrei	0513	Piberegg	0872	Trieben
0115	Oberes Lechtal	0514	Donnersbach	0874	St. Veit/Glan
0122	St. Veit/Pongau	0521	Kappl-See	0883	Gfoellwald
0130	Lessach, 132	0523	Schladming, F. V. Coburg	0893	Niederndorferberg
0133	Murau	0534	Scheifling	0901	Ennstal
0135	Grossarl	0535	Berwang	0906	Lantschbauern
0137	Tamsweg/Salzburg	0538	Freiland	0920	Knittelfeld
0140	Leibnitz	0540	St. Veit/Pongau	0944	Elbigenalp
0153	Seewiesen, Seeberg	0559	Floning Kapfenberg	0952	Weitra
0157	Buchberg, Flachwald	0566	Fuerstenfeld	0953	Unken, Salzburg
0190	Buergerwald	0568	Lilienfeld	0954	Himmelberg-Maitrattenw
0196	Fladnitz-Schrems	0571	Sternwald/Leonfelden	0956	Breitenau-Mixnitz
0198	Groebming-Winkl	0574	Trieben	0965	Haus/ im Ennstal
0201	Kapfenberg	0582	Glashuette	0970	Laintal Hafning
0222	Leutasch	0615	Murau	0974	Gsengegg
0224	Ramsau-Eisenerz	0619	Leoben-Leising	0977	Gsengegg
0236	Buchberg Flachwald	0624	Kalwang	0986	Foelz, Mayerberg
0248	Freiland	0625	Jaidhof	0992	Buchberg Bodenwald
0258	Martei in Osttirol	0626	Fladnitz-Passail	0993	Brandenberg/Tirol
0272	Gallmannsegg	0631	Kreisbach	0998	Obernberg-Gries
0275	Groebming-Winkel	0637	Niederndorferberg	1010	Stuebing/Peggau
0282	Pfunds	0649	Rauris	1011	Soboth
0283	Gsengegg	0665	Aich	1015	Oberzeiring
0284	Seefeld	0666	Foelz, Greith	1019	Oberndorf
0285	Altenhof, Attnang	0669	Passail-Teichalpe	1020	Frohnleiten
0312	Oberhofen	0686	Raitis	1023	Kraubath
0314	Glashuette	0687	Hinterhof-West	1026	Taxenbach/Salzburg
0318	Foelz	0688	Untertal, St. Kathrein	1033	Kindberg, Veitsch
0322	Oeblarn	0696	Poitschach	1035	Gsengegg
0325	Karlstift	0716	Reutte	1036	Trieben
0336	Kaltwasser B. Stadl	0725	St. Salvator	1041	Laerchschachen
0342	Klein Soelk/Steiermark	0727	Thiersee	1043	Aich-Althofen
0344	Brandenberg	0735	Knittelfeld	1065	Neukirchen
0347	Hohenegg	0737	Lessach	1066	Rohr im Geb.
0350	Eisenkappel	0738	Zeltschach	1073	Untertal/Schladming
0369	Himmelberg-Mooswald	0750	Eisenkappel	1101	Himmelberg-Hochwald
0372	Kreuzen, Stockenboi	0758	Vorau	1119	Schneegattern
0382	Hinterhof West, Eibelkogel	0759	Veitsch-Neuberg	1129	Wildalpen
0385	Gaischorn	0761	Liembergwald/Zell am See	1135	Tamsweg
0392	Seiz	0762	Mitterberg I. Ennstal	1136	Dobersberg
0404	Kitzbuehel	0765	Stuebing/Gamskogel	1138	Soelktal
0405	Gschwornrieser Bergwald	0784	Kramersdorf	1144	Oberes Gailtal
0406	Rauris	0792	Judenburg	1149	Wipptal/Tirol
0417	Stanz-Kindtal-Allerheiligen	0798	Gurktal	1154	Obsteig/Gruenberg
0423	St. Martin am Silberberg	0799	Liezen	1159	Turnau-Aflenz
0428	Lessach, 146	0801	Hinterhof Ost, Brenner	1167	Foelz, Greith
0433	Brunnerberg	0805	Mitterdorf	1169	Stixenstein
0436	Eisenerz	0810	Ramsau	1172	Donnersbach
0441	Deutschlandsberg	0812	Grossarl		cont. next page
0451	Seewiesen	0815	Emmach/Murau		

Table A.4 cont.

Provenance IUFRO No. and name		Provenance IUFRO No. and name		Provenance IUFRO No. and name	
	Austria (AT) cont.	0186	Bilovec, Fulnek	0600	Trebic
		0191	Prostejov, Dzbel	0610	Zelezna Ruda
1177	Buchberg Aegidiwald	0194	Zdarske Vrchy	0611	Melnik, Semanovice
1185	Friedstein	0206	Hnojnik, Rovina	0618	Rajnochovice
1194	Gries	0210	Albrechtice, Tisova	0620	Prasily
		0213	Trebon, Zamecky	0621	Cesky Krumlov
	Belarus (BY)	0227	Ostravice, Stare Hamry	0661	Jablunkov, Girova
		0229	Ostravice	0663	Krivoklat
0111	Bricalovic	0235	Bechyne	0664	Plana nad Luznici
0300	Cemerjansk	0257	Habartice/Planice	0672	Sternberk, Mutkov
0401	Teljakov, Uzda	0261	Zdirec nad Doubravou	0683	Horni-Marsov
0606	Wolozin	0263	Moravsky Krumlov	0692	Hnojnik, Kosariska
0743	Witebsk	0265	Knysperg nad Ohri	0702	Nove Hrady-Dolni Hvozd
0840	Soboljansk Revier	0270	Cervena Recice	0712	Luhacovice, Strani
0939	Minsk	0273	Trebic IV	0714	Moravska Trebova
1147	Mogilevskoje Oblast	0277	Bucovice, Nevojice	0720	Nove Hrady-Horni Hvozd
		0291	Hencov-Trest	0726	Boubin 2
	Belgium (BE)	0319	Mlada Boleslav-Zehrov	0729	Nove Hrady, Horni Hvozd
		0328	Pribram	0731	Frantiskovy Lazne
0241	Manderfeld	0329	Vrchlabi	0732	Vitkov-Budisov
0528	Manderfeld/Gilbuscheek	0332	Kydne, Babylon	0736	Velke Karlowice, Vranca
1075	Mellier/Bois Bayai	0334	Cesky Rudolec, Lipnice	0748	Policka, Pusta Kamenice
		0348	Nove Mesto na Morave	0751	Vrchlabi
	Bulgaria (BG)	0356	Svetla nad Sazavou	0757	Horni Marsov, Velka Upa
		0371	Policka, Budislav	0766	Dobris, Obora
0148	Parangalitza	0376	Milevsko-Kostelec	0791	Dobris, Chouzava
0268	Razlog	0380	Plana u Marianskych Lazni	0813	Cervene Porici Kaliste
0373	Rila-Gebirge, Nr. 1	0386	Kdydne-Loucim	0814	Bruntal, Siroka Niva
0402	Beglika	0394	Vrchlabi	0816	Nove Hrady, Dolni Hvozd
0573	Belogradtschik	0407	Visoky Chlumec-Veletin	0826	Znojmo
0640	Jundola Nr. 41	0408	Boubin 1	0854	Jilove u Prahy
0678	Pirin	0409	Vlasim	0857	Lukov u Holesova
0778	Borovec	0411	Moravska Trebova	0859	Nove Mesto na Morave
0849	Diktschanska	0422	Vsetin, Pozdechov	0866	Vsetin, Hovezi
0960	Marischka 2	0426	Vysoky Chlumec, Veletin	0868	Suchdol
1183	Avramov, Jundola	0427	Moravska Trebova	0877	Zamberk-Zajeciny
		0429	Frenstat pod Radhostem	0881	Vimperk-Prameny
	Canada (CA)	0454	Chlum u Trebone	0887	Cizova u Pisku
		0456	Ceska Trebova	0892	Cesky Rudolec
1021	Hudsons Place, Ont.	0465	Chlum u Trebone	0896	Kromeriz, Halenkovice
		0466	Konopiste, Dubsko	0908	Cervene Porici
	Croatia (HR)	0477	Vsetin, Hovezi	0909	Konopiste
		0492	Janovice u Rymarova	0910	Karlovice, Ludvikov
0790	Mali Lom	0498	Boubin 4	0921	Milevsko, Klucenice
0863	Stirovaca	0506	Vlasim	0933	Telc, Horni Dubenky
		0507	Bruntal, Mezina	0943	Jilove u Prahy
	Czech Republic (CZ)	0508	Vrchlabi	0955	Cervena Recice
		0516	Chlum u Trebone-Hamr	0957	Cizova u Pisku
0131	Vlasim-Votice	0518	Cervena Recice, Rousinov	0962	Sternberk, Ridec
0139	Sternberk, Hruba Voda	0526	Frenstat p. Radhostem-Ob.	0967	Tepla I
0144	Rozmital pod Tremsinem	0544	Luzna	0971	Kynsperk n. Ohri
0145	Luhacovice, Loucka	0545	Ostravice	0972	Policka-Milovy
0152	Luhacovice, Stary Hroz.	0575	Tepla	0989	Ledec nad Sazavou
0161	Horsovsky Tyn	0580	Litovel, Lostice	0994	Jihlava-Hencov
0164	Zamberk, Letohrad	0581	Cizova u Pisku	1002	Brumov, Navojna
0171	Cervena Recice-Lukavec	0588	Boskovice, Kunstat	1009	Ledec nad Sazavou
0178	Jesenik-Zlate Hory	0594	Olomouc, Hranice	1012	Cesky Krumlov-Borova
0181	Prachatice, Ceske Zleby	0597	Kraslice-Nancy	1024	Nove Hrady-Dolni Hvozd
0184	Nepomuk	0598	Rajnochovice	1025	Milevsko, Chysky

cont. next page

Table A.4 cont.

Provenance IUFRO No.	and name
	Czech Republic (CZ) cont.
1029	Jaromerice, Lazany
1032	Trebon
1047	Lanskroun
1050	Trebic
1051	Velke Karlovice
1070	Boubin
1074	Melnik, Semanovice
1078	Hnojnik, Tyra
1079	Hranice
1100	Brumov nad Vlarou
1102	Zdar nad Sazavou
1105	Ronov nad Doubravou
1106	Zlutice
1107	Kraslice
1118	Tepla-Touzim
1124	Velke Mezirici-Rudolec
1153	Lanskroun, Albrechtice
1165	Jablunkov-Girova
1166	Vizovice, Bratrejov
1170	Frenstat pod Radhostem
1174	Buchlovice-Koryzany
1187	Kamenice nad Lipou
1196	Olomouc, Olsovec
	Denmark (DK)
0155	Graasten
0424	Loendal
0627	Fussingoe, Udskovene
0728	Lindenborg
0835	Graasten
	Estonia (EE)
0480	Saaremaa Revier
0556	Viljandi Revier
0756	Verior Revier
1057	Laeaenema Revier
1184	Voeru Revier
	Finland (FI)
0219	Vesijako pajulahden
0333	Rantasalmi
0546	Maenttae Kasvuala
0609	Satakunta
0779	Urjala Honkolan
0850	Sonkajaervi
0981	Mikkelin
1086	Lohja
1125	Saarijaervi och Karstula
	France (FR)
0119	Esserval-Tartre
0170	Lantosque
0223	Le Pertuis
0256	Le Reposoir
0362	Plan Bois
0364	Chamrousse
0467	Plan Bois
0479	Bonetage
0531	Passy
0548	Massif Central
0685	St. Laurent-du-Jura
0689	Passy
0699	Chatel
0797	Gerardmer
0871	Grand-Cote
0886	Magland
0978	Montriond
0995	Autrans
1076	Chamonix
1156	Nancy sur cluses
1157	Peisey-Nancroix
	Germany (DE)
0100	Oberhof
0101	Stryck, Sonderherkunft
0103	Schussenried
0105	Klingenbrunn
1013	Lichtenstein
0114	Blumberg
0118	Bad Grund
0121	Taennesberg
0123	Mindelheim
0124	Riechenhall-Nord
0125	Reit im Winkel
0127	Garmisch
0129	Wasserburg
0138	Goenenbach
0149	Freudenstadt
0165	St. Oswald
0173	Rabenstein
0175	Zwiesel-West
0177	Sieber
0179	Walsrode
0180	Zwiesel-Ost
0183	Zwiesel-Ost
0185	Donaueschingen
0188	Klingenbrunn
0189	Kuernach
0192	Crailsheim
0193	Hagenow
0195	Memmingen
0197	Balingen
0199	Ramspau
0203	Steinheim
0204	Fall
0205	Deggendorf
0209	Schluchsee, Eschenmoos
0211	Neureichenau
0212	Tegernsee
0214	Ebersberg
0217	Stryck, Sonderherkunft
0220	Weingarten
0225	Tegernsee
0228	Schmiedefeld, Freibachtal
0234	Tellerhaeuser, 44
0242	Pielenhofen
0243	Blumberg
0246	Oberammergau
0249	Peiting
0254	Partenkirchen
0255	Neustrelitz
0259	Wunsiedel
0260	Siegenburg
0264	Eglharting
0269	Denklingen
0274	Pfalzgrafenweiler
0276	Rabenstein, Typengemisch
0279	Wehingen
0280	Westerhof
0287	Marquartstein-West
0288	Starnberg
0289	Zwiesel-Ost VI/13
0290	Altshausen
0296	Gammertingen
0297	Moosburg
0298	Muehlheim
0301	Utzmemmingen
0302	Eberbach
0303	Hoechenschwand Kurhaus
0304	Bad Doberan
0305	Balingen
0307	Werder 72
0310	Todtmoos
0311	Cham, Kugel-Gebiet
0315	Starnberg
0317	Diessen, ob. Spindler
0321	Tailfingen
0323	Eberbach
0324	Altenau 317
0335	Mittenwald
0339	Isen
0346	Steinheid, Kieferleskopf
0349	Zwiesel/West, Sandau
0352	Hohenschwangau
0354	St. Oswald
0360	Zwiesel-Ost, Dachshuette
0363	Muesingen
0365	Altoetting
0377	Betzigaus
0384	Baindt
0387	Berchtesgaden
0389	Spiegelau
0390	Kelheim-Nord
0400	Parchim
0403	Pfullendorf
0410	Lenzkirch
0413	Hauzenstein
0415	Anzing
0418	Tuttlingen
0420	Ziegenberg

cont. next page

Table A.4 cont.

Provenance IUFRO No. and name		**Provenance IUFRO No. and name**		**Provenance IUFRO No. and name**	
	Germany (DE) cont.	0603	Teisendorf, Lebenau	0800	Kirchzarten
		0604	Lenzkirch, Feldsee	0802	Burladingen
0421	Oberammergau	0605	St. Oswald	0803	Mochenwangen
0425	Zwiesel-Ost	0622	Justingen	0804	Traunstein
0430	Blaubeuren	0629	Ottobeuren	0806	Peitz/Tannenwald
0438	Muehldorf, Fors Puerten	0636	Partenkirchen	0809	Klingenbrunn
0440	Zwiesel-West, Schmalzau	0638	Weidenberg	0811	Stammham
0448	Kirchzarten	0641	Wunsiedel	0817	Passau-Nord
0449	Zwiesel-Ost, Typengemisch	0642	Flachslanden	0818	Weissenstadt
0450	Mindelheim	0645	Dieburg	0819	Wolfach
0453	Bayreuth-West	0648	Westerhof 50, 58	0822	Bebenhausen
0458	Amorbach-West	0652	Illertissen	0824	Muehldorf
0460	Klingenbrunn	0657	Spiegelau	0829	Zwiesel-Ost
0461	Mauth-Ost	0658	Muenchen-Sued	0833	Wasserburg
0463	Baden-Baden	0660	Diessen	0842	Weidenberg
0471	Mechterstaedt	0671	Rottweil	0843	Wundelsiedel-Weissenstadt
0472	Isny	0673	Diessen	0845	Kuernach
0474	Westerhof	0674	Groenenbach	0846	Garmisch
0475	Babenhausen	0675	Zwiesel-Ost	0853	Moosburg
0481	Reit im Winkel	0676	Kohlstetten	0858	Bischofswiessen
0483	Schoenmuenzach	0677	Bischofswiesen	0867	Zwiesel-Ost
0488	Bad Grund 126	0679	Memmingen	0869	Bad Doberan
0489	Kuernach	0680	Suedharz	0870	Kaufbeuren
0490	Westerhof 48 A	0681	Bischofswiesen	0873	St. Johann
0493	Dietenheim	0682	Spiegelau	0880	St. Oswald
0494	Ruhpolding-West	0684	Riedlingen	0882	Braunlage
0495	Hohenaschau	0693	Ottobeuren	0888	Bayr. Eisenstein
0496	Murnau	0694	Pappenheim	0890	Mengen
0497	Rabenstein	0695	Elgersburg	0891	Spiegelau
0499	Stralsund	0697	Bad Doberan	0894	Beerfelden
0502	Sauerlach	0701	Koenigsbronn	0899	Berchtesgaden
0503	Ebersberg	0711	Zwingenberg	0902	Triberg
0504	Ottobeuren	0715	Tussenhausen	0907	Ravensburg
0505	Kaisheim	0721	Burghausen	0911	Schernfeld
0509	Lichtenstein	0722	Mengen	0914	Zwiesel-West, Schmalzau
0511	Zwiesel-Ost, Haselau	0723	Baden-Baden	0915	Tuttlingen
0512	Fuerstenberg/KRS B.	0724	Pfronstetten	0919	Hoechendschwand
0515	Neustadt	0739	Altoetting	0924	Rossfeld
0519	Oberkochen	0740	Rungstock	0934	Hauzenstein
0522	Schoenmuenzach	0741	Betzigau, Boerwang	0945	Oberammergau
0536	Neureichenau	0742	Mauth-Ost	0946	Seeshaupt
0537	Kaufbeuren	0746	Wismar	0947	Zwiesel-Ost, Rannenau
0539	Pressath	0747	Kuernach	0948	Zwiesel-West
0541	Oberhof, Mittelberg	0753	Tegernsee	0950	Torgelow
0542	Gundelsheim	0760	Siessen	0951	Isen
0543	Wehingen	0767	Blankenburg	0958	Stauffenburg
0549	Eglharting	0769	Hohenaschau	0959	Hohenaltheim
0550	Westerhof, Elit	0771	Ipsheim	0963	Rehefeld, 146
0551	Betzigau	0775	Clausthal-Zellerfeld	0964	Altenau 316
0557	Partenkirchen	0776	Rabenstein	0966	Eichstaett
0558	Einsiedel	0777	Zwiesel-Ost, Plattenfichte	0968	Sachsenried
0562	Carlsfeld, 275	0780	Landsberg	0969	Daun-Ost
0569	Marquarstein-West	0782	Muenchen-Sued	0973	Freising
0572	Salem	0787	Tegernsee	0975	Klingenbrunn
0578	Kuernach	0788	Neustadt	0982	Cottbus, Tannenwald
0579	Westerhof	0789	Herrenwies	0983	Spiegelau
0584	Gessertshausen	0793	Passau-Sued	0984	Offenburg
0591	Illertissen	0794	Baindt	0987	Denklingen
0599	Koenigseggwald	0795	Schluchsee		cont. next page

Table A.4 cont.

Provenance IUFRO No.	**and name**	**Provenance IUFRO No.**	**and name**	**Provenance IUFRO No.**	**and name**
	Germany (DE) cont.	1158	Oberammergau		**Lithuania (LT)**
		1160	Tellerhaeuser		
0990	Sulzschneid	1161	Zwiesel-Ost	0294	Anyksiu
0997	Unterliezheim	1162	Ulm-Soeflingen	0351	Ukmerges
1000	Sigmaringen	1168	Todtnauberg	0383	Dobele Revier
1005	Ergoldsbach	1173	Templin	0590	Ukmerges
1013	Bodenmais, Plattenfichten	1175	Unterliezheim	0607	Zjeimeny
1014	Mauth-Ost, Plattenfichten	1179	Denklingen	0841	Ignalino
1027	Westerhof 51 B	1181	Sachsenried	0918	Ukmerges
1030	Rostock	1189	Schluchsee	0999	Anyksiu
1034	Tettnang	1195	Oderhaus	1197	Ignalino
1038	Seeshaupt	1199	Crawinkel		
1039	Enzkloesterle				**Montenegro (ME)**
1040	Dillingen		**Greece (GR)**		
1042	Lenzkirch			0182	Jelak-Ceripasina
1048	Landsberg	0330	Pyramis Koutra	0345	Nedzinant
1049	Sauerlach	0670	Pyramis Koutra		
1052	Leogang	0879	Pyramis Koutra		**Norway (NO)**
1053	Velden	0904	Mpoukowaki		
1054	Krumbach	1112	Mpoukowaki	0126	Roan och Aafjord
1055	Glindfeld			0128	Bogstad, 1434
1060	St. Oswald, Huettensch.		**Hungary (HU)**	0215	Bogstad, 1422
1061	Neuwirtshaus			0232	Hurdal, B 400
1063	Walchensee	0154	Magyarlak	0353	Snilfjord, Troendelag
1064	Bischofsreuth	0271	Sarospatak/Haromhuta	0358	Bogstad, 1426
1067	…	0341	Sopron	0397	Bogstad, 1435
1072	Traunstein	0455	Koeszeg 60 A	0416	Velfjord, Velvelstad
1077	Muensingen	0510	Szentgotthard	0560	Bogstad, 1421
1080	Ochsenhausen	0633	Kercaszomor	0589	Hurdal, B 300
1081	Passau-Sued	0796	Buekkszentkereszt	0602	Bogstad 1432
1084	Oberhof, Schlossbergkopf	0905	Nagykanizsa/Iharos	0651	Selbu, Klaebu
1085	Burghausen	1044	Malyinka	0733	Oestlandsgarn
1088	Oberhof, Kanzlersgrund	1090	Koeszeg 1 C	0734	Bogstad, 1440
1091	Bad Teinach	1163	Miskolc/Lillafuered	0831	Tyldal, Aalen
1094	Wolfach			0832	Bogstad, 1433
1098	Wolfstein		**Italy (IT)**	0927	Austagder
1099	Westdeutsches Bergland			0932	Bogstad, 1425
1103	Markt Biberbach	0525	Val Vistende	1059	Aasnes
1109	Wolfstein	0770	Val di Fiemme	1114	Bogstad 1424
1110	Freising	1018	Foresta di Panaveggio		
1111	Teisendorf				**Poland (PL)**
1113	Kulmbach		**Latvia (LV)**		
1120	Passau-Nord			0132	Klodzko
1121	Peiting	0151	Kuldiga Revier	0136	Rycerka
1123	Altensteig	0163	Saldus Revier	0143	Nekla
1126	Siessen	0230	Varakalani Revier	0146	Puszcza Bialowieska
1127	Fuerstenberg	0250	Dagdskin	0156	Borki
1128	Hechingen	0452	Saldus Revier	0160	Obleze
1130	Bodenmais	0555	Saldus Revier	0174	Wisla, 54 A
1132	Reichanhall	0565	Rezekne Revier	0202	Ujsoly
1134	Osterode	0577	Dagdskin	0237	Witow
1139	Rottweil	0659	Ventspils Revier	0247	Zytkiejmy
1142	Seestetten	0690	Bausskij	0251	Smolno
1143	Isny	0864	Bauska Revier	0252	Szczecinek
1146	Ochsenhausen	0913	Incukalns Revier	0253	Serwy
1148	Zwiefalten	0936	Vilaka Revier	0266	Karnieszewice
1152	Ergoldsbach	1190	Ugale Revier	0292	Bystrzyca Klodzka
1155	Kaisheim			0293	Kolonowskie

cont. next page

Table A.4 cont.

Provenance IUFRO No. and name		Provenance IUFRO No. and name		Provenance IUFRO No. and name	
	Poland (PL) cont.	0949	Radom		**Russian Federation (RU)**
		0961	Dygowo		
0309	Jemielno	0988	Kartuzy	0106	Ostrovsk
0313	Karwice	1003	Czerwony Dwor	0107	Brjansk, Zukovsk
0326	Knyszyn	1006	Zalesie	0109	Njubsk
0327	Jodlowno	1008	Stronie Slaskie	0166	Udmurtsk, Glazov
0331	Bialowieza	1037	Augustow	0200	Tjumen, Uvat
0337	Przysucha	1045	Istebna, 148-149	0207	Kaluga
0343	Piwniczna	1046	Bystra	0316	Novgorod
0355	Rycerka, Kiczora	1097	Polczyn-Zdroj	0320	Knusk, 2
0399	Orawa	1104	Wloszczowa	0359	Rjasan, Pervmaisk
0414	Klodzko, 68 E	1115	Rabino	0361	Sosnovsk
0431	Narewka	1116	Urszulewo	0432	Udmurtsk, Balezinsk
0442	Wegierska Gorka	1131	Bialowieza	0470	Bezcetsk
0443	Prochowice	1150	Szczytna Slaska	0485	Njubsk
0444	Wloclawek	1151	Nowy Dwor	0585	Sverdlovskoje Oblast
0445	Damnica	1178	Bystra	0616	Rjasan, Moshary
0447	Borki Knieja	1192	Plaska	0643	Knusk, 19
0462	Polanow	1198	Istebna	0744	Knusk, 19
0500	Olecko			0772	Udmurtsk, Balezinsk
0501	Broczyno		**Romania (RO)**	0807	Prionegsk
0517	Poniki			0834	Molvotitsk
0529	Wielgowo	0158	Borca, XV Sabasa Sting	0856	Roslavl
0552	Ujsoly	0169	Dorna Cindreni	0897	Jaroslawl Oblast
0553	Stronie Slaskie	0172	Valea Putnei, 60	0900	Kartuzy
0564	Witow	0231	Moldovita, Sacries	0903	Moskva
0570	Bialobrzegi	0239	Cimpeni, Nedei	0912	Knusk, Tunopol
0583	Kup, Murow	0262	Moldovita. I Demacusa	1001	Veliz
0614	Rycerka	0286	Gheorghieni, I Ditrau	1095	Tatyschlinsk
0630	Sichow	0340	Cimpeni, XV Valea Mare	1122	Gzatsk
0632	Sierpc	0374	Cimpeni, Dara		
0634	Krynica	0388	Cimpeni, Valea Mare		**Serbia (RS)**
0650	Sobowidze	0412	Brosteni, Piriul Omului		
0654	Kumialka	0439	Dorna Cindreni, II Rosia	0601	Kaludjerske Bare
0656	Zwierzyniec	0487	Cucureasa, 65		
0691	Gorowo Ilaw	0530	Frasin, X Ursoaia		**Slovakia (SK)**
0698	Bolkow	0532	Comanesti, IV Bortea		
0706	Stary Krakow	0554	Sibiu, Paltinis	0117	Javorova Dolina
0707	Babki	0576	Sinaia-Gurguiata	0141	Kevele
0709	Broczyno	0612	Brasov, Piatra Mare	0147	Cervena Skala,
0710	Zlota Wies	0613	Remeti, Zerna	0150	Svrcina Hrabusice
0764	Przerwanki	0635	Toplita	0176	Liptovsky Hradok
0781	Klodzko	0700	Cosna, Cucureasa	0187	Klastor pod Znievom
0785	Zakopane	0749	Cucureasa	0226	Tatranska Lesna
0786	Wegierska Gorka	0755	Marginea	0238	Smolnicka Hut
0823	Bialowieza	0847	Galu	0240	Podolinec
0825	Ruciane	0884	Strimbu-Baiut	0244	Sucha
0837	Wronki	0885	Toplita, Voivodeasa	0278	Cierny Vah
0848	Rycerka	0922	Cucureasa, 65	0281	Smolnicka Huta
0851	Zwierzyniec Lubelski	0935	Turda, v Virtopeni	0306	Tatranska Lesna
0852	Luban Slaski	0941	Stalin, Poiana	0367	Spisska Nova
0861	Lipowa	1007	Valea Putnei	0375	Cierny Vah/Rovienky
0878	Mestwinowo	1022	Dorna Cindreni	0381	Sucha
0916	Mochy	1031	Sinaia-Paduchiosul	0391	Kezmarok
0917	Mikaszowka	1056	Bicaz, II Floarea Ivanesii	0393	Javorova Dolina
0925	Tarnawa	1176	Brosteni, Bradu	0398	Javorova Dolina
0928	Istebna	1180	Crucea	0434	Hronec
0930	Szczytna Slaska	1188	Gheorghieni	0435	Kysthybel
0940	Bialowieza			0446	Liptvsky Hradok

cont. next page

Table A.4 cont.

Provenance IUFRO No.	and name
	Slovakia (SK) cont.
0486	Cervena Skala
0491	Klastor pod Znievom
0520	Cervena Skala
0524	Poprad
0527	Javorova Dolina
0533	Liptovsky Mikulas
0547	Cervena Skala/Martaluskka
0593	Tatranska Lesna
0628	Cervena Skala
0646	Tatranska Lesna
0655	Javorova Dolina
0662	Hnusta
0667	Cierny Vah/Rovienky
0713	Liptovsky Hradok
0718	Javorova Dolina
0730	Klastor pod Znievom
0745	Ruzomberok
0752	Cervena Skala
0754	Hrabusice
0821	Javorova Dolina
0827	Hrabusice
0828	Sucha
0844	Klastor pod Znievom
0855	Cervena Skala
0895	Liptovsky Hradok
0923	Liptovsky Mikulas
0929	Sucha
0931	Javorova Dolina
0976	Podolinec
0991	Tatranska Lesna
0996	Cierny Vah
1004	Liptovsky Mikulas
1016	Cervena Skala
1017	Presov
1028	Muran
1071	Javorova Dolina
1089	Cadca, Makov
1137	Roznava
1164	Tatranska Lesna
1171	TANAP/Podspady
1191	Cierny vah
1193	Hnusta
	Sweden (SE)
0120	Ramsaasa
0134	Umeaa Oestra, Zon 1
0142	Oviken Bev.
0159	Froejered
0162	Alby Bev.
0167	Laxaa
0168	Ljungsnaes KRP
0218	Helgum
0221	Groenbo
0233	Umeaa Oestra, Zon 2
0245	Kroppefjaell
0267	Karlstad. Zon 0
0295	Bispgaarden 1
0299	Sandvik KRP
0308	Foerarp, Sk 1
0338	Skinnskatteberg
0357	Kristinehamn
0366	Edsleskog
0378	Bispgaarden 2
0379	Nordmaling
0395	Buxabygd KRP
0396	Puus, I AVD 64-67
0419	Viken och Turinge
0437	Hoting Bev
0464	Virserum
0476	Aakakoep
0482	Oerebro
0567	Ryssby
0586	Riksstens KRP
0587	Bottnaryd
0592	Bodum
0595	Groenbo
0617	Sandvik KRP
0623	Nyboda
0639	Aelvdalen
0644	Karlsdal
0653	Naes
0668	Ed, Dalsland
0703	Ringamaala KRP
0704	Eckersholm
0705	Floda
0763	Kloten, Zon 1
0768	Vallen Bev.
0774	Fjaellsjoe Bev.
0783	Joenstorp, Galthult
0820	Villingsberg
0838	Hillet
0839	Turinge Bev.
0875	Berg Bev.
0876	Bjoerlida KRP
0898	Degerfors
0926	Hanefors
0937	Christinehovs Fideikommiss
0938	Geraasaag, Bispgaarden
0942	Bjurfors KRP
0979	Karlstad, Zon 2
0980	Kinnared, Kult
1058	Hammerdal Bev.
1082	Dalby KRP, Soedra
1083	Floda
1092	Mo Haerad Bev.
1093	Kloevsjoe Bev.
1096	Kloten, Zon 2
1108	Karlstad, Zon 1
1117	Kroppelfjaell
1133	Gammlia
1141	Karlsholm Gods
1145	Barsebaeck
1182	Aasan, Bispgaarden
1186	Malingsbo
	Switzerland (CH)
0112	Bedretto, Airolo
0116	Piana Selva, Faido
0208	Faido, Nante
0216	Altanca
0368	Klosters
0370	Altanca
0459	Piana Selva/Faido
0473	Foret de Risoud
0561	Crespato
0563	Cavagnago
0608	Disentis
0647	Altanca
0708	Tavejanne
0717	Crespato, Airolo
0719	Cavagnago
0808	Cazis
0889	Piana Selva
0985	Altanca
1068	Tavejanne
1069	Crespato
1087	Cavagnago
1140	Altanca
	Ukraine (UA)
0596	Jasina
0773	Jasina
1062	Jasina

Appendix 5

Table A.5 Regions and number of provenances by regions (after Krutzsch 1974, completed with name of regions and countries)

Region No.	and name	Country	Number of provenances
01	Massif Central	France, Belgium, Switzerland	5
02	West Alps, Mont Blanc		13
03	Jura		5
04	Ardennes, Vosges		5
05	Hessian Foothills	NW- Germany	9
06	Westerhof		7
07	Harz Mts		12
08	Mecklenburg	Germany, Czech Republic	12
09	Lausitz		2
10	Erzgebirge		11
11	Thüringerwald		9
12	Odenwald	SW- Germany, Switzerland	7
13	Schwarzwald N.		19
14	Schwarzwald S., Breisgau		16
15	Western Alps		18
16	Swabian Upland		15
17	Swabian Alb		28
18	Franconian Alb	SE-Germany, Czech Republic, Austria	11
19	Franconia, Fichtel Mts		11
20	Bavarian Forest		7
21	Bavarian-, Bohemian Forest		58
22	Swabian-Bavarian Upland		31
23	Swabian-Bavarian Upland		35
24	Swabian-Bavarian Upland		13
25	Bavarian Alps		14
26	Kitzbühel Alps S		26
27	Allgäu Alps, Tyrol	Austria, Italy, Czech Republic	16
28	N. Kitzbühel Alps, Tyrol		21
29	Eastern Alps, Italy		5
30	Salzkammergut		24
31	Carinthia-Styria		24
32	Wild Alps, NE. Styria		49
33	SE. Styria		7
34	Semmering, E. Styria		12
35	Upper Austria		3
36	Lower Austria, E. Sumava		17
37	Bohemian Forest	Czech Republic	12
38	Central Bohemia		8
39	Sudeten		7
40	N. Sumava, S. Bohemia		9
41	Bohemian Hills W.		19

Table A.5 cont.

Region No. and name		Country	Provenances
42	Bohemian-Moravian Hills	Czech Republic	25
43	Orlice Mts., Moravia		10
44	Moravia		11
45	Moravian Mts.		24
46	Fatra	Slovakia	5
47	Low Tatras		23
48	High Tatras		25
49	Beskidy E., East Slovakia		3
50	Slovakian Ore Mts.		7
51	Kysihybel		2
52	W Hungary	Hungary	7
53	N. Hungarian Mts.		4
54	Velebit, Dalmatia	Croatia, Montenegro, Serbia	2
55	Crna Gora		3
56	Rhodope Mts	Bulgaria, Greece	16
57	S. Carpathians,Transilvania	Romania	5
58	Bihor Mts, Transilvania		6
59	Eastern Carpathians		25
60	Jasina, Ukraine	Poland, Ukraine, Czech Republic	4
61	Little Poland, Upland		5
62	E. Beskids,		6
63	W. Beskids, Istebna		15
64	Klodzko Valley, Sudeten		9
65	Silesian Lowland		10
66	W-Pomeranian Lakeland		17
67	E-Pomeranian Lakeland		8
68	Masurian Lakeland		7
69	Augustów Lakeland		8
70	Bialowieza P. Forest		7
71	Lithuania, Belarus	Baltic States, Belarus, Russia	9
72	Latvia		8
73	Latvia, Estonia		5
74	Latvia, Estonia		8
75	Belarus		6
76	Valdai Hills, E. Russia		5
77	N. Russia		5
78	Central Russian Upland		7
79	Upper Kama Upland,		4
80	Altai, Siberia		3
81	Knusk(?), Russia		3
82	Jutland	Denmark	5
83	Drammen, Bogstad	Norway	10
84	SE. Norway		5
85	Trondheim, Central Norway		5

Table A.5 cont.

Region No. and name		Country	Provenances
86	Scania	Sweden	7
87	Götland, Värmland		9
88	Västergötland		8
89	Södermanland		4
90	Karlstad, Västmanland		18
91	Norrland		9
92	Jämtland, Angermanland		9
93	Bothnia, Umea		6
94	Uudenmaa, S. Finland	Finland	6
95	Karelia		4
96	Hudson, Ontario	Canada	1

Appendix 6

Table A.6.1 Mean height, diameter in breast height and survival of tested provenances (in percentage of the block mean), Block 01
Serial numbers are blockwise planting codes of provenances

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1993	1999	2003	2011	1977	1983
00	Oberhof	93	96		98		103	98		97	101	
01	Stryck, Sonderherkunft	106	100		105		110	109		104	101	
02	Gurker-Sirnitzwald	94	100		104		103	103		103	96	
03	Schussenried	106	103		109		108	102		104	97	
04	Froeschnitz	92	97		89		87	91		105	100	
05	Klingenbrunn	105	109		113		109	110		109	106	
06	Ostrovsk	84	91		81		84	87		81	106	
07	Brjansk, Zukovsk	107	109		107		91	91		90	101	
08	Soell	103	102		103		92	94		93	101	
09	Njubsk	57	54		35		61	75		85	96	
10	Matrei	104	104		108		96	96		96	101	
11	Bricalovic	100	99		88		84	83		80	81	
12	Bedretto, Airolo	71	83		75		75	81		82	96	
13	Lichtenstein	95	101		102		103	99		98	97	
14	Blumberg	98	96		102		101	93		96	101	
15	Oberes Lechtal	118	111		118		108	104		103	106	
16	Piana Selva, Faido	99	101		102		102	97		102	102	
17	Javorova Dolina	117	107		100		85	96		98	101	
18	Bad Grund	113	109		118		117	109		102	101	
19	Esserval-Tartre	90	78		77		77	82		86	101	
20	Ramsaasa	99	97		95		102	106		107	106	
21	Taennesberg	94	107		110		116	118		121	101	
22	St. Veit/Pongau	106	97		103		110	105		101	106	
23	Mindelheim	114	112		121		118	109		112	101	
24	Riechenhall-Nord	98	101		102		110	104		101	101	
25	Reit im Winkel	107	107		113		111	108		106	101	
26	Roan och Aafjord	62	65		47		59	63		59	106	
27	Garmisch	82	83		81		88	94		100	106	
28	Bogstad, 1434	82	91		84		96	90		89	106	
29	Wasserburg	97	95		99		101	103		102	97	
30	Lessach, 132	97	100		100		100	96		95	101	
31	Vlasim-Votice	116	114		119		113	112		110	97	
32	Klodzko	119	101		106		99	108		100	86	
33	Murau	110	107		117		115	115		119	101	
34	Umeaa Oestra, Zon 1	56	54		33		50	57		49	99	
35	Grossarl	110	109		117		114	111		114	101	
36	Rycerka	115	118		122		115	108		106	101	
37	Tamsweg/Salzburg	94	96		97		96	97		99	101	
38	Goenenbach	103	102		105		107	104		106	89	
39	Sternberk, Hruba Voda	104	114		113		112	113		113	97	
40	Leibnitz	113	110		120		113	114		117	97	
41	Kevele	101	103		101		100	100		97	101	
42	Oviken Bev.	67	62		46		59	66		58	96	
43	Nekla	116	104		109		121	113		113	98	
44	Rozmital pod Tremsinem	112	110		119		116	120		114	106	
45	Luhacovice, Loucka	99	108		111		112	114		114	97	
46	Puszcza Bialowieska	110	109		105		109	106		99	101	
47	Cervena Skala,	127	123		126		121	113		106	86	
48	Parangalitza	92	97		101		99	106		103	106	
49	Freudenstadt	93	88		95		90	90		85	92	

Table A.6.1 cont.

Provenance		Height			Diameter						Survival	
					%							
No.	Name	1972	1977	1983	1977	1983	1993	1999	2003	2011	1977	1983
50	Svrcina Hrabusice	112	115		117		115	114		105	106	
51	Kuldiga Revier	105	110		108		96	93		91	102	
52	Luhacovice, Stary Hroz.	88	97		93		100	102		110	106	
53	Seewiesen, Seeberg	102	98		102		92	93		100	106	
54	Magyarlak 2 A	114	109		111		105	98		98	106	
55	Graasten	104	100		102		100	99		96	96	
56	Borki	111	105		98		97	98		98	97	
57	Buchberg, Flachwald	110	100		101		91	93		108	101	
58	Borca, XV Sabasa Sting	129	127		123		108	110		108	106	
59	Froejered	100	97		96		95	91		92	101	
60	Obleze	105	99		99		97	94		96	101	
61	Horsovsky Tyn	117	107		109		111	118		122	101	
62	Alby Bev.	72	73		56		63	98		96	106	
63	Saldus Revier	99	101		93		91	88		85	106	
64	Zamberk	102	105		108		108	103		108	101	
65	St. Oswald	74	73		69		77	83		78	97	
66	Udmurtsk, Glazov	67	73		61		67	74		72	106	
67	Laxaa	97	97		94		92	89		90	101	
68	Ljungsnaes KRP.	81	83		71		87	84		85	106	
69	Dorna Cindreni	127	133		130		124	122		123	98	
70	Lantosque	96	94		103		99	99		102	101	
71	Cervena Recice-Lukavec	119	122		130		125	118		113	101	
72	Valea Putnei, 60	128	133		131		127	123		118	106	
73	Rabenstein	79	79		76		83	86		104	101	
74	Wisla, 54 A	123	119		132		126	114		113	101	
75	Zwiesel-West	90	98		91		95	96		97	106	
76	Liptovsky Hradok	106	114		110		107	105		106	93	
77	Sieber	98	103		107		110	107		108	93	
78	Jesenik-Zlate Hory	122	119		125		116	106		108	97	
79	Walsrode	115	109		116		109	119		117	99	
80	Zwiesel-Ost	94	93		97		96	95		90	101	
81	Prachatice, Ceske Zleby	110	109		115		114	116		120	106	
82	Jelak-Ceripasina	69	76		75		76	81		84	106	
83	Zwiesel-Ost	95	87		88		89	99		95	97	
84	Nepomuk	114	109		108		105	110		107	93	
85	Donaueschingen	86	88		82		89	86		85	97	
86	Bilovec, Fulnek	113	115		117		122	116		119	106	
87	Klastor pod Znievom	83	91		87		95	97		92	101	
88	Klingenbrunn	92	94		96		95	95		96	97	
89	Kuernach	102	103		107		111	110		109	106	
90	Buergerwald	101	104		109		104	101		100	106	
91	Prostejov, Dzbel	107	95		94		109	104		104	83	
92	Crailsheim	106	104		107		109	108		112	101	
93	Hagenow	94	96		91		97	97		90	97	
94	Zdarske Vrchy	116	112		121		111	114		115	97	
95	Memmingen	109	110		120		109	103		104	101	
96	Fladnitz-Schrems	99	101		106		97	100		100	97	
97	Balingen	93	97		94		101	100		102	101	
98	Groebming-Winkl	89	93		88		93	96		101	97	
99	Ramspau	90	94		90		95	96		102	86	
Block mean: H (m); D (cm); S (%)		**1.13**	**3.28**		**4.0**		**12.9**	**16.5**		**20.4**	**94.6**	

Table A.6.2 Mean height, diameter in breast height and survival of tested provenances (in percentage of the block mean), Block 02

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1992	1999	2002	2011	1977	1983
00	Tjumen, Uvat	70	63		47				68	67	83	
01	Kapfenberg	104	107		107				99	101	106	
02	Ujsoly	102	111		109				102	103	89	
03	Steinheim	83	93		85				101	104	94	
04	Fall	83	89		92				93	92	111	
05	Deggendorf	102	103		106				114	116	96	
06	Hnojnik, Rovina	116	111		118				104	105	89	
07	Kaluga	94	94		90				82	79	98	
08	Faido, Nante	107	102		102				108	108	88	
09	Schluchsee, Eschenmoos	105	103		108				107	116	96	
10	Albrechtice, Tisova	114	118		117				106	106	82	
11	Neureichenau	92	89		93				89	91	111	
12	Tegernsee	87	90		91				99	98	87	
13	Trebon, Zamecky	109	106		115				110	111	81	
14	Ebersberg	104	101		102				107	108	102	
15	Bogstad, 1422	81	89		80				93	88	106	
16	Altanca	79	84		84				89	92	106	
17	Stryck, Sonderherkunft	92	92		91				98	97	107	
18	Helgum	61	67		52				56	49	88	
19	Vesijako Pajulahden L.	88	81		66				73	69	111	
20	Weingarten	101	101		100				111	110	55	
21	Groenbo	87	94		86				91	95	105	
22	Leutasch	92	91		91				97	97	107	
23	Le Pertuis	109	108		110				113	111	82	
24	Ramsau-Eisenerz	110	102		100				98	97	106	
25	Tegernsee	100	96		105				100	98	96	
26	Tatranska Lesna	103	102		104				96	99	94	
27	Ostravice, Stare Hamry	107	106		104				101	97	111	
28	Schmiedefeld, Freibachtal	106	98		105				102	107	98	
29	Ostravice	108	109		110				102	107	102	
30	Varakalani Revier	116	118		113				97	94	99	
31	Moldovita, Sacries	111	116		114				113	114	102	
32	Hurdal, B 400	91	86		85				76	80	96	
33	Umeaa Oestra, Zon 2	39	46		23				-	-	89	
34	Tellerhaeuser, 44	95	101		110				111	106	116	
35	Bechyne	107	113		109				110	112	106	
36	Buchberg Flachwald	94	92		93				97	104	102	
37	Witow	116	115		112				104	105	106	
38	Smolnicka Huta	118	117		117				109	107	102	
39	Cimpeni, Nedei	103	110		108				105	106	116	
40	Podolinec, Levocske P.	115	108		106				103	103	88	
41	Manderfeld, Gilbuschheek	120	112		124				114	114	111	
42	Pielenhofen	103	102		108				109	111	101	
43	Blumberg	90	94		94				105	107	106	
44	Sucha 139 A/L	88	97		91				88	86	106	
45	Kroppefjaell	80	91		80				84	82	110	
46	Oberammergau	83	92		89				87	85	101	
47	Zytkiejmy	111	108		108				100	103	107	
48	Freiland	102	103		105				98	99	106	
49	Peiting	94	102		109				93	98	83	

Table A.6.2 cont.

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1992	1999	2002	2011	1977	1983
50	Dagdskin	98	102		98				86	82	106	
51	Smolno	113	101		106				108	108	116	
52	Szczecinek	117	105		110				109	108	89	
53	Serwy	131	124		122				104	103	102	
54	Partenkirchen	107	102		104				99	101	97	
55	Neustrelitz	100	96		94				99	99	98	
56	Le Reposoir	92	88		88				83	80	97	
57	Habartice/Planice	116	115		123				116	117	99	
58	Martei in Osttirol	97	90		95				89	88	102	
59	Wunsiedel	102	102		97				105	103	101	
60	Siegenburg	110	99		105				112	115	97	
61	Zdirec nad Doubravou	110	112		114				107	112	97	
62	Moldovita. I Demacusa	118	118		113				107	108	101	
63	Moravsky Krumlov	120	110		117				105	106	102	
64	Eglharting	97	95		93				109	108	83	
65	Knysperg nad Ohri	126	122		133				112	111	102	
66	Karnieszewice	111	107		112				106	104	111	
67	Karlstad. Zon 0	87	92		85				85	79	116	
68	Razlog	69	79		71				90	88	96	
69	Denklingen	105	103		111				102	105	92	
70	Cervena Recice	111	112		112				102	102	97	
71	Sarospatak, Haromhuta	100	90		100				109	109	111	
72	Gallmannsegg	105	101		102				99	96	111	
73	Trebic IV	115	112		118				122	124	106	
74	Pfalzgrafenweiler	98	97		102				105	105	97	
75	Groebming-Winkel	92	88		87				85	83	102	
76	Rabenstein, Typengemisch	94	95		98				96	90	106	
77	Bucovice, Nevojice	105	107		110				113	114	116	
78	Cierny Vah, Ipeltica	119	125		124				108	105	87	
79	Wehingen	85	90		91				93	92	96	
80	Westerhof	102	108		109				111	112	102	
81	Smolnicka Huta	120	115		117				109	110	116	
82	Pfunds	79	86		86				94	94	116	
83	Gsengegg	99	100		105				100	101	89	
84	Seefeld	81	86		90				91	88	111	
85	Altenhof, Attnang	100	101		107				106	111	96	
86	Gheorghieni, I Ditrau	97	101		101				109	110	96	
87	Marquartstein-West	105	98		98				100	103	100	
88	Starnberg	102	97		98				103	105	106	
89	Zwiesel-Ost VI/13	102	105		106				106	104	111	
90	Altshausen	90	96		94				107	115	92	
91	Hencov-Trest	110	105		106				118	122	111	
92	Bystrzyca Klodzka	105	105		107				100	98	97	
93	Kolonowskie	132	122		116				101	99	92	
94	Anyksiu	102	104		100				89	85	92	
95	Bispgaarden, 1	62	70		58				80	76	93	
96	Gammertingen	97	99		99				94	92	94	
97	Moosburg	105	104		110				112	112	97	
98	Muehlheim	99	97		96				97	95	102	
99	Sandvik KRP	93	101		97				94	93	105	
Block mean: H (m); D (cm); S (%)		**1.15**	**3.36**		**4.1**				**17.2**	**19.8**	**86.4**	

Table A.6.3 Mean height, diameter in breast height and survival of tested provenances (in percentage of the block mean), Block 03

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1992	1999	2002	2011	1977	1983
00	Cemerjansk	99	104		98				96	92	104	
01	Utzmemmingen	96	103		101				111	109	75	
02	Eberbach	92	94		91				102	96	70	
03	Hoechenschwand Kurhaus	92	93		99				101	98	110	
04	Bad Doberan	87	86		87				100	103	101	
05	Balingen	96	97		100				101	103	106	
06	Tatranska Lesna	108	114		113				100	97	106	
07	Werder 72	97	98		96				102	96	106	
08	Foerarp, Sk 1	96	98		99				103	112	109	
09	Jemielno	108	109		107				99	103	101	
10	Todtmoos	95	98		94				106	107	99	
11	Cham, Kugel-Gebiet	104	99		104				105	107	87	
12	Oberhofen	105	101		101				106	104	86	
13	Karwice	119	116		119				104	104	110	
14	Glashuette	96	95		95				105	108	101	
15	Starnberg	104	99		101				94	91	90	
16	Novgorod	87	94		86				89	84	90	
17	Diessen, ob. Spindler	110	104		107				105	106	101	
18	Foelz	96	95		89				96	99	110	
19	Mlada Boleslav-Zehrov	121	114		128				119	114	95	
20	Knusk, 2	113	106		94				84	80	105	
21	Tailfingen	95	99		99				105	104	91	
22	Oeblarn	102	99		104				107	105	70	
23	Eberbach	87	90		88				99	104	90	
24	Altenau 317	109	105		115				103	103	105	
25	Karlstift	112	110		115				113	109	75	
26	Knyszyn	105	110		107				104	103	96	
27	Jodlowno	115	114		115				107	109	82	
28	Pribram	110	109		111				112	109	94	
29	Vrchlabi	115	112		121				112	117	110	
30	Pyramis Koutra	87	92		94				91	91	101	
31	Bialowieza	115	112		107				99	98	91	
32	Kydne, Babylon	105	107		110				106	107	96	
33	Rantasalmi	88	85		74				63	61	109	
34	Cesky Rudolec, Lipnice	122	122		125				115	117	110	
35	Mittenwald	86	94		94				97	101	110	
36	Kaltwasser B. Stadl	88	89		86				91	89	100	
37	Przysucha	100	104		107				100	97	76	
38	Skinnskatteberg	93	96		94				90	87	105	
39	Isen	98	94		92				95	100	78	
40	Cimpeni, XV Valea Mare	114	110		106				102	103	91	
41	Sopron 203 D	110	103		112				115	115	109	
42	Klein Soelk/Steiermark	100	98		97				99	100	114	
43	Piwniczna	115	113		116				105	105	99	
44	Brandenberg	95	89		94				99	96	96	
45	Nedzinant	85	87		93				88	93	110	
46	Steinheid, Kieferleskopf	108	105		113				110	108	114	
47	Hohenegg	94	96		94				101	102	101	
48	Nove Mesto na Morave	103	104		105				112	108	110	
49	Zwiesel/West, Sandau	103	110		111				115	115	95	

Table A.6.3 cont.

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1992	1999	2002	2011	1977	1983
50	Eisenkappel	108	107		117				115	114	97	
51	Ukmerges, Paschilsk Rev.	98	100		95				87	81	96	
52	Hohenschwangau	74	78		72				75	79	107	
53	Snilfjord, Troendelag	57	58		41				61	-	82	
54	St. Oswald	95	95		99				100	105	73	
55	Rycerka, Kiczora	106	102		96				113	113	114	
56	Svetla nad Sazavou	122	114		121				119	120	101	
57	Kristinehamn	75	82		72				79	82	99	
58	Bogstad, 1426	96	93		88				94	95	114	
59	Rjasan, Pervomaisk	85	95		86				87	84	109	
60	Zwiesel-Ost, Dachshuette	101	101		103				106	106	110	
61	Sosnovsk	93	99		92				84	78	102	
62	Plan Bois	90	81		80				100	99	105	
63	Muesingen	88	99		105				105	105	65	
64	Chamrousse	94	86		86				91	93	109	
65	Altoetting	102	99		98				95	101	99	
66	Edsleskog	80	90		82				90	88	103	
67	Spisska Nova Ves	116	116		121				111	110	94	
68	Klosters	86	82		85				85	83	105	
69	Himmelberg-Mooswald	96	97		97				106	109	105	
70	Altanca	86	95		101				99	99	98	
71	Policka, Budislav	117	113		118				115	114	104	
72	Kreuzen, Stockenboi	95	97		101				99	103	110	
73	Rila-Gebirge Nr 1, Abt. 8	99	104		110				113	117	114	
74	Cimpeni, Dara	123	120		124				121	123	114	
75	Cierny Vah, Rovienky	115	118		121				112	113	105	
76	Milevsko-Kostelec	116	108		114				115	114	106	
77	Betzigaus	90	90		88				110	113	91	
78	Bispgaarden 2	68	73		58				81	73	102	
79	Nordmaling	62	61		45				64	54	103	
80	Plana u Marianskych Lazni	113	112		112				103	103	100	
81	Sucha 139 A/L	114	107		107				94	92	109	
82	Hinterhof West, Eibelkogel	99	93		94				91	93	86	
83	Dobele Revier	110	108		101				90	89	109	
84	Baindt	96	99		99				96	97	101	
85	Gaischorn	104	103		107				105	104	109	
86	Kdydne-Loucim	110	108		111				104	105	114	
87	Berchtesgaden	107	105		107				102	100	82	
88	Cimpeni, Valea Mare	105	113		111				102	103	94	
89	Spiegelau	111	110		110				110	109	105	
90	Kelheim-Nord	111	104		106				103	104	110	
91	Kezmarok, Vaj. Lesy	113	108		107				96	97	114	
92	Seiz	103	100		105				109	106	109	
93	Javorova Dolina 155 A	87	85		82				87	82	105	
94	Vrchlabi	108	108		112				109	110	101	
95	Buxabygd KRP	84	95		87				88	84	105	
96	Puus, I AVD 64-67	101	98		102				102	100	109	
97	Bogstad, 1435	94	98		90				90	87	109	
98	Javorova Dolina 155 A	103	99		100				96	94	109	
99	Orawa	119	119		122				110	106	105	
Block mean: H (m); D (cm); S (%)		**1.23**	**3.62**		**4.6**				**17.1**	**19.8**	**87.6**	

Table A.6.4 Mean height, diameter in breast height and survival of tested provenances (in percentage of the block mean), Block 04

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1993	1999	2003	2011	1977	1983
00	Parchim	86	92		91		93	94		97	103	
01	Teljakov, Uzda	109	108		100		92	92		87	89	
02	Beglika	92	90		92		90	90		92	103	
03	Pfullendorf	98	93		99		94	98		100	103	
04	Kitzbuehel	95	95		99		97	100		100	91	
05	Gschwornrieser Bergwald	89	95		97		98	97		98	95	
06	Rauris	92	95		96		102	100		122	112	
07	Visoky Chlumec-Veletin	114	107		109		102	106		110	107	
08	Boubin 1	103	105		107		116	118		110	101	
09	Vlasim	105	109		112		111	110		113	102	
10	Lenzkirch	75	73		67		82	85		82	97	
11	Moravska Trebova	101	104		105		101	107		105	103	
12	Brosteni, VII Piriul Omului	115	121		112		118	118		107	112	
13	Hauzenstein	112	111		117		114	113		113	87	
14	Klodzko, 68 E	115	118		126		117	119		117	103	
15	Anzing	93	95		94		106	106		116	93	
16	Velfjord, Velvelstad	64	65		50		66	67		59	106	
17	Stanz-Kindtal-Allerheiligen	114	114		120		110	109		105	107	
18	Tuttlingen	90	88		86		96	95		100	99	
19	Viken och Turinge	56	59		42		78	72		48	91	
20	Ziegenberg	103	103		104		105	105		101	96	
21	Oberammergau	97	101		103		104	102		110	102	
22	Vsetin, Pozdechov	124	117		127		112	107		103	98	
23	St. Martin am Silberberg	113	109		114		111	111		104	102	
24	Loendal F. 355	110	107		107		95	92		108	93	
25	Zwiesel-Ost	97	94		95		98	95		110	98	
26	Vysoky Chlumec, Veletin	100	103		104		109	115		110	103	
27	Moravska Trebova	109	105		110		115	114		106	98	
28	Lessach, 146	102	95		95		90	94		109	103	
29	Frenstat pod Radhostem	105	110		114		110	115		119	97	
30	Blaubeuren	109	108		106		110	108		111	112	
31	Narewka	114	116		116		104	104		102	107	
32	Udmurtsk, Balezinsk 23	69	67		55		63	72		78	117	
33	Brunnerberg	98	98		96		93	91		105	91	
34	Hronec	103	113		114		112	111		108	112	
35	Kysihybel	109	110		112		107	105		101	98	
36	Eisenerz	101	101		100		96	96		92	107	
37	Hoting Bev.	57	61		47		66	63		-	86	
38	Muehldorf, Fors Puerten	93	97		96		101	109		98	85	
39	Dorna Cindreni, II Rosia	115	124		121		117	115		111	98	
40	Zwiesel-West, Schmalzau	109	99		109		99	97		102	103	
41	Deutschlandsberg	106	104		106		103	102		99	98	
42	Wegierska Gorka	105	108		105		107	107		95	99	
43	Prochowice	110	111		115		116	115		115	89	
44	Wloclawek	102	106		103		111	115		94	103	
45	Damnica	110	103		104		113	110		100	103	
46	Liptovsky Hradok	105	109		106		95	98		90	103	
47	Borki Knieja	102	105		99		95	99		110	107	
48	Kirchzarten	113	100		104		103	103		117	103	
49	Zwiesel-Ost (mix of types)	100	91		95		89	91		83	103	

Table A.6.4 cont.

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1993	1999	2003	2011	1977	1983
50	Mindelheim	100	98		98		103	107		111	90	
51	Seewiesen, Seereith	104	98		100		100	97		96	107	
52	Saldus Revier	106	109		103		92	84		85	98	
53	Bayreuth-West	113	114		114		114	115		107	103	
54	Chlum u Trebone	122	110		112		110	111		99	97	
55	Koeszeg 60 A	118	115		116		116	115		111	107	
56	Ceska Trebova	114	111		111		118	117		121	81	
57	Schneegattern	111	107		113		108	107		94	85	
58	Amorbach-West	112	109		113		109	108		102	98	
59	Piana Selva, Faido	85	90		91		89	88		91	94	
60	Klingenbrunn	81	80		77		73	77		66	107	
61	Mauth-Ost	80	91		87		89	89		98	107	
62	Polanow	112	108		112		117	116		111	94	
63	Baden-Baden	109	100		99		100	98		76	102	
64	Virserum	98	99		95		96	93		83	98	
65	Chlum u Trebone	112	114		115		122	124		111	105	
66	Konopiste, Dubsko	120	117		118		108	109		92	112	
67	Plan Bois	98	83		84		89	87		84	84	
68	Oberes Lechtal	98	98		101		108	110		104	99	
69	Reinberg/Vorau	108	105		106		99	98		96	107	
70	Bezcetsk	88	86		76		78	75		83	93	
71	Mechterstaedt	102	107		111		109	108		105	107	
72	Isny	113	107		117		112	110		107	98	
73	Foret de Risoud	79	80		80		85	81		75	92	
74	Westerhof	102	107		111		116	117		108	98	
75	Babenhausen	94	101		98		95	93		101	88	
76	Aakakoep	91	96		88		86	89		91	97	
77	Vsetin, Hovezi	119	119		124		113	112		120	98	
78	Eisenkappel 1.	99	95		98		96	97		98	103	
79	Bonetage	82	79		77		86	92		89	107	
80	Saaremaa Revier	89	89		77		78	76		83	102	
81	Reit im Winkel	106	100		103		94	96		105	107	
82	Oerebro	83	92		84		93	90		83	106	
83	Schoenmuenzach	92	90		89		90	88		93	95	
84	Gradisch	106	109		115		112	114		113	102	
85	Njubsk	57	59		43		59	55		-	103	
86	Cervena Skala	101	105		105		106	104		109	112	
87	Cucureasa, 65	121	126		128		117	119		115	103	
88	Bad Grund 126	101	101		103		104	105		103	103	
89	Kuernach	96	91		95		91	89		102	94	
90	Westerhof 48 A	109	115		119		118	119		121	94	
91	Klastor pod Znievom	108	116		114		107	105		108	88	
92	Janovice u Rymarova	119	116		125		110	107		114	101	
93	Dietenheim	102	101		101		100	101		102	98	
94	Ruhpolding-West	93	95		96		104	103		96	112	
95	Hohenaschau	93	100		102		100	99		98	98	
96	Murnau	81	90		89		89	88		108	97	
97	Rabenstein	72	70		67		63	67		52	108	
98	Boubin 4	97	99		99		95	92		94	94	
99	Stralsund	95	94		95		99	100		113	103	
Block mean: H (m); D (cm); S (%)		**1.18**	**3.60**		**4.6**		**14.9**	**17.5**		**22.9**	**89.4**	

Table A.6.5 Mean height, diameter in breast height and survival of tested provenances (in percentage of the block mean), Block 05

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1992	1999	2003	2011	1977	1983
00	Olecko	116	115		113				116	116	106	
01	Broczyno	98	99		100				96	100	114	
02	Sauerlach	94	91		88				95	106	116	
03	Ebersberg	109	118		124				107	104	103	
04	Ottobeuren	120	110		118				112	107	102	
05	Kaisheim	110	108		114				105	113	83	
06	Vlasim	142	121		132				112	109	108	
07	Bruntal, Mezina	103	106		104				95	88	88	
08	Vrchlabi	108	104		110				102	108	95	
09	Lichtenstein	100	102		106				108	111	83	
10	Szentgotthard 1 C	122	102		103				101	104	127	
11	Zwiesel-Ost, Haselau	83	89		88				106	100	106	
12	Fuerstenberg/KRS B.	118	114		117				129	126	101	
13	Piberegg	113	111		112				107	112	95	
14	Donnersbach	116	113		117				99	92	99	
15	Neustadt	103	91		91				93	104	95	
16	Chlum u Trebone-Hamr	98	103		101				103	109	112	
17	Poniki	102	96		96				93	98	83	
18	Cervena Recice, Rousinov	123	115		124				104	107	112	
19	Oberkochen	89	92		83				101	103	110	
20	Cervena Skala	110	113		119				101	98	95	
21	Kappl-See	67	74		65				73	72	95	
22	Schoenmuenzach	84	89		84				104	110	114	
23	Schladming, F. V. Coburg	99	103		105				102	102	114	
24	Poprad	93	98		101				110	120	102	
25	Val Visdende	104	98		111				112	109	108	
26	Frenstat p. Radhostem-Ob.	122	115		117				115	118	83	
27	Javorova Dolina 155 A	100	102		102				85	85	126	
28	Manderfeld, Gilbuschneek	94	101		101				111	106	89	
29	Wielgowo	116	106		111				115	123	102	
30	Frasin, X Ursoaia	117	118		120				102	102	106	
31	Passy	84	88		84				86	98	108	
32	Comanesti, IV Bortea	112	116		125				115	112	108	
33	Liptovsky Mikulas	123	126		130				101	108	86	
34	Scheifling	97	93		95				92	96	89	
35	Berwang	80	78		72				103	109	76	
36	Neureichenau	82	87		84				85	79	99	
37	Kaufbeuren	96	99		101				99	92	123	
38	Freiland	88	84		78				101	101	76	
39	Pressath	122	119		128				118	121	85	
40	St. Veit/Pongau	103	98		100				100	98	117	
41	Oberhof, Mittelberg	107	102		105				97	104	76	
42	Gundelsheim	99	107		102				104	93	104	
43	Wehingen	102	98		106				120	110	97	
44	Luzna	103	107		109				110	116	110	
45	Ostravice	97	95		92				107	106	102	
46	Maenttae, Kasvuala	93	87		76				81	65	90	
47	Cervena Skala, Martaluska	98	104		110				87	85	124	
48	Massif Central, Mt. Megal	104	100		103				106	108	79	
49	Eglharting	69	73		62				102	102	87	

Table A.6.5

Provenance		Height			Diameter						Survival	
							%					
No.	Name	1972	1977	1983	1977	1983	1992	1999	2003	2011	1977	1983
50	Westerhof, Elit	90	97		92				94	105	127	
51	Betzigau	78	85		78				104	111	87	
52	Ujsoly	100	107		108				98	96	108	
53	Stronie Slaskie	96	96		98				95	101	131	
54	Sibiu, Paltinis	89	93		93				98	106	123	
55	Saldus Revier	94	105		98				83	77	99	
56	Viljandi Revier	93	100		95				80	83	95	
57	Partenkirchen	91	95		94				118	116	98	
58	Einsiedel	113	117		122				101	99	92	
59	Floning Kapfenberg	110	106		105				107	96	89	
60	Bogstad, 1421	72	75		60				81	87	79	
61	Crespato, Airolo	90	96		91				101	97	93	
62	Carlsfeld, 275	89	88		95				87	87	99	
63	Cavagnago	90	87		88				86	88	98	
64	Witow	137	130		143				124	118	92	
65	Rezekne Revier	101	105		100				94	90	98	
66	Fuerstenfeld	113	110		119				110	110	76	
67	Ryssby	91	89		84				75	73	93	
68	Lilienfeld	84	88		86				95	96	112	
69	Marquarstein-West	78	86		80				95	94	123	
70	Bialobrzegi	95	107		102				94	85	102	
71	Sternwald/Leonfelden	79	88		83				105	103	121	
72	Salem	83	83		82				86	83	121	
73	Belogradtschik	89	88		88				97	87	63	
74	Trieben	109	104		106				91	97	95	
75	Tepla	105	106		105				119	117	126	
76	Sinaia-Gurguiata	80	87		88				93	92	83	
77	Dagdskin	112	105		97				84	83	97	
78	Kuernach	90	96		100				113	113	108	
79	Westerhof	113	109		113				109	108	119	
80	Litovel, Lostice	120	110		113				100	96	99	
81	Cizova u Pisku	103	101		102				103	112	114	
82	Glashuette	102	95		94				101	103	112	
83	Kup, Murow	108	105		100				96	86	114	
84	Gessertshausen	93	99		102				93	86	91	
85	Sverdlovskoje Oblast	71	68		51				-	-	91	
86	Riksstens KRP	80	80		71				82	75	79	
87	Bottnaryd	83	84		74				106	100	128	
88	Boskovice, Kunstat	116	108		113				107	105	108	
89	Hurdal, B 300	92	94		92				87	94	114	
90	Ukmerges	125	127		128				105	107	86	
91	Illertissen	87	85		88				103	117	44	
92	Bodum	86	77		65				96	88	91	
93	Tatranska Lesna	109	111		111				103	100	89	
94	Olomouc, Hranice	118	120		125				110	114	90	
95	Groenbo	106	102		94				80	78	83	
96	Jasina	118	128		126				100	94	92	
97	Kraslice-Nancy	107	109		124				97	94	94	
98	Rajnochovice	96	97		97				105	106	102	
99	Koenigseggwald	95	98		93				81	83	112	
Block mean: H (m); D (cm); S (%)		**0.96**	**3.51**		**4.3**				**20.4**	**23.6**	**63.0**	

Table A.6.6 Mean height, diameter in breast height and survival of tested provenances (in percentage of the block mean), Block 06

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1992	1999	2004	2011	1977	1983
00	Trebic	105	109		109				106	105	100	
01	Kaludjerske Bare	82	82		82				89	86	123	
02	Bogstad 1432	96	101		99				113	111	101	
03	Teisendorf, Lebenau	118	111		111				101	112	98	
04	Lenzkirch, Feldsee	90	88		90				85	83	99	
05	St. Oswald	94	89		88				86	88	114	
06	Wolozin	120	114		117				101	99	118	
07	Zjeimeny	98	102		95				84	85	112	
08	Disentis	80	78		73				73	70	110	
09	Satakunta	99	93		87				90	87	90	
10	Zelezna Ruda	96	98		94				108	107	104	
11	Melnik, Semanovice	114	115		116				112	114	103	
12	Brasov, Piatra Mare	85	95		96				96	94	95	
13	Remeti, Zerna	139	130		141				119	117	106	
14	Rycerka	109	113		112				102	99	108	
15	Murau	96	93		93				84	82	103	
16	Rjasan, Moshary	97	102		92				94	93	88	
17	Sandvik KRP	96	91		89				89	84	105	
18	Rajnochovice	118	116		124				113	114	97	
19	Leoben-Leising	109	108		111				112	114	95	
20	Prasily	92	93		91				86	84	98	
21	Cesky Krumlov	106	101		101				98	101	98	
22	Justingen	97	97		101				100	100	91	
23	Nyboda	60	59		44				69	78	93	
24	Kalwang	98	96		92				81	83	97	
25	Jaidhof	105	100		105				132	132	94	
26	Fladnitz-Passail	96	96		96				98	100	104	
27	Fussingoe, Udskovene	106	102		108				108	107	88	
28	Cervena Skala	98	105		105				115	111	107	
29	Ottobeuren	94	89		87				111	111	102	
30	Sichow	102	103		101				109	110	88	
31	Kreisbach	95	99		99				108	107	114	
32	Sierpc	96	93		90				92	95	90	
33	Kercaszomor 20 A	100	101		104				107	100	93	
34	Krynica	103	112		112				108	107	113	
35	Toplita	119	118		126				114	114	113	
36	Partenkirchen	81	79		82				84	96	112	
37	Niederndorferberg	102	99		99				102	100	93	
38	Weidenberg	104	105		110				96	93	101	
39	Aelvdalen	78	80		73				72	77	104	
40	Jundola	91	91		99				114	109	123	
41	Wunsiedel	115	117		120				112	111	107	
42	Flachslanden	105	105		105				106	108	98	
43	Knusk, 19	92	99		92				92	89	101	
44	Karlsdal	101	101		99				72	71	61	
45	Dieburg	113	110		113				117	116	90	
46	Tatranska Lesna	88	102		95				102	102	106	
47	Altanca	97	96		99				95	94	99	
48	Westerhof 50, 58	133	130		134				113	114	77	
49	Rauris	97	93		96				104	104	107	

Table A.6.6 cont.

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1992	1999	2004	2011	1977	1983
50	Sobowidze	110	113		115				103	100	93	
51	Selbu, Klaebu	76	74		65				58	67	108	
52	Illertissen	103	103		106				106	109	116	
53	Naes	75	75		66				86	83	88	
54	Kumialka	102	108		103				89	90	112	
55	Javorova Dolina	110	110		109				101	103	108	
56	Zwierzyniec	105	108		102				105	103	98	
57	Spiegelau	116	112		123				102	100	88	
58	Muenchen-Sued	102	99		99				95	96	70	
59	Ventspils Revier	99	100		91				94	92	101	
60	Diessen	97	100		100				101	104	104	
61	Jablunkov, Girova	114	114		119				115	121	104	
62	Hnusta	103	112		111				104	102	103	
63	Krivoklat	103	110		112				105	105	90	
64	Plana nad Luznici	115	110		112				113	119	103	
65	Aich	108	100		102				109	105	107	
66	Foelz, Greith	104	100		96				91	94	98	
67	Cierny Vah, Rovienky	107	109		110				114	107	103	
68	Ed, Dalsland	85	89		86				91	89	90	
69	Passail-Teichalpe	103	99		103				102	107	91	
70	Pyramis Koutra	91	94		101				94	94	113	
71	Rottweil	98	96		99				108	108	103	
72	Sternberk, Mutkov	118	116		118				119	111	88	
73	Diessen	96	103		103				102	100	91	
74	Groenenbach	104	104		101				104	102	82	
75	Zwiesel-Ost	103	107		107				102	101	107	
76	Kohlstetten	104	91		92				101	99	91	
77	Bischofswiesen	98	97		100				97	97	103	
78	Pirin	85	93		94				109	109	109	
79	Memmingen	107	108		113				112	112	103	
80	Suedharz	108	105		113				104	105	99	
81	Bischofswiesen	95	95		95				83	90	91	
82	Spiegelau	86	81		83				101	98	98	
83	Horni-Marsov	103	108		111				103	99	98	
84	Riedlingen	90	95		92				98	101	118	
85	St. Laurent-du-Jura	77	77		79				85	83	108	
86	Raitis	91	91		89				94	92	104	
87	Hinterhof-West	111	102		108				97	100	109	
88	Untertal, St. Kathrein	110	108		108				102	101	97	
89	Passy	92	91		92				95	93	99	
90	Bausskij	108	106		97				97	93	95	
91	Gorowo Ilaw.	101	105		96				95	93	107	
92	Hnojnik, Kosariska	100	107		106				95	92	94	
93	Ottobeuren	103	103		106				103	107	103	
94	Pappenheim	98	91		89				118	124	91	
95	Elgersburg	104	110		112				107	111	99	
96	Poitschach	100	97		100				100	97	88	
97	Bad Doberan	88	88		89				115	117	104	
98	Bolkow	114	112		118				120	118	109	
99	Chatel	72	74		68				82	90	101	
Block mean: H (m); D (cm); S (%)		**1.21**	**3.96**		**5.0**				**19.5**	**21.6**	**77.7**	

Table A.6.7 Mean height, diameter in breast height and survival of tested provenances (in percentage of the block mean), Block 07

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1992	1999	2003	2011	1977	1983
00	Cosna, Cucureasa	114	118	112	121	113	109	108	108	76	95	96
01	Koenigsbronn	97	96	104	100	102	109	110	113	107	99	91
02	Nove Hrady-Dolni Hvozd	125	116	111	117	112	107	112	107	178	95	96
03	Ringamaala KRP	75	85	91	76	83	91	94	88	84	104	105
04	Eckersholm	79	87	95	78	87	92	87	87	92	99	100
05	Floda	93	96	99	90	94	89	85	92	85	99	100
06	Stary Krakow	113	109	103	109	105	102	101	100	109	99	100
07	Babki	111	108	108	106	108	107	109	108	100	99	100
08	Tavejanne, Bex	77	78	82	71	74	61	61	61	-	104	105
09	Broczyno	111	112	108	115	112	112	112	109	90	95	96
10	Zlota Wies	106	108	103	103	101	106	104	103	106	99	100
11	Zwingenberg	98	100	99	97	98	104	104	107	118	95	96
12	Luhacovice, Strani	115	113	111	114	112	110	111	110	113	99	100
13	Liptovsky Hradok	116	113	110	117	113	114	117	114	114	95	96
14	Moravska Trebova	111	116	110	116	114	117	117	115	110	100	101
15	Tussenhausen	99	97	98	96	97	100	107	105	109	99	100
16	Reutte	122	114	108	112	106	105	107	107	97	95	96
17	Crespato, Airolo	95	99	97	97	101	100	101	111	112	104	105
18	Javorova Dolina	97	98	100	105	101	95	93	96	82	99	96
19	Cavagnago	83	79	83	85	84	89	87	93	92	104	100
20	Nove Hrady-Horni Hvozd	102	107	107	106	106	104	103	100	95	104	105
21	Burghausen	108	103	104	108	103	110	112	110	122	104	105
22	Mengen	92	92	96	88	92	85	89	90	101	94	95
23	Baden-Baden	90	94	98	94	96	95	95	98	112	96	97
24	Pfronstetten	99	99	101	98	104	101	104	101	86	60	57
25	St. Salvator	97	96	95	96	93	93	96	99	96	104	105
26	Boubin 2	110	106	103	102	105	104	104	103	111	99	96
27	Thiersee	96	98	98	106	105	102	101	98	97	104	105
28	Lindenborg	104	106	104	104	102	101	103	98	97	104	105
29	Nove Hrady, Horni Hvozd	104	106	104	109	107	107	108	107	-	99	100
30	Klastor pod Znievom	107	111	110	109	109	105	106	105	117	95	96
31	Frantiskovy Lazne	104	103	104	105	104	107	109	111	116	99	96
32	Vitkov-Budisov	109	104	101	108	104	109	110	107	92	104	100
33	Oestlandsgarn	86	89	92	83	87	78	73	70	-	104	105
34	Bogstad, 1440	89	90	95	87	92	106	106	114	136	99	100
35	Knittelfeld	104	104	106	100	98	93	90	90	93	99	100
36	Velke Karlowice, Vranca	106	106	103	103	104	105	107	104	96	87	84
37	Lessach	100	97	96	98	94	98	95	93	89	104	105
38	Zeltschach	113	109	110	112	108	99	98	93	96	100	101
39	Altoetting	96	90	93	89	90	91	90	95	88	99	96
40	Rungstock	104	108	106	111	110	110	110	105	108	99	100
41	Betzigau, Boerwang	100	101	100	99	99	101	100	105	114	104	105
42	Mauth-Ost	98	98	99	102	100	105	104	101	97	104	100
43	Witebsk	87	97	99	90	95	92	90	89	88	99	95
44	Terepetsk	97	96	92	89	88	92	94	90	71	104	105
45	Ruzomberok	112	110	110	114	116	113	116	109	110	104	100
46	Wismar	110	111	111	112	112	109	109	110	102	104	105
47	Kuernach	95	96	98	96	97	104	109	110	95	104	105
48	Policka, Pusta Kamenice	109	110	106	111	110	107	106	101	99	104	105
49	Cucureasa	102	113	111	115	115	114	114	111	102	99	100

Table A.6.7 cont.

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1992	1999	2003	2011	1977	1983
50	Eisenkappel	105	96	95	99	95	95	94	98	96	100	101
51	Vrchlabi	102	105	105	113	109	108	109	111	110	99	100
52	Cervena Skala	112	111	108	116	113	107	105	103	100	104	100
53	Tegernsee	96	94	94	103	102	98	96	99	88	99	100
54	Hrabusice	121	114	110	119	115	112	113	111	100	99	100
55	Marginea	113	116	110	117	114	114	113	112	102	104	105
56	Verior Revier	103	102	100	97	96	94	92	91	70	104	100
57	Horni Marsov, Velka Upa	99	102	104	103	102	97	97	91	80	104	105
58	Vorau	109	104	102	105	100	105	104	99	99	104	105
59	Veitsch-Neuberg	103	101	99	100	97	96	96	106	91	104	105
60	Siessen	98	95	95	94	95	94	97	101	91	99	100
61	Liembergwald/Zell am See	99	99	102	99	97	99	100	103	104	104	105
62	Mitterberg I. Ennstal	102	97	100	93	92	102	102	97	136	99	100
63	Kloten, Zon 1	92	97	99	93	97	89	86	89	79	93	94
64	Przerwanki	106	105	106	101	104	105	105	102	102	104	105
65	Stuebing/Gamskogel	104	105	103	107	103	98	100	102	88	104	105
66	Dobris, Obora	116	113	108	120	117	114	113	110	106	104	105
67	Blankenburg	108	105	104	108	107	115	114	109	101	104	105
68	Vallen Bev.	54	56	61	41	51	81	82	80	-	92	93
69	Hohenaschau	102	102	101	105	101	102	102	104	103	104	105
70	Val di Fiemme	99	101	106	105	107	104	105	104	120	95	96
71	Ipsheim	110	105	104	106	103	104	106	114	129	95	96
72	Udmurtsk, Balezinsk	66	72	78	62	67	72	77	85	102	104	96
73	Jasina	115	114	109	116	110	107	105	101	78	104	105
74	Fjaellsjoe Bev.	72	74	75	68	74	68	69	72	68	86	81
75	Clausthal-Zellerfeld	91	93	99	91	96	103	103	98	108	95	92
76	Rabenstein	91	95	98	99	101	103	100	102	97	104	105
77	Zwiesel-Ost, Plattenfichte	75	76	80	73	77	68	62	69	70	91	92
78	Borovec	68	74	77	69	75	75	70	70	62	104	100
79	Urjala Honkolan	97	91	90	91	90	80	75	70	104	99	100
80	Landsberg	99	101	102	102	103	98	101	102	115	100	101
81	Klodzko	106	105	100	110	111	112	114	108	106	104	105
82	Muenchen-Sued	96	97	98	97	101	103	104	104	103	104	105
83	Joenstorp, Galthult	100	100	102	101	106	108	112	106	100	104	100
84	Kramersdorf	105	104	104	106	102	106	106	103	98	104	105
85	Zakopane	77	84	89	84	89	88	86	84	76	104	105
86	Wegierska Gorka	110	111	110	111	113	112	111	113	112	100	101
87	Tegernsee	97	96	97	99	97	99	98	97	92	104	105
88	Neustadt	91	95	97	91	94	93	96	101	119	95	96
89	Herrenwies	94	90	91	91	91	90	87	93	98	95	96
90	Mali Lom	100	93	90	100	98	99	95	100	103	104	105
91	Dobris, Chouzava	113	112	107	108	110	116	118	117	115	104	105
92	Judenburg	103	99	100	97	96	96	96	99	84	104	100
93	Passau-Sued	99	97	102	100	100	97	95	98	84	104	100
94	Baindt	99	106	106	102	105	107	108	109	118	99	100
95	Schluchsee	92	91	92	98	100	98	102	106	124	104	105
96	Buekkszentkereszt	103	105	104	106	107	100	96	97	72	104	100
97	Gerardmer	99	93	95	97	96	95	93	103	-	104	105
98	Gurktal	108	104	104	105	103	101	103	100	103	104	105
99	Liezen	116	111	108	112	108	111	110	105	97	104	105
Block mean: H (m); D (cm); S (%)		**1.39**	**4.50**	**9.11**	**5.9**	**10.8**	**16.6**	**19.2**	**21.1**	**24.8**	**96.5**	**95.5**

Due to severe windbreak, the 2011 assessment found a low number of living trees in more than 30 provenances in Block 07 (see *Table A.12*). Grey marked values in the table are only informative; the authors do not recommend using them for statistical purposes.

Table A.6.8 Mean height, diameter in breast height and survival of tested provenances (in percentage of the block mean), Block 08

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1992	1999	2003	2011	1977	1983
00	Kirchzarten	86	90	93	89	91	90	86	89	90	103	104
01	Hinterhof Ost, Brenner	110	101	99	104	96	100	100	99	100	99	100
02	Burladingen	96	93	96	99	98	95	96	97	108	103	104
03	Mochenwangen	98	100	101	99	98	106	105	105	104	103	104
04	Traunstein	100	97	100	95	97	97	97	104	105	103	104
05	Mitterdorf	99	104	104	103	101	103	103	102	104	103	104
06	Peitz/Tannenwald	105	103	100	105	100	101	101	111	111	103	104
07	Prionegsk	77	77	83	70	77	78	73	70	66	103	95
08	Cazis	82	87	95	86	92	83	84	84	90	103	104
09	Klingenbrunn	88	93	100	91	95	94	95	100	102	85	86
10	Ramsau	102	101	102	106	101	96	100	95	93	95	96
11	Stammham	91	92	98	88	90	99	107	106	106	87	88
12	Grossarl	94	94	96	96	96	93	94	101	97	99	100
13	Cervene Porici Kaliste	101	112	108	108	105	106	106	110	110	103	104
14	Bruntal, Siroka Niva	105	108	108	105	103	109	107	107	111	103	100
15	Emmach/Murau	105	108	107	112	106	103	101	100	100	91	92
16	Nove Hrady, Dolni Hvozd	108	115	107	119	117	110	111	113	112	103	104
17	Passau-Nord	104	106	106	108	106	100	99	100	101	95	96
18	Weissenstadt	104	106	108	107	107	111	110	113	118	99	100
19	Wolfach	93	89	100	97	96	97	100	97	99	84	85
20	Villingsberg	82	83	88	73	78	80	77	80	77	103	104
21	Javorova Dolina	93	100	100	90	92	92	89	96	95	103	104
22	Bebenhausen	109	106	107	111	107	118	117	112	118	99	100
23	Bialowieza	111	110	106	106	104	109	107	112	112	103	104
24	Muehldorf	103	104	104	103	105	104	109	102	111	103	104
25	Ruciane	116	108	105	104	103	98	97	98	99	103	104
26	Znojmo	115	109	104	113	109	104	104	104	110	99	100
27	Hrabusice	109	109	105	113	109	107	101	99	98	103	104
28	Sucha	107	106	102	103	99	96	94	89	86	103	104
29	Zwiesel-Ost	78	79	84	76	82	69	67	74	68	99	87
30	Emmach/Murau	101	100	102	101	98	94	96	99	104	103	104
31	Tyldal, Aalen	63	65	70	55	63	70	73	65	63	89	85
32	Bogstad, 1433	91	92	91	86	87	81	86	87	87	98	100
33	Wasserburg	97	98	99	99	104	98	99	99	97	103	104
34	Molvotitsk	96	98	98	94	93	86	82	85	82	103	104
35	Graasten	117	109	105	112	111	102	100	105	102	103	104
36	Nasswald	94	93	100	92	100	101	102	99	94	103	104
37	Wronki	106	108	108	109	111	114	119	117	119	99	100
38	Hillet	77	84	87	75	81	82	87	88	85	103	104
39	Turinge Bev.	77	75	80	65	70	67	66	61	58	103	94
40	Soboljansk Revier	110	113	107	107	106	103	101	98	94	103	104
41	Ignalino	106	107	102	99	98	94	89	85	80	103	100
42	Weidenberg	107	109	106	108	105	113	115	113	114	103	104
43	Wundelsiedel-Weissenstadt	104	106	104	104	104	109	107	109	108	99	100
44	Klastor pod Znievom	108	110	106	113	109	106	114	115	116	99	100
45	Kuernach	98	94	97	96	98	82	78	82	78	99	96
46	Garmisch	86	90	94	83	90	78	75	72	77	90	91
47	Galu	113	116	111	111	109	111	111	108	108	99	100
48	Rycerka	112	113	109	118	109	117	115	110	108	103	104
49	Diktschanska	75	86	93	87	98	105	108	104	99	99	95

Table A.6.8 cont.

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1992	1999	2003	2011	1977	1983
50	Sonkajaervi	70	67	74	57	63	56	57	58	59	95	92
51	Zwierzyniec Lubelski	113	111	105	110	111	112	114	108	111	99	96
52	Luban Slaski	114	112	109	118	116	118	117	110	109	103	104
53	Moosburg	104	106	105	104	103	106	109	106	105	103	104
54	Jilove u Prahy	117	109	106	111	112	110	108	111	107	103	104
55	Cervena Skala	108	103	101	106	108	115	115	111	111	99	100
56	Roslavl	98	97	98	91	94	93	90	88	85	95	96
57	Lukov u Holesova	110	110	108	112	115	112	112	111	110	103	100
58	Bischofswiessen	101	99	102	104	101	100	98	100	98	95	96
59	Nove Mesto na Morave	122	114	109	119	114	114	112	109	102	103	104
60	Altenburg/Horn	115	111	107	112	110	107	106	114	113	103	104
61	Lipowa	113	113	110	116	116	117	120	116	109	95	96
62	Voitsberg	103	109	108	113	109	109	109	111	110	103	104
63	Stirovaca	90	86	85	91	85	93	98	95	96	103	104
64	Bauska Revier	111	104	104	100	96	101	99	99	98	103	104
65	Lobming-Obertal	111	110	109	119	114	118	119	119	122	103	104
66	Vsetin, Hovezi	116	115	110	119	115	115	116	116	115	99	101
67	Zwiesel-Ost	91	91	95	95	98	93	97	98	102	103	100
68	Suchdol	116	115	112	118	114	115	116	113	115	103	104
69	Bad Doberan	116	112	112	119	118	119	121	122	121	95	96
70	Kaufbeuren	110	108	106	115	112	115	116	111	112	103	104
71	Grand-Cote	91	91	94	96	98	95	94	90	89	103	104
72	Trieben	106	103	101	104	105	97	88	91	89	103	104
73	St. Johann	101	106	103	107	108	111	111	109	104	103	104
74	St. Veit/Glan	103	101	102	102	101	99	99	106	107	103	104
75	Berg Bev.	64	64	74	51	66	70	69	72	72	90	78
76	Bjoerlida KRP	87	91	95	85	88	91	89	86	91	103	104
77	Zamberk-Zajeciny	111	114	110	119	116	123	121	117	115	103	104
78	Mestwinowo	113	111	107	116	110	125	126	120	123	95	96
79	Pyramis Koutra	100	101	99	111	105	105	107	103	103	99	100
80	St. Oswald	88	85	86	89	87	71	85	93	89	103	104
81	Vimperk-Prameny	105	101	99	103	98	98	97	102	105	103	104
82	Braunlage	94	97	97	98	101	98	97	106	102	95	96
83	Gfoellwald	94	91	94	90	90	87	85	94	93	103	104
84	Strimbu-Baiut	101	105	101	107	105	106	105	113	113	103	100
85	Toplita, Voivodeasa	122	119	115	119	119	123	123	117	117	103	104
86	Magland	97	90	92	95	94	97	96	99	97	103	100
87	Cizova u Pisku	106	103	102	105	104	101	99	99	95	99	100
88	Bayr. Eisenstein	104	108	105	114	109	106	106	108	109	99	100
89	Piana Selva, Faido	91	94	97	94	98	100	99	103	106	103	104
90	Mengen	92	91	97	96	96	93	95	101	104	103	104
91	Spiegelau	94	98	100	98	101	106	108	106	108	99	100
92	Cesky Rudolec	112	113	106	117	112	113	114	110	109	95	96
93	Niederndorferberg	99	100	100	99	96	89	87	88	87	99	100
94	Beerfelden	108	106	103	106	105	113	112	113	117	103	104
95	Liptovsky Hradok	110	111	107	114	115	124	125	119	118	103	104
96	Kromeriz, Halenkovice	115	112	107	109	108	121	122	117	115	91	92
97	Jaroslawl Oblast	75	82	85	70	78	73	67	67	73	95	96
98	Degerfors	49	51	58	36	51	69	65	60	66	86	65
99	Berchtesgaden	110	105	105	109	106	102	102	99	100	103	104
Block mean: H (m); D (cm); S (%)		**1.37**	**4.41**	**8.98**	**5.6**	**10.3**	**17.0**	**20.3**	**22.3**	**25.4**	**97.0**	**95.9**

Table A.6.9. Mean height, diameter in breast height and survival of tested provenances (in percentage of the block mean), Block 09

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1992	1999	2003	2011	1977	1983
00	Timirjas	53	41	39	24	27	31	24	-	-	92	58
01	Ennstal	109	108	103	113	105	104	103	100	101	98	99
02	Triberg	104	105	107	105	105	104	107	105	106	97	98
03	Moskva	80	84	89	73	79	80	77	77	75	101	98
04	Mpoukowaki	89	101	100	102	105	101	99	96	93	101	102
05	Nagykanizsa, Iharos	113	115	111	112	113	109	108	113	112	101	102
06	Lantschbauern	102	100	99	104	102	101	103	104	106	101	102
07	Ravensburg	94	97	98	94	98	91	90	89	94	101	98
08	Cervene Porici	102	107	107	102	110	109	112	110	111	101	102
09	Konopiste	116	113	111	116	115	122	124	120	120	98	99
10	Karlovice, Ludvikov	120	116	110	125	118	116	119	123	125	97	98
11	Schernfeld	103	102	104	106	106	106	114	111	112	101	102
12	Knusk, Tunopol	113	106	105	107	110	122	120	113	114	101	98
13	Incukalns Revier	100	102	103	97	98	97	95	91	89	101	102
14	Zwiesel-West, Schmalzau	94	91	91	91	88	85	93	89	88	101	102
15	Tuttlingen	103	96	99	99	99	102	102	104	107	101	102
16	Mochy	108	106	106	107	108	107	110	109	111	99	98
17	Mikaszowka	111	104	103	96	101	100	99	95	94	101	98
18	Ukmerges	98	95	98	88	90	91	87	93	90	101	102
19	Hoechendschwand	89	88	93	89	93	87	86	88	92	101	102
20	Knittelfeld	114	109	104	113	106	106	105	107	107	101	98
21	Milevsko, Klucenice	109	107	105	106	104	107	110	110	113	101	102
22	Cucureasa, 65	109	118	114	112	111	109	107	109	109	101	102
23	Liptovsky Mikulas	105	110	110	109	110	108	109	106	106	97	98
24	Rossfeld	103	108	105	110	107	112	114	110	111	93	94
25	Tarnawa	112	113	105	108	105	100	98	96	94	97	98
26	Hanefors	95	92	97	87	88	85	82	79	75	101	102
27	Austagder	73	77	84	64	76	73	68	67	70	101	97
28	Istebna	111	118	113	119	119	122	124	120	121	101	102
29	Sucha 139 A/L	110	105	104	107	105	106	104	99	97	98	99
30	Szczytna Slaska, 292 B	101	102	101	107	110	97	95	106	107	101	102
31	Javorova Dolina 155 A	93	97	102	97	101	107	107	101	98	101	93
32	Bogstad, 1425	76	82	86	70	76	73	72	71	72	101	102
33	Telc, Horni Dubenky	90	96	102	98	99	107	106	104	104	101	102
34	Hauzenstein	105	104	101	104	102	92	96	97	99	97	98
35	Turda, v Virtopeni 34 A	130	131	120	139	132	130	128	124	124	96	97
36	Vilaka Revier	100	101	104	95	97	89	88	89	88	101	102
37	Christinehovs Fideikommiss	95	96	100	97	101	99	96	94	94	101	102
38	Geraasaag, Bispgaarden	67	65	71	51	62	60	58	52	53	101	97
39	Minsk	106	101	98	98	95	86	83	78	74	101	102
40	Bialowieza	99	101	99	98	94	95	91	95	92	101	102
41	Stalin, Poiana	106	102	99	107	102	105	105	107	106	101	102
42	Bjurfors KRP	85	87	91	81	86	81	76	74	74	101	102
43	Jilove u Prahy	122	121	114	125	121	122	123	120	120	101	102
44	Elbigenalp	89	90	94	90	90	90	88	92	92	101	102
45	Oberammergau	91	91	95	91	92	97	96	95	95	101	102
46	Seeshaupt	103	103	102	107	104	101	100	98	98	101	102
47	Zwiesel-Ost, Rannenau	102	103	104	110	111	114	109	107	104	101	102
48	Zwiesel-West	102	99	98	100	99	94	94	90	88	101	102
49	Radom	106	108	106	113	112	117	119	115	115	101	97

Table A.6.9. cont.

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1992	1999	2003	2011	1977	1983
50	Torgelow	106	102	104	104	105	115	117	115	117	97	98
51	Isen	109	110	108	112	111	107	110	112	113	94	95
52	Weitra	116	112	107	118	111	105	104	106	107	101	102
53	Unken, Salzburg	100	100	102	107	101	105	117	112	111	101	102
54	Himmelberg-Maitrattenw.	95	93	93	92	89	94	93	102	103	101	102
55	Cervena Recice	103	105	104	105	103	103	102	99	99	101	102
56	Breitenau-Mixnitz	92	89	94	84	87	95	101	103	105	101	102
57	Cizova u Pisku	102	108	105	106	108	106	107	104	105	101	102
58	Stauffenburg	102	100	101	102	103	104	105	114	115	101	102
59	Hohenaltheim	98	99	100	101	105	115	118	117	121	101	102
60	Marischka 2	80	88	96	85	93	90	87	91	89	101	98
61	Dygowo	108	105	103	109	108	115	124	119	120	101	102
62	Sternberk, Ridec	108	106	105	108	110	106	113	109	109	101	98
63	Rehefeld, 146	99	98	100	109	104	93	92	92	89	101	102
64	Altenau 316	103	105	104	108	107	108	105	104	105	101	102
65	Haus/ im Ennstal	97	104	101	104	97	95	89	81	77	101	102
66	Eichstaett	92	92	95	90	93	104	104	102	102	84	85
67	Tepla I	112	107	105	115	114	116	118	117	117	97	98
68	Sachsenried	99	98	100	99	102	103	104	105	107	97	98
69	Daun-Ost	99	105	104	108	109	118	121	120	120	101	102
70	Laintal Hafning	106	108	106	109	107	108	111	109	112	101	102
71	Kynsperk n. Ohri	113	108	106	113	111	117	117	112	112	101	102
72	Policka-Milovy	117	110	108	117	115	115	116	117	116	101	102
73	Freising V/6B, 7AB	101	102	102	104	104	107	108	107	105	97	98
74	Gsengegg	101	102	102	109	102	113	114	115	114	101	102
75	Klingenbrunn	70	73	77	71	75	67	61	73	71	101	102
76	Podolinec	109	109	105	110	108	106	104	101	99	101	102
77	Raitis	99	96	98	98	95	100	98	94	94	101	102
78	Montriond	-	-	-	-	-	-	-	-	-	-	-
79	Karlstad, Zon 2	75	77	85	61	71	81	87	89	90	101	102
80	Kinnared, Kult	99	99	97	104	102	101	104	100	99	101	102
81	Mikkelin Mlk.	68	70	78	55	68	67	65	70	68	101	93
82	Cottbus, Tannenwald	96	98	99	95	96	90	87	86	84	101	102
83	Spiegelau	105	105	104	106	105	103	106	108	109	101	102
84	Offenburg	88	94	97	98	99	109	111	109	110	101	102
85	Altanca	89	82	87	83	87	82	76	74	77	101	102
86	Foelz, Mayerberg	110	108	105	108	101	93	92	98	104	101	102
87	Denklingen	105	103	103	107	103	101	101	107	108	94	94
88	Kartuzy	114	108	106	112	110	109	107	106	104	101	102
89	Ledec nad Sazavou	117	114	110	118	113	117	118	117	119	101	102
90	Sulzschneid	102	100	100	101	99	106	108	107	107	89	90
91	Tatranska Lesna 559 C	105	103	102	107	103	92	89	92	91	97	98
92	Buchberg Bodenwald	108	106	104	106	101	110	111	111	111	101	102
93	Brandenberg/Tirol	91	94	98	92	92	88	87	82	81	101	102
94	Jihlava-Hencov	117	115	110	119	115	114	111	111	110	101	102
95	Autrans	86	79	78	80	79	72	76	74	72	101	102
96	Cierny Vah, Kolesarky	98	106	109	101	107	112	114	112	114	97	94
97	Unterliezheim	102	104	104	108	109	108	108	104	107	101	102
98	Obernberg-Gries	70	74	80	74	77	72	71	69	65	101	102
99	Anyksiu	115	112	106	106	103	91	87	83	78	101	102
Block mean: H (m); D (cm); S (%)		**1.31**	**4.20**	**8.63**	**5.4**	**10.2**	**16.4**	**19.7**	**21.5**	**24.2**	**98.7**	**97.7**

Table A.6.10 Mean height, diameter in breast height and survival of tested provenances (in percentage of the block mean), Block 10

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1993	1999	2004	2011	1977	1983
00	Sigmaringen	103	96		98		105		105	105	102	
01	Veliz	92	100		88		86		81	80	102	
02	Brumov, Navojna	95	103		102		103		100	102	102	
03	Czerwony Dwor	103	111		100		102		97	95	102	
04	Liptovsky Mikulas	105	111		110		106		109	107	102	
05	Ergoldsbach	99	101		98		101		101	101	102	
06	Zalesie	108	105		110		105		105	107	102	
07	Valea Putnei	125	125		126		119		117	115	98	
08	Stronie Slaskie	91	96		98		92		91	88	102	
09	Ledec nad Sazavou	109	110		109		105		107	110	102	
10	Stuebing/Peggau	104	105		102		105		107	106	102	
11	Soboth	103	102		110		100		103	101	102	
12	Cesky Krumlov-Borova	107	102		101		112		114	115	102	
13	Bodenmais, Plattenfichten	88	80		86		78		81	79	98	
14	Mauth-Ost, Plattenfichten	88	86		90		86		94	92	97	
15	Oberzeiring	103	103		104		109		114	113	99	
16	Cervena Skala	106	109		112		101		100	99	102	
17	Presov	117	118		127		117		113	110	102	
18	Foresta di Paneveggio	87	85		92		93		94	95	102	
19	Oberndorf	100	98		103		100		101	101	102	
20	Frohnleiten	111	108		109		102		99	100	102	
21	Hudson s Place, Ont. CA	111	107		103		101		93	91	102	
22	Dorna Cindreni	115	116		116		109		107	106	98	
23	Kraubath	103	97		97		92		98	97	95	
24	Nove Hrady-Dolni Hvozd	112	108		108		107		108	114	102	
25	Milevsko, Chysky	102	108		103		108		108	107	102	
26	Taxenbach/Salzburg	103	103		105		101		101	100	102	
27	Westerhof 51 B	102	106		102		107		110	110	98	
28	Muran	107	113		111		107		107	104	95	
29	Jaromerice, Lazany	103	101		99		106		108	108	102	
30	Rostock	94	102		101		105		101	100	98	
31	Sinaia-Paduchiosul	105	101		102		100		101	102	102	
32	Trebon	122	116		119		107		111	113	93	
33	Kindberg, Veitsch	96	101		99		100		101	100	102	
34	Tettnang	103	107		106		106		102	103	102	
35	Gsengegg	94	92		92		96		107	116	99	
36	Trieben	112	105		109		105		104	100	102	
37	Augustow	107	109		105		108		105	109	98	
38	Seeshaupt	102	103		104		103		104	102	98	
39	Enzkloesterle	92	91		96		101		96	99	98	
40	Dillingen	116	109		117		106		106	106	98	
41	Laerchschachen	86	85		86		91		92	100	102	
42	Lenzkirch	91	90		90		93		96	89	102	
43	Aich-Althofen	99	101		101		98		97	96	102	
44	Malyinka 49 F	95	103		105		103		100	101	102	
45	Istebna, 148-149	114	111		125		111		108	108	102	
46	Bystra	118	114		116		104		102	97	102	
47	Lanskroun	112	110		112		101		104	103	102	
48	Landsberg	110	108		114		107		107	107	102	
49	Sauerlach	95	92		92		98		101	101	102	

Table A.6.10 cont.

Provenance		Height			Diameter						Survival	
							%					
No.	Name	1972	1977	1983	1977	1983	1992	1999	2004	2011	1977	1983
50	Trebic	98	105		102		101		99	98	102	
51	Velke Karlovice	116	112		116		105		105	104	98	
52	Leogang	97	97		102		99		98	107	99	
53	Velden	93	96		93		96		100	104	98	
54	Krumbach	106	109		109		107		109	111	98	
55	Glindfeld	94	96		95		93		93	91	98	
56	Bicaz, II Floarea Ivanesii	119	125		126		118		117	116	102	
57	Laeaenema Revier	102	96		88		83		85	81	102	
58	Hammerdal Bev.	62	63		50		95		91	88	102	
59	Aasnes	75	79		64		84		89	104	94	
60	St. Oswald, Huettensch.	106	99		100		103		102	101	99	
61	Neuwirtshaus	107	103		103		101		98	96	98	
62	Jasina	130	124		129		119		124	124	94	
63	Walchensee	101	102		101		98		98	99	102	
64	Bischofsreuth	97	96		103		99		95	96	89	
65	Neukirchen	96	93		94		101		108	106	102	
66	Rohr im Geb.	95	94		94		93		99	99	98	
67	.	83	79		81		88		83	94	102	
68	Tavejanne, Bex	86	87		89		86		81	82	102	
69	Crespato, Airolo	83	85		87		90		89	93	94	
70	Boubin	100	94		91		101		97	101	102	
71	Javorova Dolina	87	94		89		87		88	87	98	
72	Traunstein	94	93		93		106		106	106	90	
73	Untertal/Schladming	111	106		112		101		99	101	102	
74	Melnik, Semanovice	106	108		112		109		110	110	99	
75	Mellier, Bois Bayai	98	107		106		104		112	115	94	
76	Chamonix	83	85		85		84		85	84	99	
77	Muensingen	98	98		100		104		104	106	102	
78	Hnojnik, Tyra	116	116		118		114		108	106	102	
79	Hranice	116	116		117		114		117	118	102	
80	Ochsenhausen	100	97		97		96		93	97	98	
81	Passau-Sued	102	98		100		100		106	106	98	
82	Dalby KRP, Soedra	109	111		113		107		103	101	98	
83	Floda	82	81		68		91		91	89	97	
84	Oberhof, Schlossbergkopf	94	97		101		98		91	88	102	
85	Burghausen	100	101		100		101		100	99	95	
86	Lohja+Laakspohjan Kart.	83	85		71		80		74	74	94	
87	Cavagnago	97	103		108		98		97	98	102	
88	Oberhof, Kanzlersgrund	96	101		99		111		114	107	102	
89	Cadca, Makov	103	111		108		102		99	96	99	
90	Koeszeg 1 C	117	108		113		105		103	100	98	
91	Bad Teinach	91	94		96		100		102	105	102	
92	Mo Haerad Bev.	89	89		80		79		76	76	93	
93	Kloevsjoe Bev.	63	60		48		79		95	90	98	
94	Wolfach	97	90		94		96		92	91	102	
95	Tatyschlinsk	80	75		62		73		71	67	94	
96	Kloten, Zon 2	82	86		79		86		81	78	98	
97	Polczyn-Zdroj	108	109		114		107		110	108	102	
98	Wolfstein	85	86		86		85		81	87	98	
99	Westdeutsches Bergland	102	100		103		110		108	108	102	
Block mean: H (m); D (cm); S (%)		**1.37**	**4.17**		**5.3**		**15.9**		**19.7**	**22.0**	**97.6**	

Table A.6.11 Mean height, diameter in breast height and survival of tested provenances (in percentage of the block mean), Block 11

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1993	1999	2003	2011	1977	1983
00	Brumov nad Vlarou	107	112		114		112	113		116	102	
01	Himmelberg-Hochwald	89	83		83		73	79		92	102	
02	Zdar nad Sazavou	105	103		101		100	100		98	102	
03	Markt Biberbach	103	98		105		107	107		108	102	
04	Wloszczowa	111	113		109		101	100		96	102	
05	Ronov nad Doubravou	115	118		122		120	122		116	102	
06	Zlutice	105	108		110		108	109		108	102	
07	Kraslice	123	118		129		119	118		113	102	
08	Karlstad, Zon 1	108	102		99		91	87		80	92	
09	Wolfstein	99	98		105		106	106		108	98	
10	Freising	96	96		95		96	95		99	98	
11	Teisendorf	99	100		97		101	104		108	97	
12	Mpoukowaki	89	90		92		89	89		95	102	
13	Kulmbach	90	87		82		84	88		89	89	
14	Bogstad 1424	78	82		72		78	76		72	97	
15	Rabino	118	109		113		112	113		113	102	
16	Urszulewo	102	107		101		97	98		95	102	
17	Kroppelfjaell	78	84		77		85	82		89	102	
18	Tepla-Touzim	108	112		111		107	109		103	102	
19	Schneegattern	104	103		110		106	107		103	97	
20	Passau-Nord	103	103		104		104	104		100	102	
21	Peiting	92	93		92		99	100		99	102	
22	Gzatsk	84	88		77		83	80		77	102	
23	Altensteig	101	94		99		100	99		102	97	
24	Velke Mezirici-Rudolec	114	117		119		115	117		113	98	
25	Saarijaervi och Karstula	77	67		53		72	66		80	97	
26	Siessen	96	96		99		98	99		99	102	
27	Fuerstenberg	93	98		99		99	99		105	102	
28	Hechingen	100	100		102		106	105		106	102	
29	Wildalpen	92	100		99		94	94		95	102	
30	Bodenmais	67	69		67		67	65		71	102	
31	Bialowieza	114	115		109		100	101		101	102	
32	Reichanhall	88	95		96		100	100		98	102	
33	Gammlia	70	65		50		72	71		79	91	
34	Osterode	109	111		106		108	110		104	102	
35	Tamsweg	94	98		94		93	91		91	98	
36	Dobersberg	113	110		110		109	109		105	102	
37	Roznava	106	110		113		99	102		98	102	
38	Soelktal	109	100		102		102	101		103	102	
39	Rottweil	97	100		104		109	111		106	102	
40	Altanca	84	84		84		78	79		82	102	
41	Karlsholm Gods	111	109		111		107	106		103	102	
42	Seestetten	106	102		106		102	104		106	102	
43	Isny	95	98		101		96	95		90	102	
44	Oberes Gailtal	102	99		104		85	83		83	102	
45	Barsebaeck	103	106		111		117	117		124	94	
46	Ochsenhausen	98	100		103		112	111		112	102	
47	Mogilevskoje Oblast	109	108		101		101	100		98	102	
48	Zwiefalten	101	98		100		101	104		102	102	
49	Wipptal/Tirol	90	96		100		102	103		102	102	

Table A.6.11 cont.

Provenance		Height			Diameter						Survival	
		%										
No.	Name	1972	1977	1983	1977	1983	1993	1999	2003	2011	1977	1983
50	Szczytna Slaska	104	101		102		105	104		114	102	
51	Nowy Dwor	105	102		107		100	99		88	98	
52	Ergoldsbach	101	99		101		99	98		101	98	
53	Lanskroun, Albrechtice	112	110		114		116	116		107	98	
54	Obsteig/Gruenberg	96	100		102		105	104		108	91	
55	Kaisheim	85	89		86		91	89		90	98	
56	Nancy sur Cluses	85	85		85		81	84		90	102	
57	Peisey-Nancroix	83	88		84		78	74		73	94	
58	Oberammergau	92	93		93		86	83		92	94	
59	Turnau-Aflenz	94	99		99		106	105		107	102	
60	Tellerhaeuser	102	99		103		104	105		111	102	
61	Zwiesel-Ost	101	100		101		102	102		98	102	
62	Ulm-Soeflingen	97	100		105		107	108		110	98	
63	Miskolc, Lillafuered	108	108		108		114	116		116	102	
64	Tatranska Lesna	97	101		98		101	101		96	98	
65	Jablunkov-Girova	107	102		104		110	119		113	102	
66	Vizovice, Bratrejov	106	105		109		103	110		109	102	
67	Foelz, Greith	104	103		104		106	107		102	98	
68	Todtnauberg	96	91		94		93	92		90	102	
69	Stixenstein	99	95		97		98	99		102	97	
70	Frenstat pod Radhostem	118	115		115		117	119		113	98	
71	TANAP, Podspady	116	113		115		107	105		104	102	
72	Donnersbach	123	107		115		109	108		106	102	
73	Templin	103	101		105		109	111		108	102	
74	Buchlovice-Koryzany	98	96		98		109	109		120	102	
75	Unterliezheim	103	100		98		108	109		111	102	
76	Brosteni, Bradu	128	122		126		117	115		113	102	
77	Buchberg Aegidiwald	108	99		99		88	87		98	98	
78	Bystra	113	106		107		106	105		98	102	
79	Denklingen	90	85		85		93	103		98	98	
80	Crucea	117	115		110		110	109		103	102	
81	Sachsenried	104	98		98		92	94		105	98	
82	Aasan, Bispgaarden	71	67		52		64	59		73	88	
83	Avramov, Jundola	81	88		85		92	90		97	102	
84	Voeru Revier	54	104		96		87	84		87	98	
85	Friedstein	111	108		112		104	103		103	98	
86	Malingsbo	96	96		90		89	85		78	92	
87	Kamenice nad Lipou	111	111		111		106	105		101	102	
88	Gheorghieni	104	116		115		106	106		103	102	
89	Schluchsee	94	90		90		87	87		85	102	
90	Ugale Revier	99	99		91		98	97		100	98	
91	Cierny Vah	107	116		119		121	123		121	102	
92	Plaska	102	102		95		100	99		97	102	
93	Hnusta	114	108		112		112	113		105	102	
94	Gries	96	96		100		101	101		109	102	
95	Oderhaus	100	100		104		93	91		99	94	
96	Olomouc, Olsovec	111	108		110		118	117		113	102	
97	Ignalino	101	98		90		89	87		78	102	
98	Istebna	114	113		115		118	117		110	102	
99	Crawinkel	97	99		100		118	120		115	102	
Block mean: H (m); D (cm); S (%)		**1.26**	**3.81**		**4.9**		**15.9**	**19.0**		**24.3**	**98.0**	

Appendix 7

Table A.7 Height means at age of 5 by regions in 1972 (Original table, Krutzsch 1973)

IPTNS 1964/68 Table 1.
Experiment No 20 Hungary

REGION HEIGHT MEANS – 1972

REGION	MEAN	F-VALUE	REGION	MEAN	F-VALUE
01	118,476	1,546	49	136,315	1,184
02	106,595	2,076	50	137,082	0,825
03	104,785	1,133	51	131,513	2,075
04	126,480	1,798	52	138,673	1,159
05	126,013	1,781	53	126,681	0,339
06	132,840	2,859	54	117,110	2,613
07	126,764	1,379	55	98,290	1,475
08	120,793	3,490	56	105,891	3,104
09	123,891	1,429	57	117,198	2,079
10	130,824	2,966	58	147,206	3,574
11	123,142	0,917	59	143,219	1,201
12	123,435	2,789	60	145,590	1,066
13	117,003	0,942	61	132,474	1,165
14	114,831	1,956	62	140,266	0,829
15	107,779	1,668	63	135,948	0,920
16	118,752	0,780	64	128,283	1,724
17	120,368	0,969	65	138,721	0,586
18	123,108	1,108	66	136,360	0,610
19	129,796	2,031	67	132,954	1,060
20	128,490	0,533	68	133,411	0,980
21	116,476	3,935	69	133,004	1,540
22	124,223	1,275	70	136,253	0,711
23	125,886	1,301	71	130,572	1,317
24	119,332	1,012	72	124,411	1,047
25	109,539	2,160	73	126,790	1,422
26	121,132	1,792	74	125,408	1,697
27	114,550	7,450	75	132,602	1,373
28	121,568	0,816	76	113,507	0,681
29	118,427	1,147	77	87,063	7,050
30	125,808	2,517	78	112,914	3,252
31	125,628	1,493	79	86,518	2,715
32	127,857	1,096	80	81,661	7,893
33	130,903	0,614	81	131,289	2,070
34	119,796	1,261	82	133,294	0,881
35	128,854	0,931	83	108,224	2,394
36	136,989	2,613	84	102,983	4,098
37	135,099	0,484	85	80,281	3,146
38	137,154	1,380	86	126,341	1,009
39	131,365	1,048	87	107,227	2,717
40	131,899	0,543	88	107,115	2,720
41	141,472	1,035	89	109,571	1,555
42	135,827	1,557	90	110,088	2,243
43	139,331	0,704	91	81,521	3,717
44	138,215	0,701	92	82,762	1,517
45	134,245	1,724	93	70,651	5,639
46	128,243	3,790	94	109,757	2,648
47	134,216	1,295	95	95,880	10,689
48	126,347	3,618	96	139,311	0,000

Appendix 8

Table A.8 *Provenances, superior to the Hungarian best ones at age of 5 (Original table, Krutzsch 1973)*

IPTNS 1964/68 Table 2.

Experiment No 20 Plant height 1972 /cm/

PROVENANCES, SUPERIOR TO THE HUNGARIAN ONES

No	RG	STHM	IPT	LAT	LONG	ALT	PROVENANCE	H 1972
1	2	3	4	5	6	7	8	9
1	58	5416	0613	46,8	22,7	900	REMETI ZERNA -R	171,168
2	06	3410	0648	51,8	10,2	300	WESTERHOF 50,58 -D	163,764
3	58	5438	0935	46,6	23,8	1100	TURDA -R	163,343
4	60	7352	1062	48,3	24,3	900	JASINA -SU	160,144
5	36	4307	0702	48,8	14,8	500	NOVE HRADY -CS	158,837
6	59	5413	1176	47,2	25,7	1475	BROSTENI -R	158,475
7	59	5402	1007	47,4	25,4	1190	VALEA PUTNEI 60 -R	158,023
8	48	6893	0564	49,3	19,8	1100	WITOW -PL	156,504
9	41	4475	0506	49,7	14,9	680	VLASIM -CS	155,921
10	59	5442	0158	47,1	25,8	675	BORCA XV -R	155,818
11	59	5420	0172	47,4	25,4	1285	VALEA PUTNEI 60 -R	155,043
12	10	4320	0265	50,1	12,5	660	KNYSPERK -CS	154,824
13	27	2214	0716	47,5	10,7	1000	REUTTE -A	154,663
14	47	4170	0147	48,9	20,2	1000	CERVENA SKALA -CS	154,139
15	36	4307	1032	49,0	14,5	450	TREBON -CS	154,131
16	59	5430	0885	46,9	25,4	880	TOPLITA -R	154,087
17	59	5431	0169	47,4	25,4	900	DORNA -R	153,918
18	69	6252	0253	53,8	23,0	120	SERWY -PL	153,624
19	42	4437	0859	49,6	16,1	580	NOVEMESTO -CS	153,293
20	47	4161	0754	49,0	20,2	900	HRABUSICE -CS	153,098
21	65	6550	0293	50,7	18,4	175	KOLONOWSKIE -PL	152,845
22	41	4434	0943	49,9	14,5	430	JILOVE UPRAHY -Cs	152,211
23	58	5415	0374	46,4	25,1	1260	CIMPENI DARA -R	151,938
24	45	4450	0422	49,3	18,0	560	VSETIN POZDERHOV -CS	151,542
25	10	4321	1107	50,3	12,6	600	KRASLICE -CS	151,479
26	30	2423	1172	47,5	14,1	700	DONNERSBACH -A	151,253
27	41	4401	0356	49,7	15,4	555	SVETLA -CS	151,198
28	41	4305	0171	49,5	15,2	610	CERVENA RECICE -CS	150,798
29	43	4467	0910	50,1	17,5	840	KARLOVICE LUDV. -CS	150,204
30	59	5434	1056	46,8	25,9	1150	BICAZ II. -R	150,004
31	63	6852	0174	49,7	18,9	615	WISLA 54 A -Pl	149,623
32	38	4412	0319	50,4	14,9	350	MLADA BOLESLAV -CS	149,598
33	42	4457	0334	49,1	15,3	570	CESKY RUDOLEC -CS	149,578
34	43	4073	0178	50,3	17,3	820	JESENIK -CS	148,441
35	75	7233	0606	54,1	26,5	225	WOLOZIN -SU	148,431
36	62	6892	1046	49,7	19,7	700	BYSTRA -PL	148,191
37	59	5421	0487	47,3	25,0	1260	CUCUREASA 65 -R	147,368
38	32	2170	0559	47,5	15,2	925	FLONING -A	147,321
39	52	5201	1090	47,3	16,4	870	KŐSZEG 1C.HUNGARY	147,314

RG= Region, STHM= Stockholm katalog-number, IPT= Provenance number, block/provenance.

Appendix 9

Table A.9 *Regions suitable for Hungarian sites. Recommendation from Krutzsch (Original table, Krutzsch 1973)*

IPTNS 1964/68 **Table 3.**

Experiment No 2o

REGIONS, SUITABLE TO HUNGARIAN SITES

No	REGION	DF a	DF b	MEAN 1972 cm	F-VALUE
1	58	5	1o9	147,2o6	3,754
2	6o	3	84	145,59o	1,o66
3	59	24	553	143,219	1,2o1
4	41	18	424	141,472	1,o35
5	62	5	133	14o,266	o,829
6	43	9	192	139,331	o,7o4
7	65	9	243	138,721	o,586
8	52	6	151	138,673	1,159
9	44	1o	221	138,215	o,7o5
1o	38	7	164	137,154	1,38o
11	5o	6	155	137,o82	o,825
12	36	16	371	136,989	2,613
13	66	16	355	136,36o	o,61o
14	49	2	56	136,315	1,884
15	7o	6	153	136,253	o,711
16	63	14	317	135,948	o,92o
17	42	24	55o	135,827	1,557
18	37	11	253	135,o99	o,484
19	45	23	497	134,245	1,724
2o	47	22	484	134,216	1,295

DF = degree of freedom a : between provenances

b : within provenances

Appendix 10

*Table A.10 Regional distribution of provenances significantly better than the experimental mean (3.86 m), and provenances significantly better than Hungarian average (4.07 m, the latter are in **bold**) based on assessment of **height at age 10**, in 1977 (after Ujvári-Jármay - Ujvári 1979, 1980, regions by Krutzsch 1974)*

Region no. and name		Provenance no. and name		Country code	Adj. H 1977 m
06	Westerhof	**0648**	**Westerhof 50, 58**	**DE**	**5.13**
10	Erzgebirge	0265	Knysperk n. Ohri	CZ	4.59
		1107	Kraslice	CZ	4.55
19	Franconia, Fichtel Mts	0641	Wunsiedel	DE	4.63
		0539	Pressath	DE	4.51
22	Swabian-Bavarian Upland	0503	Ebersberg	DE	4.48
27	Allgäu Alps, Tyrol	0716	Reutte	AT	4.48
36	Bohemian Upland, Sumava E., Lower Austria	0702	Nove Hrady-Dolni Hvozd	CZ	4.54
		0816	Nove Hrady-Dolni Hvozd	CZ	4.52
		0868	Suchdol	CZ	4.51
		1032	Trebon	CZ	4.53
38	Central Bohemia	0611	Melnik, Semanovice	CZ	4.57
39	Sudets	0877	Zamberk-Zajeciny	CZ	4.47
41	Bohemian Hills W	0506	Vlasim	CZ	4.60
		0943	**Jilove u Prahy**	**CZ**	**4.76**
		0171	Cervena Recice-Lukavec	CZ	4.56
		0989	Ledec nad Sazavou	CZ	4.48
		1105	Ronov nad Doubravou	CZ	4.54
42	Bohemian- Moravian Hills	0334	Cesky Rudolec	CZ	4.64
		0994	Jihlava-Hencov	CZ	4.48
		1124	Velke Mezirici	CZ	4.52
		0859	Nove Mesto	CZ	4.46
		0714	Moravska Trebova	CZ	4.59
43	Orlice Mts. Moravia	0672	Sternberk, Mutkov	CZ	4.59
		0910	Karlovice, Ludvikov	CZ	4.52
		0178	Jesenik Zlate-Hory	CZ	4.48
		0210	Albrechtice, Tisova	CZ	4.46
44	Moravia	1079	Hranice	CZ	4.51
		0594	Olomouc, Hranice	CZ	4.56
45	Moravian Mountains	0422	Vsetin, Pozdechov	CZ	4.47
		0866	Vsetin,Hovezi	CZ	4.50
		0477	Vsetin, Hovezi	CZ	4.55
		0618	Rajnochovice	CZ	4.57
		1078	Hnojnik, Tyra	CZ	4.54

Table A.10 cont.

Region no. and name		Provenance no. and name		Country code	Adj. H 1977 m
47	Low Tatras	1191	Cierny Vah, Kolesarky	SK	4.47
		0278	**Cierny Vah, Ipeltica**	**SK**	**4.68**
		0375	Cierny Vah, Rovienky	SK	4.49
		0147	Cervena Skala	SK	4.61
		0754	Hrabusice	SK	4.46
48	High Tatras	**0564**	**Witow**	**PL**	**4.92**
49	E. Beskids, East Slovakia	1017	Presov	SK	4.62
50	Slovakian Erzgebirge	0367	Spiska Nova Ves	SK	4.46
52	West Hungary	0905	Nagykanizsa, Iharos	HU	4.48
58	Bihor Mts., Transilvania	**0613**	**Remeti, Zerna**	**RO**	**5.14**
		0935	**Turda**	**RO**	**5.18**
		0374	Cimpeni,Dara	RO	4.60
59	East Carpathians	1188	Gheorghieni	RO	4.47
		1056	**Bicaz**	**RO**	**4.89**
		0885	**Toplita, Voivodeasa**	**RO**	**4.68**
		0635	**Toplita, III.**	**RO**	**4.69**
		0847	Galu	RO	4.55
		0158	**Borca**	**RO**	**4.74**
		0412	Brosteni, Piriul	RO	4.60
		1176	**Brosteni, Bradu**	**RO**	**4.71**
		0169	**Dorna Cindreni II. R.**	**RO**	**4.94**
		0439	**Dorna Cindreni II. R**.	**RO**	**4.71**
		1022	Dorna Cindreni, V. D.	RO	4.51
		0487	**Cucureasa**	**RO**	**4.79**
		0922	Cucureasa	RO	4.61
		0700	Cosna, Cucureasa	RO	4.65
		1007	**Valea Putnei**	**RO**	**4.90**
		0172	**Valea Putnei**	**RO**	**4.94**
		0530	Frasin, X Ursoaia	RO	4.48
		0262	Moldovita, Demacusa	RO	4.46
		0755	Marginea	RO	4.51
60	Jasina	0773	Jasina	UA	4.47
		1062	**Jasina**	**UA**	**4.84**
		0596	**Jasina**	**UA**	**4.85**
62	East Beskids, Babia Gora	0399	Orawa	PL	4.55
63	West Beskids, Istebna	0661	Jablunkov, Girova	CZ	4.52
		0533	**Liptovsky Mikulas**	**SK**	**4.76**
		0928	Istebna	PL	4.63
		0174	Wisla	PL	4.47
64	Klodzko Valley, Sudets	0414	Klodzko	PL	4.51
65	Silesian Lowland	0293	Kolonowskie	PL	4.60

Table A.10 cont.

Region no. and name		Provenance no. and name		Country code	Adj. H 1977 m
67	East-Pomeranian Lakeland	0650	Sobowidze	PL	4.47
69	Augustów Lakeand	0253	Serwy	PL	4.66
71	Lithuania	**0590**	**Ukmerges**	**LT**	**4.82**
74	Latvia, Estonia	0230	Varakalani Revier	LV	4.47
75	Belarus	0606	Wolozin	BY	4.50

Appendix 11

*Table A.11. Regional distribution of provenances significantly better than the experimental mean (22.62 cm), and provenances significantly better than Hungarian average (23.49 cm, the latter are in **bold**) based on assessment of **diameter at age of 44** (2011). Due to low number of trees per provenances left after the windbreak, Block 07 was not included in the analysis.*

Region no. and name		Provenance no. and name		Country code	DBH 2011 cm
5	**Hessian Foothills**	**0512**	**Fuerstenberg**	**DE**	**28,16**
17	Swabian Alb	0959	Hohenaltheim	DE	26,78
18	Franconian Alb	0694	Pappenheim	DE	27,32
19	Franconia, Fichtel Mts.	0539	Pressath	DE	27,00
28	Kitzbühel Alps, N. Tyrol	0406	Rauris	AT	26,86
32	Wild Alps, NE Styria	0865	Lobming-Obertal	AT	26,75
36	**Bohemian Upland, Sumava E., Lower Austria**	**0625**	**Jaidhof**	**AT**	**29,20**
37	Bohemian Forest	0161	Horsovsky Tyn	CZ	26,85
42	Bohemian- Moravian Hills	0273	Trebic IV	CZ	27,67
		0291	Hencov-Trest	CZ	27,20
43	Orlice Mts., Moravia	0910	Karlovice, Ludvikov	CZ	27,68
47	Low Tatras	1191	Cierny Vah	SK	26,87
58	Bihor Mts., Transilvania	0935	Turda, v Virtopeni 34 A	RO	27,35
		0374	Cimpeni, Dara	RO	27,13
59	East Carpathians	0169	Dorna Cindreni	RO	26,98
60	Jasina	1062	Jasina	UA	27,50
63	West Beskids, Istebna	0928	Istebna	PL	26,83
66	W-Pomeranian Lakeland	0529	Wielgowo	PL	27,52
67	East-Pomeranian Lakeland	0878	Mestwinowo	PL	26,98
86	Scania	1145	Barsebaeck	SE	27,40

Appendix 12

Table A.12 Distribution of remaining trees by provenances and by blocks at the latest assessment (2011; number of trees)

block prov. code	Blocks										
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**
00	15	2	13	10	8	14	3	9	0	13	8
01	18	17	12	4	14	11	5	10	12	10	6
02	13	18	12	4	11	10	1	6	10	14	10
03	17	14	20	9	11	10	1	10	9	15	10
04	8	16	12	7	9	6	3	8	9	17	7
05	19	14	17	11	7	11	3	10	11	16	8
06	9	16	18	5	8	16	3	8	15	18	6
07	12	14	15	8	9	9	3	3	6	16	12
08	14	10	16	9	9	4	0	5	14	11	9
09	1	14	13	11	10	7	5	7	14	15	8
10	13	14	12	3	10	17	3	7	13	18	11
11	9	9	16	10	8	13	3	8	15	16	9
12	7	9	15	9	7	12	5	9	7	17	8
13	17	12	18	8	10	18	7	12	10	5	9
14	13	19	13	13	9	16	6	12	10	6	6
15	16	11	13	7	6	7	2	8	13	12	10
16	16	12	14	3	8	8	2	11	22	11	7
17	8	14	16	16	8	9	3	9	12	17	4
18	20	1	14	9	11	16	4	10	5	7	13
19	8	10	13	1	10	17	4	4	12	15	9
20	16	6	15	7	9	12	4	3	7	16	12
21	14	10	14	6	5	10	3	7	14	15	11
22	17	15	10	7	9	11	1	5	14	17	5
23	18	14	11	12	8	2	5	12	13	9	11
24	17	14	12	6	10	11	2	8	14	12	14
25	17	14	11	6	11	14	3	10	10	20	2
26	3	16	14	14	7	13	4	9	13	19	7
27	7	16	10	8	5	12	3	8	5	17	6
28	13	13	14	5	9	13	5	12	15	20	10
29	17	18	18	9	7	9	0	2	14	9	11
30	16	12	12	8	8	13	4	6	9	16	4
31	14	17	9	10	6	13	2	1	4	15	11
32	10	5	15	3	13	5	3	5	7	15	9

Table A.12 cont.

block prov. code	Blocks										
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**
33	15	0	5	5	9	14	0	8	6	16	2
34	3	17	18	9	7	18	2	5	11	18	14
35	18	16	11	9	3	17	3	8	10	11	10
36	19	13	6	6	7	10	3	7	8	14	9
37	15	19	12	0	11	12	3	12	8	11	11
38	14	14	11	5	5	13	6	8	2	16	3
39	17	15	12	9	10	4	3	4	7	10	12
40	16	13	12	6	11	14	7	6	8	15	8
41	13	18	17	6	6	14	2	11	11	13	14
42	1	13	15	12	12	14	5	11	13	7	9
43	19	17	16	10	9	8	3	9	12	14	11
44	16	15	12	5	9	5	1	9	6	11	9
45	16	12	12	8	10	11	7	6	8	19	10
46	16	14	17	8	2	14	5	3	8	16	8
47	15	14	15	4	10	11	2	10	12	16	9
48	15	18	16	6	8	13	5	11	11	26	12
49	11	13	14	8	6	11	7	7	13	14	11
50	16	16	19	9	9	16	4	1	11	21	7
51	14	18	11	10	4	1	4	12	12	15	7
52	13	14	4	9	12	12	4	12	13	14	11
53	10	18	0	12	8	5	3	7	6	6	9
54	18	14	9	8	7	14	3	12	5	11	7
55	15	17	13	15	7	15	2	10	13	14	5
56	15	10	16	5	7	12	2	11	11	15	8
57	12	21	9	9	9	13	4	13	12	9	2
58	16	17	11	6	13	6	3	10	10	1	3
59	14	13	12	7	8	11	4	12	4	3	12
60	13	16	19	3	2	16	3	11	8	13	9
61	12	14	9	10	5	16	3	8	11	17	10
62	2	11	12	8	4	18	1	10	10	13	11
63	14	18	8	4	10	14	3	9	12	16	9
64	14	10	8	10	10	14	4	7	12	10	8
65	6	18	10	12	8	15	4	10	7	11	9
66	3	21	6	8	5	12	6	12	11	12	11
67	12	13	13	7	3	15	5	8	8	3	7
68	10	8	11	6	9	10	0	14	13	10	9
69	20	12	14	11	7	9	3	8	10	7	10

Table A.12 cont.

block prov. code	Blocks										
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**
70	12	18	13	4	11	14	5	11	11	14	9
71	21	13	13	9	9	14	2	14	13	11	9
72	18	19	16	9	11	13	1	5	13	11	12
73	7	16	17	2	3	14	2	5	11	15	11
74	18	11	19	7	7	9	1	10	10	20	7
75	13	10	18	8	15	17	4	6	4	15	10
76	12	13	16	7	7	8	2	6	12	11	25
77	17	18	12	12	6	11	1	6	6	14	6
78	15	16	5	10	12	12	1	8	-*	16	9
79	10	10	1	6	12	14	1	11	4	21	13
80	15	16	15	2	8	15	3	6	14	9	8
81	14	19	14	6	8	7	4	10	5	11	9
82	5	15	8	9	8	7	6	6	13	19	2
83	8	16	11	7	10	15	4	8	8	2	8
84	14	14	16	10	7	16	4	5	8	10	6
85	12	14	17	0	0	11	6	17	7	15	8
86	14	13	15	5	3	13	3	8	10	4	4
87	12	12	14	8	5	17	3	10	7	19	9
88	15	15	12	12	7	13	1	7	10	14	11
89	16	19	16	5	7	10	4	10	13	17	10
90	18	12	17	10	6	8	3	9	9	17	5
91	12	13	16	5	2	13	7	9	8	12	10
92	18	15	14	8	1	14	4	10	9	5	10
93	15	17	8	11	10	14	1	4	8	3	7
94	15	13	19	9	10	10	6	11	7	14	10
95	18	4	17	10	6	13	2	14	6	3	8
96	10	12	16	4	7	11	2	9	12	7	13
97	15	14	6	2	9	13	0	4	12	17	9
98	9	16	15	6	7	15	4	2	6	9	11
99	11	10	15	6	7	6	6	6	10	17	9
Block total	**1329**	**1379**	**1303**	**752**	**793**	**1183**	**327**	**833**	**977**	**1309**	**887**
Block total with x**	**1406**	**1422**	**1342**	**776**	**816**	**1216**	**337**	**862**	**1020**	**1330**	**916**

-* = missing provenance
x** = unidentified provenance

Appendix 13

Table A.13 Distribution of remaining trees by provenances and by blocks at the latest assessment (2011). The numbers are given as percentage of initial stem number

block prov. code	Blocks										
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**
00	63	8	57	40	33	52	12	38	0	52	35
01	78	68	46	16	56	52	22	40	44	40	29
02	59	69	46	16	42	43	4	26	43	56	50
03	68	67	80	38	55	40	4	42	36	60	43
04	40	70	48	26	36	23	12	33	35	71	28
05	76	61	63	41	28	41	14	40	44	64	32
06	36	62	67	22	29	67	12	35	65	75	27
07	50	54	56	35	33	39	12	13	27	64	48
08	56	40	67	43	36	19	0	19	54	46	43
09	5	58	52	50	40	30	20	30	52	58	31
10	54	58	55	14	40	65	12	27	57	67	44
11	43	38	64	38	33	52	12	32	56	59	41
12	33	38	54	39	32	52	20	35	29	61	32
13	68	44	72	30	40	78	28	52	38	21	39
14	59	76	50	50	38	64	23	50	37	33	27
15	67	44	54	29	24	28	9	32	52	46	42
16	62	48	58	15	33	36	8	42	43	48	29
17	32	54	64	64	32	41	13	35	48	68	22
18	80	5	56	33	46	67	16	43	22	37	52
19	32	43	54	5	43	63	16	18	50	60	41
20	70	26	60	33	36	48	17	14	28	64	48
21	61	48	56	26	20	40	13	41	58	60	48
22	71	58	38	29	36	46	5	20	56	74	19
23	75	58	46	52	32	8	19	48	54	33	50
24	74	56	50	25	40	46	8	33	58	50	56
25	74	58	42	25	44	54	12	40	38	80	10
26	17	59	56	58	28	50	16	38	57	73	32
27	29	67	40	33	21	55	12	33	26	71	24
28	59	50	61	20	36	54	20	48	63	71	42
29	71	72	69	39	28	38	0	8	50	36	42
30	67	57	46	35	33	52	17	24	41	67	17
31	58	68	36	40	24	50	8	5	19	60	46
32	48	22	60	14	52	25	13	23	30	68	36

Table A.13 cont.

block prov. code	Blocks										
	01	02	03	04	05	06	07	08	09	10	11
33	65	0	23	24	38	56	0	35	35	64	11
34	18	71	72	43	28	72	9	21	44	72	74
35	82	64	44	36	12	71	13	33	56	39	42
36	76	50	25	24	29	43	12	28	33	56	36
37	63	76	44	0	50	48	12	46	32	46	42
38	56	56	46	20	20	57	23	31	10	64	13
39	71	79	48	36	38	19	13	19	28	43	50
40	64	52	60	24	48	64	29	25	32	60	32
41	54	72	71	25	29	58	8	48	48	45	56
42	5	54	60	46	52	56	20	44	57	28	38
43	73	68	70	40	39	35	14	36	48	52	44
44	73	65	48	20	35	24	4	36	25	46	38
45	67	55	48	32	40	48	29	23	32	76	42
46	67	58	71	33	9	61	19	13	31	64	38
47	71	54	60	16	43	50	8	42	50	64	38
48	60	75	55	23	33	52	20	48	46	84	48
49	48	52	58	32	27	46	29	30	62	54	41
50	76	64	70	35	36	64	15	4	44	78	29
51	54	78	44	42	18	5	17	46	43	63	28
52	54	64	27	36	48	57	17	50	54	54	46
53	42	72	0	46	35	23	14	30	27	25	38
54	75	56	36	35	32	61	13	50	25	48	25
55	68	65	59	63	29	60	8	40	50	58	21
56	60	40	64	23	28	48	8	44	48	68	31
57	48	75	39	36	35	52	17	52	55	38	8
58	80	68	48	25	50	25	13	40	45	7	12
59	56	57	52	28	32	48	16	48	16	13	50
60	54	64	76	12	10	62	13	41	32	50	39
61	57	56	47	42	21	62	13	32	44	68	48
62	13	48	48	32	17	72	4	42	45	52	46
63	58	72	35	18	38	61	15	36	48	59	38
64	56	40	36	42	38	56	15	29	50	43	33
65	25	72	43	39	31	63	15	40	28	41	33
66	15	78	29	33	20	48	23	43	48	50	48
67	52	57	57	25	13	60	19	32	33	14	28
68	43	44	46	23	38	43	0	54	52	42	36
69	77	50	58	46	32	38	13	32	43	28	48

Table A.13 cont.

block prov. code	Blocks										
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**
70	55	72	62	17	44	58	20	46	46	56	38
71	84	57	57	38	36	56	8	58	50	46	36
72	75	73	64	36	44	52	4	19	50	44	52
73	30	64	71	9	15	58	8	24	46	58	42
74	78	44	76	29	28	41	6	38	40	74	33
75	62	40	72	35	63	71	17	25	19	60	42
76	48	57	59	30	30	33	8	24	48	42	56
77	68	75	48	48	26	44	4	26	24	61	25
78	63	67	26	38	48	46	4	33	-*	64	36
79	63	56	5	24	50	56	4	44	25	84	54
80	63	62	63	9	33	58	12	24	56	36	33
81	61	83	64	24	32	29	19	40	22	46	36
82	26	68	33	45	33	28	24	24	54	76	9
83	33	62	46	27	40	60	18	31	35	10	35
84	56	56	64	45	33	67	17	22	32	63	26
85	52	58	74	0	0	44	25	65	28	58	31
86	56	57	63	22	19	50	12	33	42	17	19
87	52	55	56	32	24	65	12	40	27	76	33
88	60	65	52	48	28	54	4	28	45	56	50
89	73	76	64	20	28	45	16	43	50	65	43
90	72	50	68	40	25	35	12	38	38	68	21
91	52	52	73	22	8	54	26	35	35	55	38
92	72	60	58	38	7	54	16	38	35	24	40
93	60	71	32	44	40	56	4	15	33	14	32
94	60	54	76	36	43	42	25	50	33	54	45
95	72	20	68	40	29	50	8	54	24	13	31
96	42	57	67	17	27	44	8	36	48	30	52
97	60	56	27	8	41	50	0	17	48	68	38
98	36	62	75	24	28	58	16	8	26	38	48
99	50	45	60	25	29	26	22	30	40	71	38
Block total	**57**	**57**	**54**	**31**	**33**	**49**	**13**	**34**	**41**	**53**	**37**
Block total with x**	**56**	**57**	**54**	**31**	**33**	**49**	**13**	**34**	**41**	**53**	**37**

-* = missing provenance
x** = unidentified provenances

Appendix 14

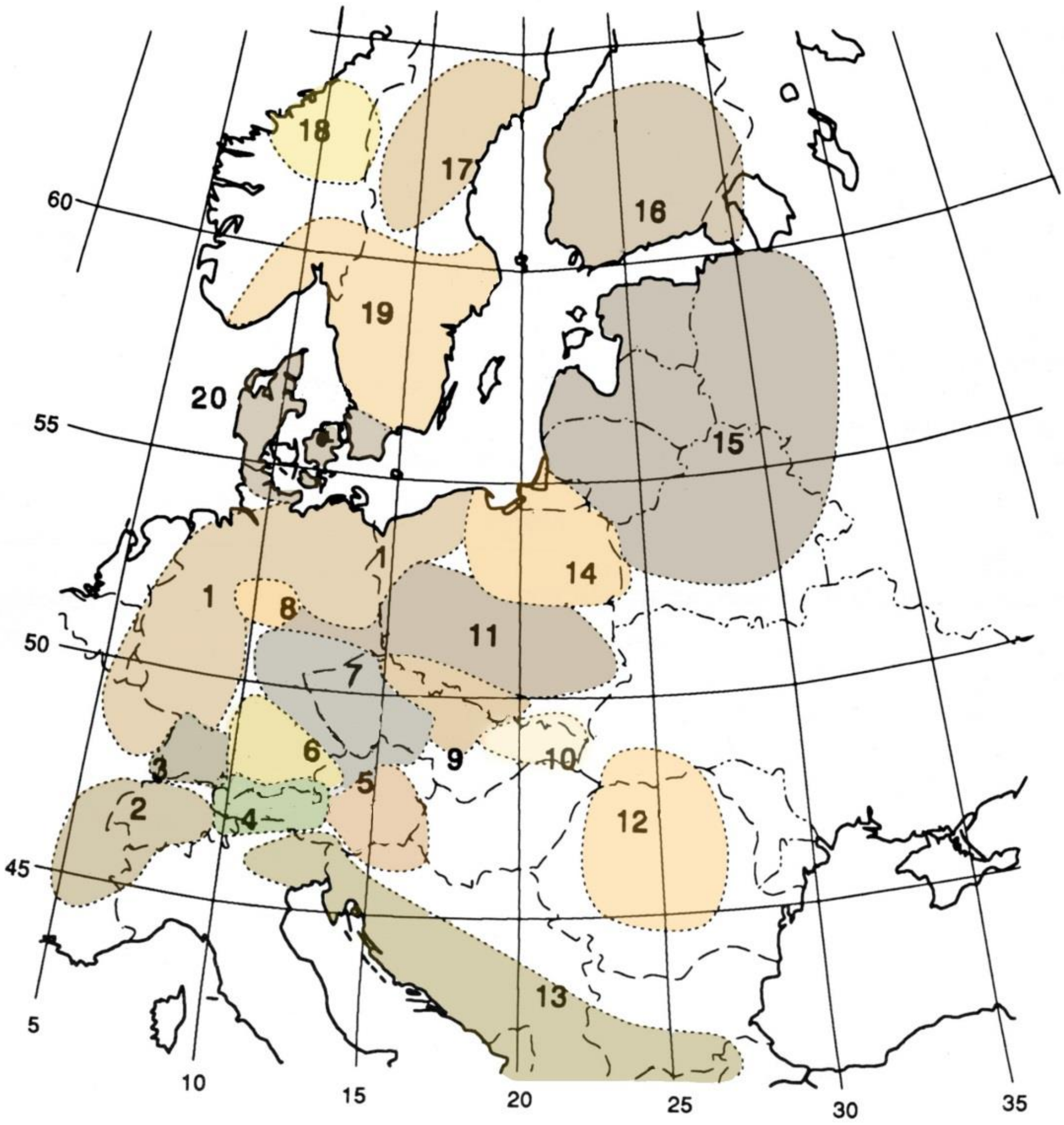


Figure A.14 Numbering and delineation of zones, refined by Skrøppa (after Dietrichson 1979, Fottland – Skrøppa 1989, A. Persson – B. Persson 1992)

Appendix 15

Table A.15 Seed classes: codes by P. Krutzsch (1967, pers. comm.), for classifying the circumstances of collecting seed samples for the trial

Seed class (SC) – Classification on the type of collection
1 –A single tree harvest
2 – Collection from at least 10 trees within one stand
3 – Sample from collection in a single stand
4 – Sample from seed harvested in several neighboring stands, or area greater than a “stand” (ranger district)
5 – Sample from seed harvested in stands defined as ‘Anerkannt’ (phenotypically selected by local forest authority)
6 – Sample from seed harvested in a greater area (Forstamt – management district)
7 – Mixture of 2-3 single tree collections