GROWTH PERFORMANCE OF NORWAY SPRUCE IN THE CZECH-GERMAN PROVENANCE TRIAL PLOT LEDEČ*

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A long term experimental project DDR-ČSR 1972/76 was carried out to study the growth characteristics and evaluate the progeny variability of Norway spruce (*Picea abies* (L.) Karst.) provenances from Central Europe, Hercynian-Sudetes area. The study presents the evaluation of the increment characteristics, mortality, and qualitative morphological characteristics of forty-two studied spruce provenances at one of international experimental plots situated at Ledeč-Zaháj, the Czech Republic, 46 years after the beginning of the experiment. The best growth was observed at the provenances from the Středočeská pahorkatina upland and the Krušné hory Mts. (Erzgebirge, Ore Mts.) in the given conditions. The highest average height increment was confirmed for spruce provenances from Jedlá, Reinhardtsdorf, Hainsbach, Gehlberg (Nos. 17, 37, 41, 46, respectively), diameter increment was the highest for similar provenances with the addition of Älterthal (Nos. 17, 41, 44, 46). Results did not separate the provenances into clearly specified groups according to the original locality, latitude or altitude, probably due to suitable (not extreme) conditions at the experimental plot. According to the correlation analysis, correlations were found between mean diameter and original stand altitude (negative) and original stand latitude (positive). The tree survival rate was negatively correlated with both the mean diameter and mean height probably as a result of the trees competition on the stand.

Picea abies; international provenance test; growth parameters; qualitative characteristics

INTRODUCTION

Intensive provenance trials of important forest tree species were established in European countries during the 20th century as a tool for forestry breeding improvement, coordinated in most cases by the International Union of Forest Research Organizations (IUFRO). These experiments based on open-pollinated progenies from different geographic areas can show the plasticity of individual populations, mutual interactions of genotype and environment, as well as vitality and regeneration ability of different populations, creating an opportunity to establish ranges for the cultivation of the best progenies of specific forest tree provenances.

The largest Norway spruce provenance inventory experiments were established in 1938 (for 36 seed sources, planted out in 26 field tests), in 1964–1968 (for 1100 populations originating from the Norway spruce natural range area in Europe, planted in 20 field trials), and in 1972 (43 plantation locations) under the IUFRO supervision as an international project including the participation of 12 European countries and Canada (further details published in Dietrichson et al., 1976; Krutzsch, 1992; Persson, Persson, 1997; Oleksyn et al., 1998; Giertych, 2001; Chałupka et al., 2008; Gömöry et al., 2012; Romšáková et al., 2012). Follow-up experiments were often aimed more at a detailed study of provenances from a specific country or focused on specific characteristics. The Alpine region provenances study was established in 1978 (Kapeller et al., 2012) comprising 480 provenances from the Alps and 60 other provenances. Provenances trial in Finland was focused on the particular physiological and morphological characteristics of populations from southern and northern regions (Beuker et al., 1998). The provenance experiments in Poland considered a drought tolerance and differences between populations in variable altitudes (Modrzyński, Eriksson, 2002; Chmura, 2006) or they were focused on high productivity (Chałupka et al., 2008). Some of these results show that provenances from the Carpathian and Baltic republics had higher productivity than northern provenances and that provenances from the Swedish trial (Persson, Persson, 1997) and those from

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southern European mountains are not suitable for the central European plantations (Šindelář, 2004).

The long term experimental project DDR-ČSR 1972/76 was carried out to study the growth characteristics and to evaluate the progeny variability of spruce provenances from Central Europe – Hercynian-Sudetes area (central part of the spruce natural dispersion area), and to verify applicability of the provenances in particular vegetation zones and immission areas (Šindelář, 2004). To obtain results based on different climatic and site conditions, originally 19 plots from the altitude of 250–1250 m a.s.l. were selected – 10 in the Czech Republic (CR) and 9 in Germany.

The presented study shows the production potential and qualitative morphological characteristics of the studied Norway spruce (*Picea abies* (L.) Karst.) provenances on one of the plots, situated in the CR close to Ledeč, in the Českomoravská vrchovina highland, 46 years after the beginning of the experiment. Last decades results have been published so far mainly as a part of final reports (Forestry and Game Management Research Institute Strnady - FGMRI) and are not widely accessible.

MATERIAL AND METHODS

Spruce (*Picea abies* (L.) Karst.) international provenance experimental plot No. 241 Ledeč-Zaháj (DDR-ČSR 1972/76-77) is situated close to the Ledeč nad Sázavou – Zaháj territory at Českomoravská vrchovina highland, within the area of spruce natural distribution (Hamerník, Musil, 2008). The plot is situated in a flat terrain at 465 m a.s.l. (latitude 49.68°N, longitude 15.22°E), characterized by annual average temperature 7.9 °C, average temperature at vegetation period 14.1°C, annual average precipitation 635 mm (according to the Czech Hydrometeorological Institution (CHMI) – see http://www.chmi.cz/portal/dt?portal_lang=cs&menu=JSPTabContainer/P4_Historicka_data), prevailing type of forest stands 4Q6 (oak-fir poor gleyed site), soil type Cambisol, and parent rock paragneiss.

Provenances were originally collected from areas which could be broadly described like localities with natural spruce occurrence (Hamerník, Musil, 2008) at the altitude above 370 m a.s.l. and within the latitude 48.8–51.8°N (southern border is delimited by the Šumava Mts., the northern by the Harz Mts.) and longitude 10.6–18.5°E (western border delimited by the Harz Mts. and the eastern by the Beskydy Mts.). Since the provenances were collected almost 50 years ago, there is a problem with a detailed determination of particular forest stands – exact coordinates were roughly recorded at the time of the trial establishment and thus the identification of particular areas was based solely on coordinates with one decimal place and local name found using google maps website (unfortunately in some cases exact identification was not possible – provenances Nos. 2, 44, 47). Presented accurate coordinates are listed in Table 1. Provenances collected from the closest distance from the experimental plot are Nos. 17–19. Original data with provenances origin are stored by the responsible manager of the evaluated plot, Forestry and Game Management Research Institute, Strnady.

The experimental plot was established on the area of 2.56 ha in a uniform experimental double grid design, with trees of each population split in randomized blocks (replications). Four-year-old trees (2/2 – two years after transplantation in forest nursery) were outplanted in 1976. Each single provenance within a subplot of 10 × 10 m consisted of 50 plants initially (25 as target), planted with spacing 1 × 2 m in 5 rows (recommended standard IUDRO methodology – Šindelář, 2004). First (schematic) reduction of individuals was carried out in the autumn of 1996 (20 years after planting) and included also removing of individuals damaged by frost or by hailstorm (higher occurrence in 1995). Stem cleaning of border individuals up to the height of 3 m was carried out in 1996, declined individuals have been continuously removed since that time. Second thinning followed in 2006 with the goal to reach the target numbers of trees per plot. Damaged (with fungi infestation), declining, and forked trees were also removed.

For the purposes of this study, 42 provenances were evaluated in 3 replications (Table 1).

Dendrometrical measurements and qualitative characteristics were evaluated in the autumn (October and November) of 2012. Tree height was measured by the digital hypsometer Vertex Laser 400 (Haglöf, Langsele, Sweden) with the accuracy of 0.1 m. Diameter (DBH) was measured at the standard height of 1.3 m by caliper (accuracy 0.1 cm).

Qualitative characteristics were evaluated on a three-value scale: trunk shape (1 = straight, 2 = slightly contorted, 3 = contorted or fork); branches density (1 = low, 2 = average (2 whorls per 1 m of height), 3 = dense (more than 2 whorls per 1 m)); branches shape (1 = vertical, 2 = horizontal, 3 = upright); foliation/density of assimilatory organs (1 = dense (75 = 100%), 2 = average (50 = 75%), 3 = thin (less than 50%)). Mortality (or the number of the surviving trees per plot) should be considered as a subsidiary criterion, due to the undertaken management treatment. Data from the plots were analyzed using STATISTICA 10.0 software. ANOVA, Levene, and Neumann-Keuls tests were used to compare provenances characteristics and characteristics of variance (significance level $\alpha = 0.05$). Since the data on the height show higher variance differences, square transformation was used as a data preparation for Levene test. Multiple-comparison Tukey's test was used to separate groups significantly different in height and diameter. Pearson's correlation

Table 1. Origin and coordinates of particular provenances from former Czechoslovakia (CR), and the German Democratic Republic (D)

State	Area	No.	Provenance	Latitude	Longitude	Altitude (m a.s.l.)
CR	Krušné hory	1	Nové Hamry	50.35	12.72	870
CR	Krušné hory	2	Strádov	50.6	13.8	660
CR	Šumava	3	Horní Les	48.80	13.99	870
CR	Šumava	4	Kvilda	49.02	13.57	910
CR	Šumava	5	Ježová	48.65	14.04	945
CR	Šumava	6	Černý Kříž	48.51	13.51	735
CR	Český les	7	Babylon	49.40	12.86	540
CR	Český les	8	Nová Huť	49.46	13.30	610
CR	Brdy	9	Kokšín	49.60	13.67	540
CR	Jizerské hory	10	Smědava	50.84	15.27	660
CR	Jizerské hory	11	Kateřinky	50.80	15.08	695
CR	Krkonoše	12	Černá hora	50.65	15.74	760
CR	Krkonoše	13	Černý důl	50.64	15.72	840
CR	Krkonoše	14	Labská	50.72	15.57	950
CR	Krkonoše	15	Rezek	50.70	15.51	950
CR	Středočeská pahorkatina	16	Voděrady	49.96	14.79	370
CR	Středočeská pahorkatina	17	Jedlá	49.73	15.24	390
CR	Středočeská pahorkatina	18	Želivka	49.69	15.11	450
CR	Středočeská pahorkatina	19	Zbraslavice	49.84	15.18	430
CR	Českomoravská vrchovina	20	Svinošice	49.34	16.57	410
CR	Českomoravská vrchovina	21	Lísek	49.65	16.11	545
CR	Českomoravská vrchovina	22	Herálec	49.70	15.96	710
CR	Českomoravská vrchovina	23	Městec	49.68	15.91	710
CR	Českomoravská vrchovina	24	Devět skal	49.67	16.03	730
CR	Jeseníky	25	Vrbno	50.13	17.39	810
CR	Jeseníky	26	Hubertov	50.08	17.30	920
CR	Jeseníky	27	Vidly	50.10	17.27	1070
CR	Beskydy	28	Řečice	49.52	18.48	680
CR	Orlické hory	34	Mladkov	50.08	16.59	630
CR	Orlické hory	35	Říčky	50.12	16.46	780
D	Lausitzer Park	36	Kauschwitz	51.43	14.60	120
D	Älbsandsteingebirge	37	Reinhardtsdorf	50.89	14.17	240
D	Erzgebirge – west	38	Schindelbach	50.60	13.12	610
D	Erzgebirge – west	39	Bütterbächel	50.40	12.56	735
D	Erzgebirge – central	40	Grosse Mittweida	50.49	12.90	830
D	Erzgebirge – central	41	Hainsbach	50.70	13.20	465
D	Erzgebirge – central	42	Tellerhäuser	50.43	12.89	920
D	Erzgebirge – east	43	Rehefeld	50.74	13.69	685
D	Thüringer Wald	44	Älterthal	50.6	10.7	410
D	Thüringer Wald	45	Katzhütte	50.54	11.04	590
D	Thüringer Wald	46	Gehlberg	50.69	10.79	715
D	Harz	47	Scharfenstein	51.8	10.6	665

coefficient was used to describe correlation of some variables. Cluster analysis was performed using S+ statistical software.

RESULTS

Tree height and diameter

Average tree height is presented in Fig. 1. Among the provenances, it varied by approximately 30% within the range between 14.2 m (Jeseníky Mts., No. 26) and 19.3 m (Středočeská pahorkatina upland, No. 17). Based on Tukey's test the provenances were divided according to the mean height into six groups with significant differences (Table 2) among some of them. Detail results including differences between groups are presented in Figs. 1 and 2. Almost the same distribution although with much less significant difference can be seen for the mean diameter values ranging 13.6–18.4 cm (Fig. 2). Both the lowest mean height (14.2 m) and the lowest mean diameter (13.6 cm) were determined for the provenance from the Jeseníky Mts. (No. 26).

Qualitative characteristics

Qualitative characteristics (continuous values) described by Table 3 have been evaluated on a three-value scale (discreet values) and the main proportion of individuals has the same position at the scale. As a result there are very small differences among characteristic values, nevertheless ANOVA confirmed significant differences between some of the provenances in the

Fig. 1. Mean height of Norway spruce different provenances

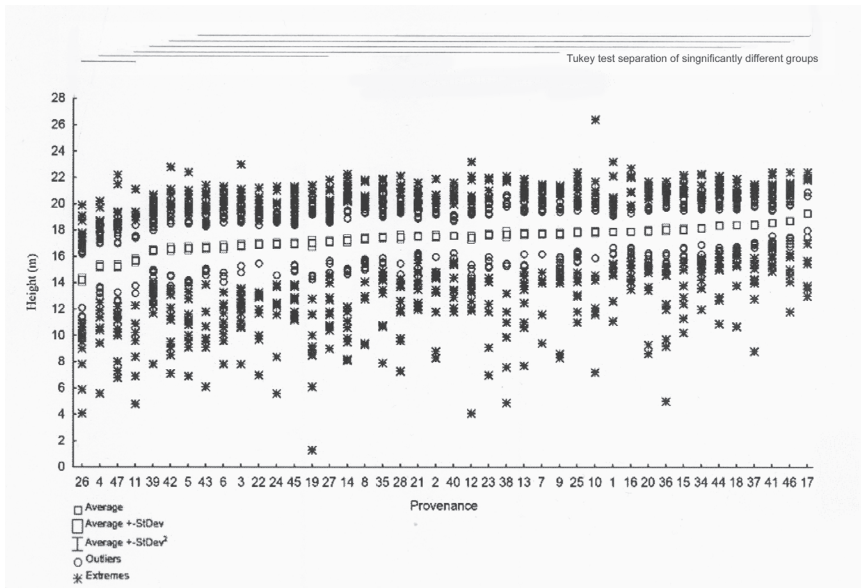

Fig. 2. Mean diameter (DBH 1.3 m) of Norway spruce different provenances

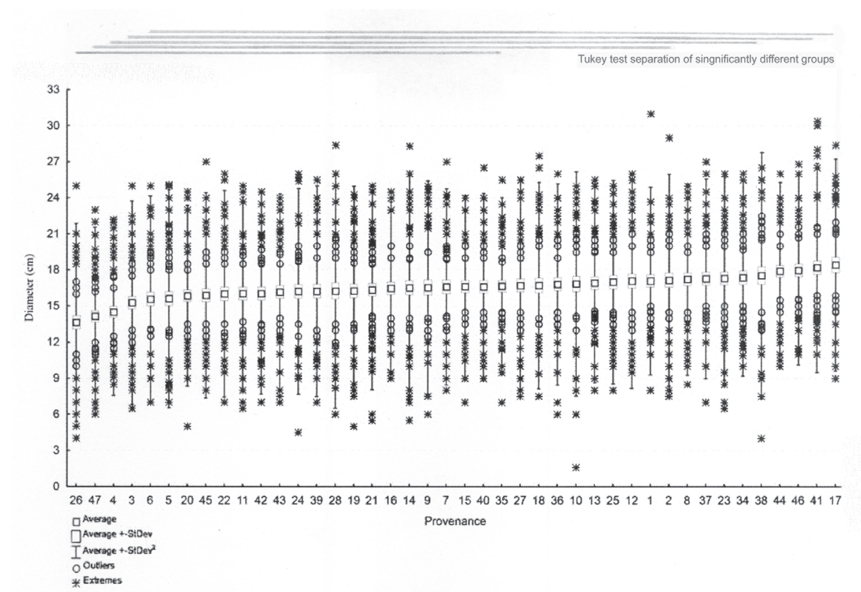

Table 2. ANOVA results for height and diameter evaluation of the experimental plot

Levene test* – result probability ratio (> *F*) 0.000139					
Neumann-Keuls test* (cm)					
	Degree of freedom	Sum square	Mean square	*F* value	Probability ratio (> *F*)
No. of observations	41	2 223	54.21	3.087	2.5 e^{-10}
Residuals	2 365	41 535	17.56		significant
Levene test** – result probability ratio (> *F*) 0.0935					
Neumann-Keuls test** (m) (data square transformation)					
No. of observations	41	2 292 117	55 905	7.276	2.0 e^{-16}
Residuals	2 365	18 171 855	7 684		significant

*diameter evaluation, **height evaluation

distribution of these characteristics. The prevailing type of trunk shape was straight with the highest trunk quality and the lowest occurrence of contortions was recorded for the provenances Nos. 1, 4, 6, 15, 25, 43, 44, ($F = 2.029$, $P < 0.0003$). Provenance No. 34 (Orlické hory Mts. origin) had the lowest trunk quality and about 30% of slightly contorted trunks. There were also differences in the density of branches ($F = 2.16$, $P < 0.0003$) and the provenances with significantly higher than average density of branches were Nos. 3, 4, 6, 11, 12,22, 23, 24, 26, 38, 42, 47, originally from the altitudes over 700 m a.s.l. The shape of the branches was prevailingly horizontal, with no significant differences among the provenances ($F = 0.39$, $P < 0.53$). In our study, the shape of the branches and crown was influenced mainly by the age of the stand and the closed canopy state. Foliation differences were also significant ($F = 17.6$, $P < 0.017$) although clear just for few provenances: Nos. 6, 27, and 43 had visibly higher than average foliation (in the range of 50–75%) and No. 26 had visibly lower than average foliation (slightly below 50%). The lowest number of individuals per plot and presumably the highest mortality was recorded for the provenances Nos. 9, 24, 45, 46; the lowest mortality for the provenances Nos. 3, 5, 19, 22, 27, 41 – nevertheless the Pearson's chi-squared test did not confirm significant differences ($F = 56.74$, $P < 0.052$).

Comparison of the provenances

The cluster analysis (Fig. 3) did not show any clear grouping factors like territory, altitude or latitude. According to the correlation analyses (Table 4) comparing the influence of known characteristics of the provenances, negative correlations were found between altitude and mean diameter. In contrast, there was a positive correlation between the original latitude and mean diameter. The tree survival rate was negatively correlated with both the mean diameter and the mean height probably as a result of the tree competition on the stand. Comparing the provenances of the two countries of origin (Czech Republic and Germany), no significant differences were found in diameter or survival rates.

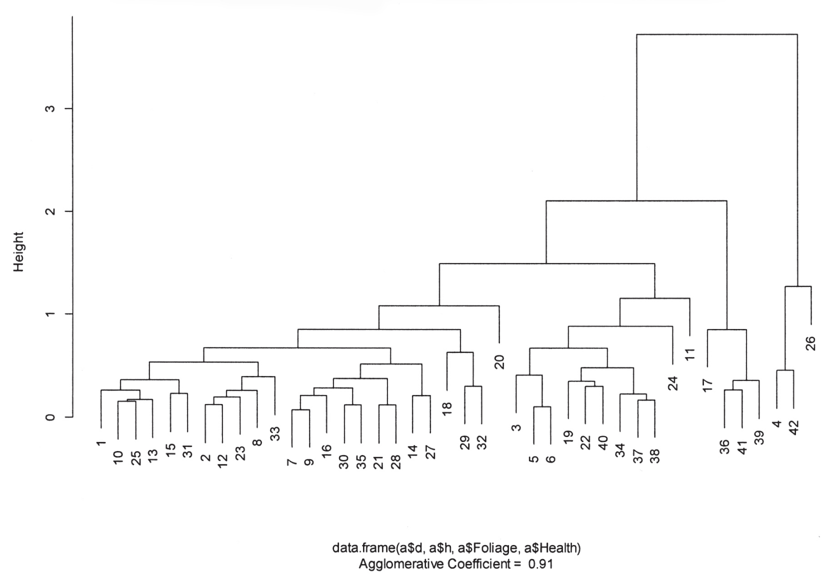

Fig. 3. Dendrogram of provenances based on the growth parameters, foliation, and health state (CLU, STATISTICA software)

Table 3. Qualitative characteristics of particular provenances in the experimental plot

Provenance No.	Place of origin	Trunk shape	Branches density	Branches shape	Foliation	No. of trees per ar ± SD
1	Krušné hory	**1.0**[*] ± 0.2	2.2 ± 0.4	2.1 ± 0.3	2.1 ± 0.3	17.3 ± 1.5
2	Krušné hory	1.1 ± 0.3	2.2 ± 0.4	2.0 ± 0.3	2.1 ± 0.3	15.3 ± 2.1
3	Šumava	1.1 ± 0.3	**2.3** ± 0.5	2.0 ± 0.3	2.1 ± 0.4	**19.3** ± 3.5
4	Šumava	**1.0** ± 0.2	2.3 ± 0.5	2.0 ± 0.2	2.1 ± 0.4	15.3 ± 2.5
5	Šumava	1.2 ± 0.4	2.2 ± 0.4	2.0 ± 0.1	2.1 ± 0.3	**19.3** ± 4.9
6	Šumava	**1.1** ± 0.2	**2.3** ± 0.4	2.0 ± 0.1	**2.0** ± 0.1	18.0 ± 3.0
7	Český les	1.1 ± 0.3	2.2 ± 0.4	2.0 ± 0.1	2.0 ± 0.3	15.6 ± 2.3
8	Český les	1.2 ± 0.4	2.3 ± 0.5	2.0 ± 0.1	2.1 ± 0.3	17.0 ± 1.7
9	Brdy	1.2 ± 0.4	2.1 ± 0.3	2.0 ± 0.1	2.1 ± 0.3	14.3 ± 2.0
10	Jizerské hory	1.3 ± 0.5	2.3 ± 0.5	2.0 ± 0.1	2.1 ± 0.4	17.0 ± 1.0
11	Jizerské hory	1.3 ± 0.5	**2.3** ± 0.5	2.0 ± 0.1	2.1 ± 0.4	17.0 ± 2.6
12	Krkonoše	1.1 ± 0.3	**2.3** ± 0.5	2.0 ± 0.1	2.1 ± 0.3	17.0 ± 1.0
13	Krkonoše	1.2 ± 0.5	2.2 ± 0.4	2.0 ± 0.1	2.1 ± 0.3	18.3 ± 2.0
14	Krkonoše	1.1 ± 0.4	2.2 ± 0.4	2.0 ± 0.1	2.1 ± 0.3	18.6 ± 2.8
15	Krkonoše	**1.1** ± 0.3	2.1 ± 0.4	2.0 ± 0.1	2.1 ± 0.3	18.0 ± 3.0
16	Středočeská pahorkatina	1.2 ± 0.4	2.1 ± 0.4	2.0 ± 0.2	2.1 ± 0.4	17.0 ± 1.0
17	Středočeská pahorkatina	1.1 ± 0.3	2.2 ± 0.4	2.1 ± 0.2	2.1 ± 0.3	16.7 ± 5.6
18	Středočeská pahorkatina	1.3 ± 0.4	2.1 ± 0.3	2.0 ± 0.1	2.1 ± 0.3	16.7 ± 3.2
19	Středočeská pahorkatina	1.2 ± 0.4	2.1 ± 0.3	2.0 ± 0.1	2.1 ± 0.3	**19.0** ± 2.8
20	Českomoravská vrchovina	1.2 ± 0.4	2.2 ± 0.4	2.0 ± 0.2	2.1 ± 0.3	17.6 ± 2.8
21	Českomoravská vrchovina	1.2 ± 0.4	2.1 ± 0.4	2.0 ± 0.2	2.1 ± 0.3	18.0 ± 2.6
22	Českomoravská vrchovina	1.2 ± 0.4	**2.3** ± 0.5	2.0 ± 0.2	2.1 ± 0.3	**19.6** ± 4.5
23	Českomoravská vrchovina	1.1 ± 0.3	**2.3** ± 0.5	2.0 ± 0.3	2.1 ± 0.4	18.6 ± 2.5
24	Českomoravská vrchovina	1.3 ± 0.4	**2.3** ± 0.4	2.0 ± 0.2	2.1 ± 0.3	15.0 ± 3.5
25	Jeseníky	**1.1** ± 0.2	2.1 ± 0.2	2.0 ± 0.3	2.1 ± 0.3	16.0 ± 5.6
26	Jeseníky	1.2 ± 0.4	**2.5** ± 0.5	2.0 ± 0.1	2.2 ± 0.4	17.6 ± 4.0
27	Jeseníky	1.2 ± 0.4	2.1 ± 0.3	**2.0** ± 0.1	2.0 ± 0.2	**19.3** ± 2.3
28	Beskydy	1.1 ± 0.4	2.2 ± 0.4	2.0 ± 0.1	2.2 ± 0.4	15.3 ± 3.2
34	Orlické hory	1.3 ± 0.5	2.2 ± 0.4	2.0 ± 0.2	2.1 ± 0.3	17.6 ± 1.5
35	Orlické hory	1.2 ± 0.4	2.1 ± 0.2	2.0 ± 0.1	2.2 ± 0.3	18.6 ± 4.6
36	Lausitzer Park	1.2 ± 0.4	2.1 ± 0.3	2.0 ± 0.1	2.1 ± 0.3	17.6 ± 1.5
37	Älbsandsteingebirge	1.2 ± 0.4	2.2 ± 0.4	2.0 ± 0.1	2.1 ± 0.3	17.3 ± 3.0
38	Erzgebirge – west	1.2 ± 0.4	**2.3** ± 0.5	2.0 ± 0.2	2.1 ± 0.3	15.3 ± 2.8
39	Erzgebirge – west	1.1 ± 0.3	2.2 ± 0.4	2.1 ± 0.3	2.1 ± 0.3	16.0 ± 1.7
40	Erzgebirge – central	1.1 ± 0.4	2.0 ± 0.5	2.0 ± 0.3	2.0 ± 0.3	18.3 ± 4.0
41	Erzgebirge – central	1.1 ± 0.3	2.1 ± 0.3	2.0 ± 0.1	2.1 ± 0.3	**19.0** ± 1.0
42	Erzgebirge – central	1.3 ± 0.4	**2.3** ± 0.5	2.0 ± 0.1	2.2 ± 0.4	17.0 ± 2.0
43	Erzgebirge – east	**1.1** ± 0.2	2.1 ± 0.3	**2.0** ± 0.1	2.0 ± 0.2	18.3 ± 4.0
44	Thüringer Wald	**1.1** ± 0.2	2.1 ± 0.3	2.1 ± 0.2	2.1 ± 0.3	16.6 ± 2.5
45	Thüringer Wald	1.1 ± 0.4	2.2 ± 0.4	2.1 ± 0.1	2.1 ± 0.3	14.6 ± 1.2
46	Thüringer Wald	1.1 ± 0.3	2.2 ± 0.4	2.0 ± 0.1	2.1 ± 0.3	14.6 ± 1.5
47	Harz	1.2 ± 0.4	**2.4** ± 0.5	2.0 ± 0.2	2.1 ± 0.4	17.6 ± 5.7

*numbers in bold show provenances with values significantly different in comparison with average values (for detailed description see the text)

Table 4. Results of correlation analyses among some variables, describing correlation coefficient *r* and significance level α

Correlation	Height	Diameter	Number per plot	Latitude	Longitude	Altitude
Height	1	0.387 0.000	–0.095 0.000	0.027 0.188	0.004 0.843	0.154 0.000
Diameter		1	–0.075 0.000	0.048 0.019	–0.012 0.556	–0.080 0.000
Number per plot			1	0.072 0.652	–0.040 0.804	0.321 0.038
Latitude				1	–0.280 0.073	–0.159 0.316
Longitude					1	0.150 0.343
Altitude						1

height, diameter, number per plot = variables describing provenances growth characteristics (average height (m), average diameter at brest height (cm), average number of surviving trees per plot; latitude, longitude, altitude = variables describing the provenance place of origin

DISCUSSION

The values of growth described by the height of trees confirmed significant differences between provenances, reaching up to 30%. The provenances distribution according to the mean height was more pronounced than the distribution according to the mean diameter, nevertheless best part of the provenances had a similar position in both characteristics. Significant effect of the place of origin onto the height growth of *Picea abies* provenances was also confirmed by Kapeller et al., 2012, describing height differences between provenances of about 10%, which is relatively low in comparison with our results, but this study had been conducted on a much younger, 15-year-old stand. In the study of Persson, Persson (1997) who compared only 17-year- old stands, Carpathian provenances had the highest stem volume, and stands from Eastern Europe and southern Scandinavia belonged to the faster-growing types. In our study, however, the Carpathian provenances (Nos. 28–33) had no exceptional results. Nevertheless, it should be reminded that significant differences among provenances in growth, especially ring width and diameter increment, can change over time and with the age of the stand (Zubizarreta-Gerendiain et al., 2012). According to other provenance tests (Gömöry et al., 2012), the response patterns in volume growth are generally consistent with height, which corresponds with our results.

The survival rate (or mortality) is a characteristic indicative of the provenance vitality. In our case, since the initial numbers were changed by silvicultural measurements, this characteristic should be considered a subsidiary value, contributing to the description of health state, nevertheless correlation with foliation (health state) is observable.

Some of the most productive provenances (Nos. 17, 41) had the highest surviving number of individuals per plot (40% from the initial number) at the same time. For a much younger stand (15 years) about a 77% survival rate was reported before artificial reduction (Kapeller et al., 2012).

Qualitative characteristics of provenances were not pronounced and mainly did not show significant differences or clearly denoted trends. An exception was the characteristic describing density of branches on the trunk – provenances with significantly higher than usual density of branches usually originated from higher altitudes (above 700 m a.s.l.). This result corresponds with Geburek et al., 2008, who assessed the influence of environmental variables on the crown types and characteristics. In their study, 74% of crown variability was related to acclimation to the temperature regime and altitude of the original stand, 23% of the variability depended on the precipitation variables. According to the same authors (Geburek et al., 2008), the basic crown architecture is probably genetically encoded but certain crown modifications may be triggered by environmental signals. In our case the climatic conditions at the experimental plot seem to be sufficient for almost all provenances with a few exceptions showing higher defoliation (No. 26 from the Jeseníky Mts.) or higher contortions of stem (No. 34 from the Orlické hory Mts.).

Comparing the provenances of the two countries of origin (Czech Republic and Germany), no significant differences were found in diameter and survival rates. Mäkinen et al., 2002, who also evaluated provenances from Germany and other countries, did not find any significant differences in comparison even with Norwegian provenances. This is in accordance with the results of Dering, Lewandowski (2009) considering Central Europe as an overlapping zone between northern and southern spruce provenances and southern Poland and adjacent countries as part of the southern zone.

In our experiment, negative correlations were found between altitude and mean diameter of the provenances. Similar results were observed by Modrzyński, Eriksson (2002) who reported negative correlation of the biomass and height of trees in a population with the altitude of their origin. Altitude could be used as a proxy for temperature and precipitation variation as environmental selection factors for spruce (Romšáková et al., 2012). Concerning altitude, some authors confirmed the negative correlation between the altitude of the original stand and the intensity of height increment as well as stem volume (Oleksyn et al., 1998), but others (Chmura, 2006) conclude that adaptation of progenies to the altitudinal environment of origin has a larger influence on their phenology than on their growth capacity. Stability characteristics indicate that provenances from higher altitudes, colder and wetter climate, tend to be more stable, whereas provenances from lower altitudes, drier and warmer sites are more responsive to site quality (Gömöry et al., 2012).

Our result also confirmed positive correlation between the latitude of original stand and diameter growth, which shows a greater significance of latitude than of longitude. Similar indication showed Beuker et al., 1998 who stated that northern and southern provenances differ in phenology and consequently deduced that they responded more to photoperiod than to temperature. Concerning the Central European provenances, Dering, Lewandowski (2009) published a hypothesis that this area is a hybrid zone of Norway spruce originating from Carpathian and Russian refuges, so these provenances may not have a consistent pattern of reactions to the climate. Their situation may be thus similar as in Latvian (Goncharenko et al., 1995), Slovak (Gömöry et al., 2012; Romšáková et al., 2012), and Beskydy (Chmura, 2006) provenances with short genetic distances and relatively small differences.

CONCLUSION

Results confirmed statistically significant differences in the growth and qualitative characteristics among particular provenances. The growth described by the height increment has the highest values for spruce provenances from Jedlá, Hainsbach, Gehlberg, Alterthal (Nos. 17, 46, 41, 37, respectively), diameter increment is the highest for provenances Nos. 17, 41, 44, 46. Results did not separate provenances into clearly specified groups according to original locality, latitude or altitude. Negative correlation was found between mean diameter and original stand altitude and positive correlation between mean diameter and original stand latitude. The tree survival rate influenced artificially as well as naturally was 30–40% and it was negatively correlated with both the mean diameter and the mean height.

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