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Provenance experiment with spruce (*Picea abies* (L.) Karst. and *Picea obovata* (Ledeb.)) in the North of Russia (Arkhangelsk region)

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Abstract

This research presents the variability in the survival and growth for 27 provenances of spruce (*Picea abies* (L.) Karst. and *Picea obovata* (Ledeb.)). All the tests were carried out in Russia, Arkhangelsk region, 62º 54' N, 40º 24' E, in the northernmost site of the State Geographic Network, established in 1977.

For the research on the spruce provenances, standard methods for studying the geographic variation of the main forest-forming species were used. Growth rates of provenances were correlated with their geographical coordinates and climatic characteristics. Data was expressed in standard deviation units to select the best in growth provenances.

Despite the significant differences in the location of the original stands (up to 12º N and 37º E), variability in survival, height and diameter is low (coefficient of variation is 12.2–19.0%). Obtained data indicated that provenances' growth is correlated on longitude of the location rather than on the latitude. Diameter and average height of provenances significantly depend on annual rainfall.

The height of provenance is mostly dependent on the location of the initial habitats and their climatic characteristics. It is also related to the length of the growing season and the air temperature (annual average and in January).

Groups of the provenances of the best and the worst growth were distinguished. The group of the best ones on the integral indicator (volume stand) includes provenances of the western origin represented by *P. abies* and its immediate hybrids – Karelia (3), Vologda (24), Leningrad (5), Pskov (7) and Moscow (29) Regions – and provenances of the eastern one represented by *P. obovata* – Komi (26) and Perm (38) Region. High plasticity of spruce (*P. abies* (L.) Karst. × *P. obovata* (Ledeb.)), growing within the Russian Plain, in sufficiently favourable conditions of middle taiga subzone (Arkhangelsk Region, Russia) was proved.

Key words

*Picea abie*s, *Picea obovata,* provenance test, provenance variability

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Table 1. Geographic coordinates and climatic characteristics of provenances in the trial of Arkhangelsk region, Russia

No*	Location	Forest vegetation subzone, zone**	Geographic coordinates		Vegetation period (days)	Mean T (°C)			Sum of T above +5 ºC	Annual rainfall (mm)	Hydrothermal coefficient	Climate continentality (%)
			Latitude (N)	Longitude (E)		Annual	January	July				
Siberian spruce (*Piceao bovata* (Ledeb.))												
1	Murmansk	NT[3]	67°51’	32°57’	90	–1.5	–10.5	11.0	1220	460	1.9	34
20	Arkhangelsk	NT	64°45’	43°14’	137	0.4	–12.5	9.0	1660	510	1.8	41.5
23	Arkhangelsk	NT	64°14’	41°38’	137	0.4	–12.5	9.0	1660	510	1.8	41.5
25	Komi	MT	61°41’	51°31’	141	–0.1	–15.0	16.6	1720	550	1.8	50
26	Komi	MT	63°27’	53°55’	155	0.4	–17.9	17.3	2000	700	2	45
38	Perm	MT	60°12’	57°08’	155	1.1	–18.0	16.0	2000	800	1.8	57.5
40	Sverdlovsk	MT	59°51’	60°00’	150	–0.6	–17.3	16.8	1926	525	1.8	45
39	Perm	ST	58°16’	56°25’	155	1.7	–15.0	18.5	2000	500	1.5	63
41	Sverdlovsk	ST	57°54’	60°00’	150	–0.6	–17.3	16.8	1926	525	1.8	45
42	Sverdlovsk	ST	58°04’	65°18’	156	0.7	–16.5	17.5	2106	438	1.4	53.5
Hybrid forms with properties of Siberian spruce (*Picea obovata* (Ledeb.))												
2	Karelia	MT	63°40’	34°23’	140	1.5	–10.0	16.0	1600	500	1.7	36
1x	Karelia	MT	62°54’	34°27’	150	2.0	–10.0	17.0	1800	600	1.8	39
19	Arkhangelsk	MT	62°59’	40°24’	148	1.0	–12.0	10.0	1810	530	1.8	45.5
22	Arkhangelsk	MT	61°15’	46°54’	148	1.0	–12.0	10.0	1810	530	1.8	41.5
28	Kirov	ST	58°49’	50°06’	137	1.3	–15.0	18.0	1800	500	1.4	54
35	Udmurtia	ST	56°50’	53°10’	150	2.1	–15.5	17.5	2500	450	1.2	61.5
Hybrid forms with properties of Norwayspruce (*Picea abies* (L.) Karst.)												
3	Karelia	MT	61°40’	33°33’	150	2.0	–10.0	17.0	1800	600	1.8	39
4	Karelia	MT	61°40’	36°40’	150	2.0	–10.0	17.0	1800	600	1.8	39
24	Vologda	ST	59°07’	37°57’	160	2.3	–12.0	17.5	2020	580	1.7	50
27	Kostroma	ST	58°24’	42°20’	160	3.1	–14.2	17.6	2100	500	1.4	52
31	Nizhny Novgorod	MF	57°11’	46°39’	170	2.7	–13.0	19.0	2400	325	1.4	58
Norway spruce (*Picea abies* (L.) Karst.)												
5	Leningrad	ST	59°30’	30°52’	160	5.0	–7.9	17.7	1900	650	2	41.5
7	Pskov	MF	56°23’	30°30’	165	5.9	–7.5	16.2	1950	530	2	41.5
30	Tver	MF	56°14’	32°48’	150	3.2	–10.5	17.5	2200	500	1.6	46
8	Estonia	MF	58°24’	25°38’	180	4.8	–3.0	16.0	2200	600	2	36
10	Latvia	MF	56°10’	26°30’	180	5.3	–2.0	16.0	2500	630	1.8	37
29	Moscow	MF	56°10’	36°58’	160	3.6	–10.0	18.0	2300	530	1.4	54

* provenance number in the State Register; ** forest vegetation subzone/zone: NT – subzone of northern taiga, MT – subzone of middle taiga, ST – subzone of southern taiga, MF – zone of mixed forests.

Introduction

The main method used for studying the geographic variability in heritable properties of forest species was the provenance trial: co-cultivation and comparative assessment of the offspring of different geographical origin. This can help to solve the problem of genotype and environment interaction (Lindgren and Persson 1995), which is one of the most important problems of origins selection and provides the basis for the regulation of seeds' transfer for reforestation (Seed zoning… 1982).

Most of the large-scale works on the provenance trial for conifers were performed in 1938 and 1964–1968 by the International Union of Forest Research Organizations (IUFRO). Based on the experience of IUFRO, a large-scale experiment under the leadership of VNIILM (ARRISMF) (Rodin and Prokazin 1996, 1997) was carried out in the 1970s in Russia to develop a State Network of forest plantations for six species in 111 locations in the country (Shutyaev 1990). The results of the provenance trial for Scots pine were summed up for data in 15 years of age (Shutyaev and Giertych 1997, 2003). Experimental results for spruce are fragmentary (Nakvasina et al. 2009; Nikolaeva et al. 2014).

The number of similar experiments with the marginal populations is small, and such experiments are extremely interesting in terms of selection and improving the stand productivity (Giertych 1989). The easternmost provenance tests of Norway spruce grow in Western Europe (Pacalaj M. et al. 2002; Matras 2009; Giertych 2009; Krajmerová et al. 2009; Ulbrichová et al. 2013, 2015), but only a few provenances from Russia have been tested.

The specificity of geographical experiments with spruce in Russia is that there are two species of spruce growing in the Eastern Europe – *Picea abies* (L.) Karst. and *Picea obovata* (Ledeb.) – and their dissemination has resulted from the historical migration in the Holocene. In an introgressive hybridisation zone (Pravdin 1972) at the contact of contiguous areas of the two species, five forms of spruce can be distinguished (Pravdin 1975). However, on studying the population diversity for silvicultural purposes, researchers (Popov 2005) recommend to consider spruce, growing within the Russian Plain, as a complex species (*P. abies* (L.) Karst. × *P. obovata* (Ledeb.)).

However, at the same time, upgrowth of the two spruce species on the Russian Plain may contribute to the population variability in the species and facilitate the selection of the best provenances for both mass (in the absence of local seeds) and target forest growing in the region.

Material and methods

The northernmost point of spruce provenance test was founded in the Arkhangelsk region (62°54' N, 40°24' E) in 1977. The area belongs to the middle taiga subzone. The climate is temperate continental. The average annual temperature is +1.2ºC. The coldest month is January; the warmest month is July. The annual rainfall is about 550–600 mm. Winter begins in the second half of November. Thickness of a snow cover is about 45–50 cm. The vegetation period is 148 days, on an average. Soils are podzolic, characterised by low natural fertility.

Planting was carried out with the use of 3-year-old seedlings. Spacing was 0.75 m in a row and 2.5 m between rows, average block size was 0.10 ha and the total crop area was 8 ha. Experiment contains offspring of 27 provenances of spruce, each in three replications. The Northern Forest Research Institute (Arkhangelsk, Russia) is a supervisor of the object.

Characteristics of the original spruce site used in the experiment are shown in Table 1; their location within the Russian Plain are shown in Figure 1. During the selection of provenances, location of the initial habitat was considered with respect to the zones/subzones of forest zoning used in Russia. Test results were published in Russian scientific journals and presented at conferences. Integrated test results for 25-year-old cultures are given in the paper (Nakvasina et al. 2008).

On research of survival, growth and productivity of provenance trial plantations of spruce in the Arkhangelsk region, a standard practice of geographic variation of the main forest-forming species study was used. For each provenance, diameter at breast height (DBH, in cm) for at least 100 plants randomly selected in each variant (accuracy = 0.5 cm) was measured. The average tree height (m) of a certain provenance was determined by the graph of heights developed based on the diameter and height (accuracy of 0.1 m) values

Figure 1. Provenances location in the experiment plot in Arkhangelsk Region, Russia

for at least 25 trees of different classes of diameter for each provenance. Survival rate was determined by the number of survived plants in total number of plants set in a variant (400 plants were set in a 0.1 ha block) in percent.

Amount of surviving plants in percentage of the number of planted blocks, as well as average tree volume and stand (m^3 ha^{-1}), was calculated according to the average density of forest planting used in forestry of the region (4,000 pcs. ha^{-1}). The age of stands during the study period was 36 years (the biological age of trees was 39 years). Growth and survival data are summarised in Table 2.

Data normality was checked using the Shapiro–Wilk test. All data were normally distributed and can be used for calculations. Statistical relationships between survival, diameter (DBH), height and spatial coordinates as well as climatic variables were evaluated by Spearman's rank-order correlations. Key indicators of stands' growth (average height, diameter (DBH) and survival) were correlated with geographic coordinates and climatic characteristics of initial habitats locations. Geographic coordinates used were latitude, longitude and altitude above sea level; climatic characteristics used were vegetation period (days), average annual temperature, average temperature in January and July, annual rainfall (mm), hydrothermal coefficient (the ratio of precipitation to the amount of evaporated moisture) and continentality (annual amplitude of average temperatures/latitude, %). To assess the offspring growth and development for spruce of different geographical origin, rates were expressed in standard deviation units. Multivariate analysis of variance (SPSS v22.0, GLM procedure) with subzone/zone and spruce species as fixed factors was used to test differences in survival and growth parameters and interactions between them. Significance was accepted at the $P < 0.05$ level.

Table 2. Growth and development of spruce provenances on experimental plot in Arkhangelsk region, Russia

No*	Location	Survival (%)	Diameter (DBH, cm)	Height (m)	Crown length (m)	Volume of single tree (m^3)	Stand volume (m^3 ha^{-1})	Rank of stand volume**
1	Murmansk	58.0	5.57	5.60	2.9	0.00836	19.401	24
20	Arkhangelsk	80.1	8.16	8.02	4.8	0.02408	77.145	13
23	Arkhangelsk	73.4	9.28	9.60	7.0	0.03606	105.886	5
25	Komi	76.8	8.94	8.95	6.3	0.03129	96.129	8
26	Komi	58.8	9.74	9.65	7.2	0.03958	93.082	10
38	Perm	72.3	9.78	9.95	7.6	0.04144	119.849	1
40	Sverdlovsk	66.4	8.97	8.40	7.0	0.03021	80.232	12
39	Perm	64.8	8.08	8.35	6.5	0.02447	63.422	18
41	Sverdlovsk	67.8	7.81	7.52	6.8	0.02065	55.997	19
42	Sverdlovsk	43.5	6.15	6.21	4.7	0.01115	19.393	24
2	Karelia	67.2	7.07	8.15	6.8	0.01843	49.529	21
1x	Karelia	73.6	7.15	8.10	7.3	0.01876	55.218	20
19	Arkhangelsk	77.2	7.78	8.10	6.6	0.02201	67.974	14
22	Arkhangelsk	78.5	8.50	9.70	6.4	0.03039	95.423	9
28	Kirov	64.0	8.25	8.20	5.8	0.02518	64.463	17
35	Udmurtia	73.3	6.02	6.11	4.9	0.01030	30.197	23
3	Karelia	70.5	9.49	10.22	6.2	0.03960	111.661	4
4	Karelia	72.3	8.98	10.20	6.9	0.03554	103.060	6
24	Vologda	68.0	9.80	10.35	7.8	0.04283	116.497	3
27	Kostroma	81.0	7.60	8.10	6.2	0.02090	67.709	15
31	Nizhny Novgorod	55.6	7.30	7.60	6.6	0.01829	40.667	22
5	Leningrad	63.5	9.54	10.23	8.6	0.03960	100.574	7
7	Pskov	64.4	9.41	10.33	7.6	0.03909	100.686	7
30	Tver	77.9	8.48	9.35	7.5	0.02960	92.234	11
8	Estonia	65.5	8.28	10.39	7.9	0.03072	80.492	12
10	Latvia	64.6	7.82	9.55	8.2	0.02537	65.554	16
29	Moscow	71.9	9.44	10.90	8.6	0.04099	117.895	2
Statystic***								
X		68.56	8.28	8.82	6.70	0.02796	77.421	
SD		8.42	1.18	1.43	1.27	0.01016	29.464	
CV.%		12.29	14.23	16.18	18.99	36.36	38.060	

* provenance number as in Table 1; ** the best = 1; *** *X* – mean, *SD* – standard deviation, *CV* – coefficient of variation.

Results

Survival of provenances (Tab. 2) ranges from 44% to 81%. The lowest survival rate of offspring was registered for Murmansk region (Kola Peninsula (No 1), as well as for the Komi Republic and Sverdlovsk region, where maternal plantations grow near the Ural Mountains with typical strong continental climate. Low survival rate also had the provenance in the Nizhny Novgorod region (No 31).

Offspring of the northernmost spruce provenance of the Murmansk region shows weak growth. Offspring

Table 3. Fisher values (*F*) and statistical significances (*P*-values)of main effects of forest vegetation subzone/zone and spruce species and their interactions on survival and growth parameters of spruce provenances (two-way ANOVA), df = 3

Factor	Statistics	Survival (%)	Diameter (DBH, cm)	Height (m)	Crown length (m)	Volume of single tree (m^3)	Stand volume (m^3 ha^{-1})	Rank of stand volume
Subzone/ zone	F	1.552	2.395	3.383	2.703	2.895	3.276	3.607
	P	0.238	0.104	0.042	0.078	0.065	0.047	0.035
Spruce species	F	1.142	3.023	4.467	3.044	3.935	3.343	3.890
	P	0.361	0.058	0.017	0.057	0.027	0.044	0.028
Subzone/ zone×Spruce species	F	1.333	0.690	0.325	0.927	0.692	0.847	1.014
	P	0.297	0.570	0.807	0.449	0.570	0.487	0.411

from the southern taiga subzone (Udmurtia, Sverdlovsk region) is similar in the growth rate. Provenances of spruce from the south-western regions of the initial locations, primarily from the mixed forest zone, have the best height and diameter growth rates. Offspring from the middle and southern taiga subzones is close to them by the growth rate.

Variability in survival, height and diameter rates is low (coefficient of variation is 12.2–19.0%), despite the fact that the differences in the location of the original plantings are almost 12º N and 37º E. With growth and survival data integration in estimations (volume of an average tree stem and the volume stand), coefficient of variation increases up to 36–38%. Stands volume depends on the survival of the offspring. Naturally, provenances with the worst rates for survival and growth in the 36-year-old stands have the lowest volume stand (19–29 m^3 ha^{-1}), four to five times lower in comparison with the best provenances (highest ranks in the experiment), where the volume stand is 111–119 m^3 ha^{-1} (Tab. 2).

The forest zone of original plants growth and spruce species do not impact offspring survival in the experiment (Tab. 3). They impact spruce height and thereafter volume of a single tree and stand volume.

Correlation analysis of survival, diameter and height of 36-year spruce provenances and geographic coordinates and climatic characteristics of the original plantings habitats showed the ambiguity of their impact (Tab. 4). The most reliable factor is vegetation period, governing shoot growth duration and proper buds formation and overwintering. The DBH reliably correlates with annual rainfall in the initial habitat (r = 0.67) and with hydrothermal coefficient (r = 0.47). Provenances height is the most depended on the location of the original habitats and their weather conditions. Seed origin impacts mostly on offspring height, significant impact is registered for six indicators, taken for estimations. For experiment, impact of longitude rather than that of latitude ranging 25–57° East (fluctuation = 32° E) was recognised. The closest correlation with annual rainfall amount both for height and diameter was observed (r = 0.70).

Table 4. Spearman Rank Order Correlations between survival, diameter (DBH), height and spatial coordinates, climatic variables

Parameter	Survival (%)	Diameter (DBH, cm)	Height (m)
Latitude	0.207665	0.039150	–0.141371
Longitude	0.003664	–0.062834	–0.423831*
Altitude	–0.254162	0.081995	–0.076829
Vegetation period	–0.353329	0.200907	0.421496*
Annual mean temperature	–0.060532	0.137171	0.487670*
Mean temperature in January	–0.003374	0.029182	0.453597*
Mean temperature in July	–0.257820	–0.044520	0.000922
Sum of temperatures above +5ºC	–0.122625	0.059564	0.121333
Annual rainfall	0.078957	0.672162*	0.700638*
Hydrothermal coefficient	–0.123148	0.465242*	0.450995*
Continentalclimate	0.022696	0.042083	–0.177014

* significant at 0.05 level.

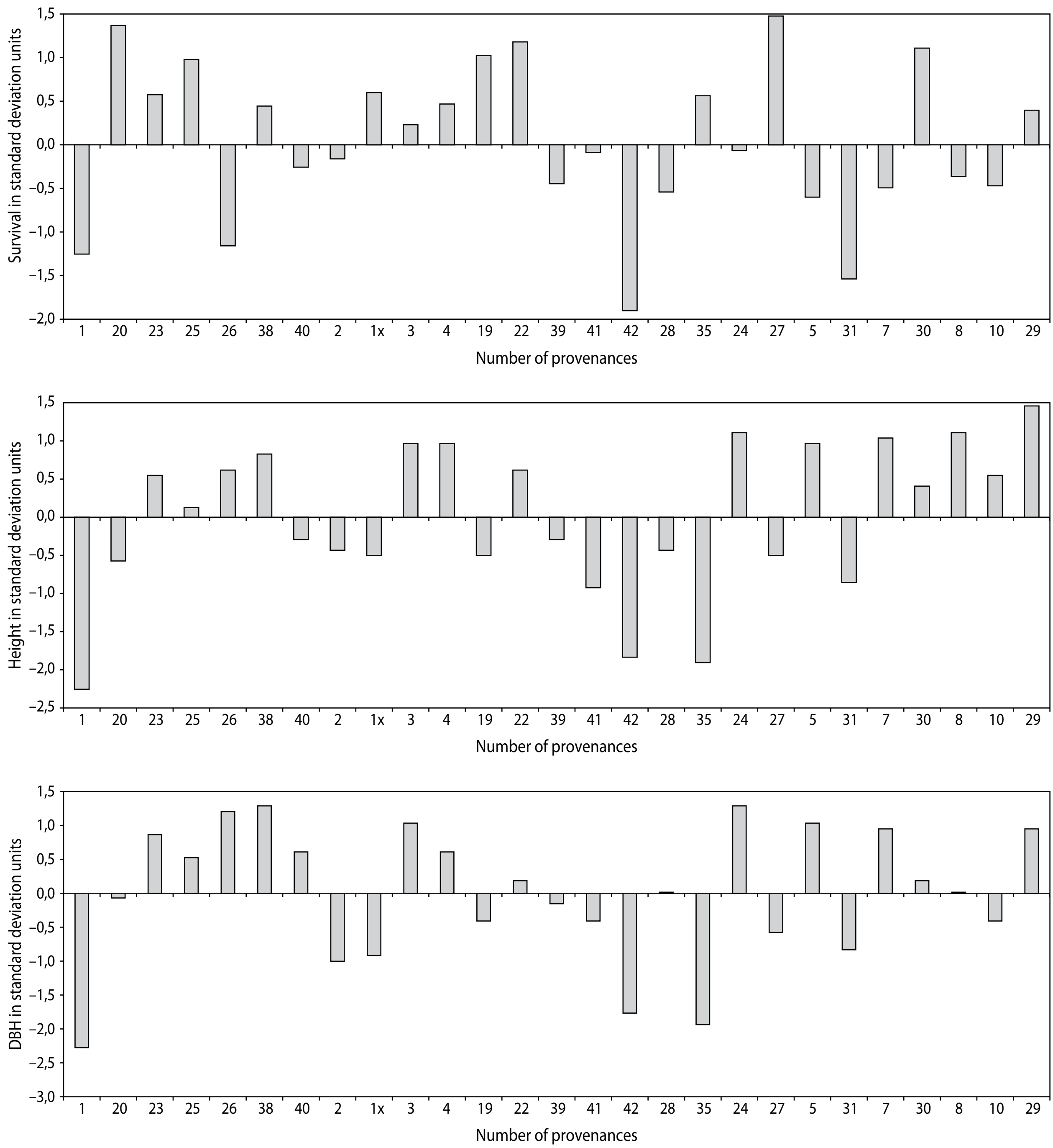

Figure 2. Survival, DBH and height of spruce provenances on experimental plot in Arkhangelsk region (in standard deviation units)

Growth and survival variability of the tested spruce provenances was examined. Mean values expressed in standard deviation units were used (Fig. 2, Tab. 5). For three studied parameters – survival, diameter (DBH), height – data ranges from −2.97 to +1.48 standard deviation units, which is significantly lower than that in European experiments (Matras 2009).

Hybrids of both spruce species have an advantage in survival rate (Tab. 6). Provenances of *P. abies* (L.) Karst. and hybrid forms with properties of *P. abies* (L.)

Karst. show the highest values of standard deviation units in terms of growth (diameter and height).

Table 5. Survival and growth of spruce provenances on experimental plot in Arkhangelsk region, Russia, in standard deviation units

No*	Location	Survival (%)	Diameter (DBH, cm)	Height (m)	Mean
1	Murmansk	–1.2542	–2.2966	–2.2518	–1.9342
20	Arkhangelsk	+1.3706	–0.1017	–0.5594	+0.2365
23	Arkhangelsk	+0.5748	+0.8475	+0.5455	+0.6559
25	Komi	+0.9751	+0.5593	+0.0909	+0.5418
26	Komi	–1.2542	+1.2373	+0.5804	+0.1878
38	Perm	+0.4442	+1.2712	+0.7902	+0.8345
40	Sverdlovsk	–0.2565	+0.5848	–0.2937	+0.0115
39	Perm	–0.4466	–0.1695	–0.3287	–0.3149
41	Sverdlovsk	–0.0903	–0.3983	–0.9091	–0.4659
42	Sverdlovsk	–2.9763	–1.8051	–1.8252	–2.2022
2	Karelia	–0.1615	–1.0254	–0.4685	–0.5518
1x	Karelia	+0.5986	–0.9576	–0.5035	–0.2875
19	Arkhangelsk	+1.0261	–0.4237	–0.5035	+0.0333
22	Arkhangelsk	+1.1805	+0.1864	+0.6154	+0.6608
28	Kirov	–0.5416	+0.0254	–0.4336	–0.3166
35	Udmurtia	+0.5630	–1.9153	–1.8951	–1.0825
3	Karelia	+0.2304	+1.0254	+0.9790	+0.7449
4	Karelia	+0.4442	+0.5932	+0.9650	+0.6675
24	Vologda	–0.0666	+1.2881	+1.0699	+0.7638
27	Kostroma	+1.4774	–0.5763	–0.5035	+0.1325
31	N. Novgorod	–1.5392	–0.8305	–0.8532	–1.0743
5	Leningrad	–0.6010	+1.0680	+0.9860	+0.4843
7	Pskov	–0.4941	+0.9576	+1.0559	+0.5065
30	Tver	+1.1093	+0.1695	+0.3706	+0.5498
8	Estonia	–0.3634	0	+1.0979	+0.2448
10	Latvia	–0.4704	–0.3898	+0.5105	–0.1166
29	Moscow	+0.3968	+0.9831	+1.4546	+0.9448

* Provenance number as in Table 1.

Fluctuations on the average of three indicators (survival, diameter and height) are −2.20 to 0.95. Spruce lineages were divided into five groups to indicate ones with the worst and the best growth (Tab. 7) based on standard deviation units: Group I (below −1.0); Group II (−1.0 to −0.5); Group III (−05 to 0); Group IV (0 to +0.5) and Group V (+0.5 to +1.0). The group with the worst growth (below −1.0) includes four provenances of *P. obovata* with the lowest rates at survival, diameter (DBH) and height: Murmansk (1), Sverdlovsk (42), Nizhny Novgorod (31) regions and Udmurtia Republic (35). Initial plantings of these provenances are located sufficiently far apart from each other.

Table 6. Survival and growth of spruce provenances on experimental plot in Arkhangelsk region (Russia) in standard deviation units (mean values)

Spruce species and forms	Survival (%)	Diameter (DBH, cm)	Height (m)
P. obovata (Ledeb.), n = 10	–0.2913	–0.0271	–0.4160
Hybrid forms with properties of *P. obovata* (Ledeb.), n = 6	+0.4442	–0.6850	–0.5315
Hybrid forms with properties of *P.* abies (L.) Karst., n = 5	+0.1092	+0.3000	+0.3314
P. abies (L.) Karst., n = 6	–0.0705	+0.4647	+0.9126

Groups of provenances that are the best in diameter and height are not the same. Offspring of spruce of western and south-western origin shows the best height growth: Vologda (24), Pskov (7), Estonia (8) and Moscow (29). By height, they comprise Group IV, and by DBH, Group III. On the contrary, provenances of eastern origin from the Urals (No. 26 and 38) are better in diameter growth and lag behind in height growth. The group of the best in diameter growth also includes some provenances from the western part of the Russian Plain: Karelia (3), Vologda (24) and Leningrad (5).

Provenance locations in the Russian Plain by average index (survival, DBH and height) in standard deviation units are shown in Figure 3.

Discussion

Collection of origins tested in the northern part of the Russian Plain (Arkhangelsk region, Russia) is represented by spruce with a wide range of habitats of original stands by latitude (North) and longitude (East).

Table 7. Growth groups in standard deviation units (mean values of survival, DBH and height) in spruce provenances on experimental plot in Arkhangelsk Region, Russia

I: below –1.0	II: –1.0 … –0.5	III: –0.5 …0	IV: 0… +0.5	V: above +0.5
P.obovata(Ledeb.)				
Murmansk (1)* Sverdlovsk (42)	–	Perm (39) Sverdlovsk (41)	Arkhangelsk (20) Komi (26) Sverdlovsk (40)	Arkhangelsk (23) Komi (25) Perm (38)
Hybrid forms with properties of *P. obovata*(Ledeb.)				
Udmurtia (35)	Karelia (2)	Karelia (1^x) Kirov (28)	Arkhangelsk (19)	Arkhangelsk (22)
Hybrid forms with properties of *P.*abies(L.) Karst.				
Nizhny Novgorod (31)		–	Vologda (24) Kostroma (27)	Karelia (3) Karelia (4)
*P.*abies(L.) Karst.				
–		Latvia (10)	Leningrad (5) Estonia (8)	Pskov (7) Moscow (29) Tver (30)

* provenance number as in Table 1.

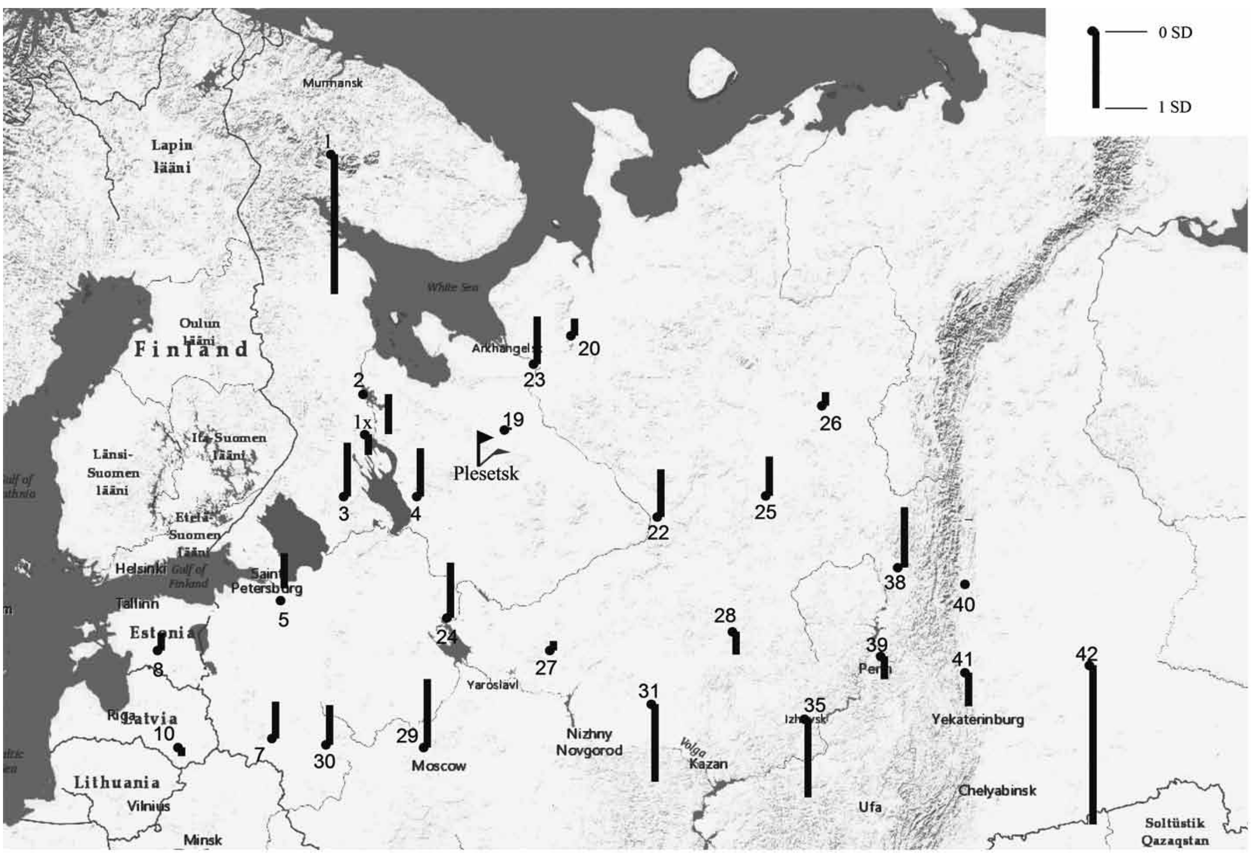

Figure 3. Provenance locations in the Russian Plain by average index (survival, DBH and height) in standard deviation units

However, the variability in survival, growth and productivity of provenances amongst cultures of second age class was quite low.

First, it can be related to conditions of the test location (middle taiga subzone), sufficiently favourable for spruce. Low variability was mentioned for experiments carried out in the Czech Republic and Germany by Ulbrichová et al. (2013). Researchers refer to sufficiently favourable (not extreme) conditions for offspring in the test location. In our studies, as well as in a number of other researches (Ulbrichová et al. 2013; Aarrestad et al. 2014; Nikolaeva et al. 2014), pronounced dependence of provenances survival and growth rates on the latitude of the original stands is not observed.

Correlation of survival and growth data to a large extent depends on variants comprising the studied collection (Nikolaeva et al. 2014) and changes in stands age. Quite close relationship of seeds' geographical origin and offspring survival is observed in stands of Age Class 1 (Arkhangelsk region, Komi Republic). For low-latitude provenances survival decreases steeply in the first decade of offspring growth; for northern provenances, it decreases in 25 years as a result of trees differentiation (Nakvasina et al. 1990; Tarkhanov 1998; Nakvasina and Gvozdukhina 2005; Nakvasina et al. 2008).

More pronounced connection is observed for offspring growth (diameter and height) and the east longitude. This can be result from increasing climate continentality of marine climate in the western part of the Russian Plain to sharply continental in the region of the Urals and decrease in annual average and winter air temperature and annual rainfall. Close correlation of height and diameter with annual rainfall ($r = 0.70$) can be result from spruce demand for moisture during the formation of shoot and wood. Similar dependence of the radial growth of spruce stands on the amount of summer precipitation was previously mentioned by Krasnobaeva (1972) and Tishin (2008). Tree growth was restricted by June precipitation in the lowlands in south-eastern Norway (Andreassen et al. 2006).

Second, low variability indicates high plasticity of a species. Its dispersal to the north of the Russian Plain took place in the Holocene because of the migration of Siberian and European refugia. High plasticity of spruce and its adaptability may be related to introgressive hybridisation at the junction of habitats of two species growing in the European part of Russia: *P. abies* (L.) Karst. and *P. obovata* (Ledeb.). Population history might explain part of the spruce growth variation (Kapeller et al. 2012).

As a result of study of 36-year-old provenances in the Arkhangelsk region (Russia), groups of provenances with the worst, the best and moderate growth were distinguished. In the group with the best survival and growth rates (+0.5 to +1.0 standard deviation units), offspring of both western (south-west) and eastern (with regard to place of offspring testing) provenances represented by both spruce species and their introgression hybrid forms were included.

At the same time, obtained results should not be considered a guide to use seeds of these provenances for large-scale reforestation, as introduction of alien progeny may eventually disrupt the stability of local populations. However, these seeds can be used for short-rotation forestry for pulpwood and bioenergy feedstock production.

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