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Intra-population variability of *Picea abies* from Zwierzyniec Lubelski and Bliżyn (Poland)

Abstract: The study investigates the intra-population variability of the growth and quality traits of Norway spruce populations from Bliżyn and Zwierzyniec Lubelski. The two populations are included in the IUFRO 1972 experiment and exhibit a high growth dynamics and a narrow crown form. The research was carried out on the experimental plot established in 1996 in Chrosno (Kutno Forest District) using 8228 two-year-old seedlings planted in a single-tree plot design at a spacing of 1.5 × 1.5 m. The seedlings represent 191 open-pollinated families, among them 93 families of Norway spruce from the Bliżyn region and 98 families from the Zwierzyniec Lubelski region. The height, height increment and DBH of trees were measured periodically, and some quality traits were assessed. The last results come from the measurements done on the trees aged 10 years. It was found that the differences between the two populations of Norway spruce are statistically nonsignificant but both of them show wide within-population variability. This suggests that they have the potential to flexibly respond to future changes in the growth conditions or to seed transfer to other seed zones. Survival in the environmental conditions of the experiment was independent of family.

Additional key words: Norway spruce, family variation, heritability

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Introduction

Norway spruce (*Picea abies* (L.) Karst.) belongs to the most common forest tree species in Europe. Its significance is due to the volume of timber production, but also to the fundamental ecological role it plays especially in mountain regions. The natural range of the species extends from the Alps eastwards to the Ural Mountains and southwards to the Balkans (Tyszkiewicz 1968). As one of the main forest tree species in Poland, Norway spruce covers an area of more than 500 000 ha. For many years, the morphological and growth characteristics of the species have been investigated in many provenance testing programmes (Giertych 1984, 2000). The history of Norway spruce in Poland is interesting from the genetic viewpoint. There are two main areas of spruce distribution, one in the northeastern part of Poland, the other in the southern part. Provenance studies revealed considerable variability among Polish populations of Norway spruce which was then reflected in the delimitation of forest seed regions and in seed transfer rules (Matras at al. 2000). The research conducted at the Forest Research Institute, Poland, showed that some other provenances, beside the famous provenance Istebna, also have a high plasticity and growth potential. One such provenance, best-growing in the IUFRO 1972 experiment with Polish provenances of spruce, is Zwierzyniec Lubelski from the Roztocze Highlands (Matras 1997; Matras et al. 2006). In this region, Norway spruce grows on wet soils in mixed stands together with Scots pine and silver fir. Another Norway spruce provenance tested in the IUFRO 1972 experiment and exhibiting a high growth dynamics and narrow crown form is that from the Bliżyn region in the Świętokrzyskie Mts. The good growth of these populations in the provenance test prompted detailed research into within-population variability to explain their very good performance.

The aim of the present study is to quantify the genetic variation in survival and growth traits among Norway spruce open-pollinated families from the Zwierzyniec Lubelski and Bliżyn populations after 10 years of growth.

Material and methods

Description of the experimental plot

The experimental plot in Chrosno (1.9 ha; 52°17'N, 19°17'E) is located in the Kutno Forest District. The open-pollinated progeny (half-sibs) of the Norway spruce stands in Bliżyn (51°04'N, 20°41'E) and Zwierzyniec Lubelski (50°34'N, 22°58E) were planted in the spring 1996 (further in the text, this half-sib progeny will be referred to as "families"). The mother trees were randomly distributed along a transect across the stand, the fathers were unknown but it was assumed that they were from the surrounding area. To identify family, each mother tree was marked with a successive number and the letter "Z" for the Zwierzyniec origin, and "B" for the Bliżyn origin. The seedlings were produced in a nursery of the Forest Research Institute in Sękocin. Two-year-old bare-root seedlings were planted at a spacing of 1.5 × 1.5 m using a random single-tree plot distribution with 14 replications. Altogether, 8228 seedlings from 191 families were planted. The Zwierzyniec Lubelski population is represented by 98 families (numbered 2 to 146), and the Bliżyn population is represented by 93 families (numbered 201 to 300). The number of seedlings per family varied between 10 and 68, the mean was 43.

Measurements and observations

Survival rate and height were measured after 1, 2, 3, 4, 5, and 10 years of growth. Diameter at breast height (DBH) was measured after 10 years. Quality features (stem straightness and branch angle) were assessed on subsamples of the material in 4 blocks using a 5-point scale where 1 is the lowest and 5 is the highest score. The results of the scoring were not analysed statistically because of the lack of enough replications.

Statistical methods

ANOVA and the estimation of variance components for the measured and assessed traits were performed according to the following model:

$$Y_{ij} = \mu + P_n + F_i + E_{ij}$$

where:

μ – total mean,

P_n – random effect of population n,

F_i – random effect of family i,

E_{ij} – random effect of tree j in family i (random error).

Families with less than 10 trees were omitted from the calculations. The components of variance for family and for residuals were estimated using S-plus statistical software, "varcomp" procedure with "reml" method.

Heritability for families and for single trees was calculated from formulas:

$$h_F^2 = \sigma_F^2 / \left(\frac{\sigma_E^2}{n} + \sigma_F^2\right)$$ – family heritability,

$$h_S^2 = 4\sigma_F^2 / \left(\sigma_E^2 + \sigma_F^2\right) = 4\sigma_F^2 / V_{Ph}$$ – single tree heritability,

σ_E^2 – variance component for residual,

σ_F^2 – variance component for family,

$$CV_A = \frac{\sqrt{4\sigma_F^2}}{\overline{x}}$$ – additive genetic coefficients of variation,

$$V_{Ph} = \sigma_E^2 + \sigma_F^2$$ – phenotypic variance,

$$V_F = \frac{\sigma_E^2}{n} + \sigma_F^2$$ – family variance.

DBH and height after 10 years of growth and height increment from age 5 to 10 were used to calculate family indexes from the formula:

$$W_f = h_{F1}^2 d_{F1} E_1 + \ldots + h_{Fk}^2 d_{Fk} E_k$$

where:

h_{F1}^2 – family heritability for trait No. 1,

$d_F = \left(\overline{x}_F - \overline{X}\right) / \sqrt{V_F}$ – selection differential for family and trait No. 1,

$\overline{x}_F$ – mean value of trait x for family (arithmetic average),

$\overline{X}$ – total mean for trait x,

V_F – family variance,

E_1 – economic values for traits (arbitrarily assumed to be 1).

Genetic correlations were calculated according to the formula:

$$r_A = \frac{\sigma_{xy}}{\sqrt{\sigma_x^2 \cdot \sigma_y^2}}$$

where:

σ_{xy} – covariance between trait x and y,

σ_x^2, σ_y^2 – family variance component for trait x or y, respectively.

Results and discussion

The whole material showed 84% survival, 4.31 m height, 45.1 mm DBH, and 2.7 index value for stem form and branch angle, on average (Table 1). The height of 10-year-old trees ranged from 3.63 m (family 221) to 5.03 m (family 236) in the Bliżyn population, and from 3.64 m (family 45) to 5.10 m (family 101) in the Zwierzyniec Lubelski population, with the respective averages being 4.30 and 4.31 m. The values of DBH were from 34.6 mm (family 221) to 55.3 mm (family 243) in Bliżyn, and from 31.5 mm (family 3) to 55.3 mm (family 137) in Zwierzyniec.

Within the first year, 264 seedlings died. These were replanted in the spring 1997 using the same material growing in the same location. The differences in height between the replanted trees and those growing on the plot from the start of the experiment (Fig. 1) were statistically significant up to 5 years of growth. After 10 years of growth, the height differences became nonsignificant, but the differences in DBH remained significant. All the 264 replanted trees as well as 32 families represented by less than 10 trees were not considered in ANOVA and variance components calculations. Omitting those trees from the calculations resulted in slightly increased average values of height and DBH (Table 2). The differences in the traits, except survival, were statistically significant between families but nonsignificant between populations. Interestingly, the results from the IUFRO 1972 provenance experiment for the same populations considerably differ from those obtained in our study (Matras at al. 2006).

The heritability of a single tree was higher at a younger age (Table 2). This reflects the influence of the growth conditions of the nursery rather than the experimental plot, particularly for height at age 1 year and 2 years. A sharp drop in heritability for height occurred between age 3 years (0.16) and age 2 years (0.42). In general, the heritability values were decreasing from the time of planting up to the age of 10 years. A similar tendency was observed by Namkoong and Conkle (1976) for Ponderosa pine, but not by Xiang at al. (2003) who reported that heritability in *Pinus taeda* increased with time up to age 8.

The additive genetic coefficients of variation and the proportion of variance explained by genotype (family) were also higher at a younger age (Table 2). The heritability for height at age 10 years (0.05) was lower than for DBH (0.10). It is interesting that the height increment between age 5 and 10 only partly depended on genotype. This indicates that the growth dynamics differed between families from age 5 to 10. Research by other authors (Bouvet and Vigneron 1995) demonstrated that variances and heritability in *Eucalyptus* were strongly affected by the experimental process, such as nursery and planting conditions, and by other environmental effects. Height heritability in Douglas fir before age 10 tended to be relatively unstable (Johnson et al. 1997). Our estimates of heritability and CV_A varied in the same range as was observed for the same traits in *Sorbus aucuparia* and *Prunus padus* (Baliuckas et al. 2005).

In the conditions of our experiment, survival did not depend on family or population; the heritability for survival was 0. This is in agreement with the findings of Isik and Kleinschmit (2003) who observed that the overall survival rate of Norway spruce clones in all the years of test was independent of genotype. Such results might rather be attributed to the high survival on the experimental plot. In Scots pine studied by Olsson and Ericsson (2002), the heritability for survival was weak (0.02), but mortality was more than 36%, which suggests that the family effect is more important when mortality is higher. In our study, the correlations between traits measured at the same age were positive and strong, while the correlation between heights at age 5 and age 10 was weak (0.34; Table 3). The genetic correlations correspond with the phenotypic correlations. The differences between the populations from Bliżyn and Zwierzyniec Lubelski in growth up to age 10 were nonsignificant. However, big differences occurred between families in the populations and between trees in the families.

The wide within-population variability of the two populations seems to reflect their poor adaptability. During its lifetime, a tree experiences large annual fluctuations in the weather conditions and even cli-

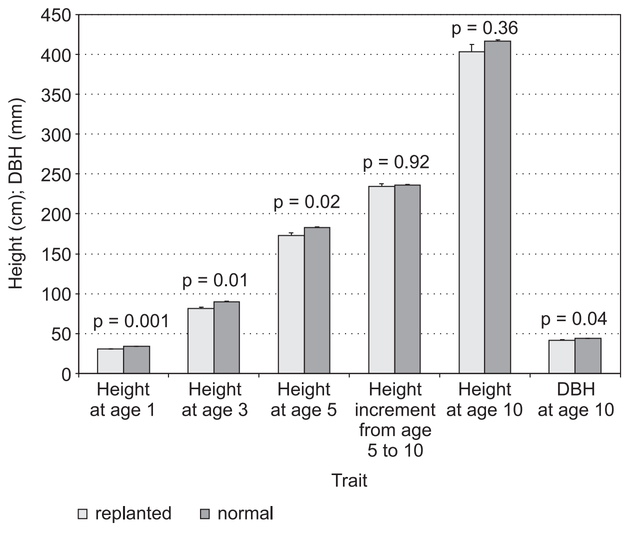

Fig. 1. Differences in growth parameters between seedlings replanted after one year and those growing on plot from start of study (bar – mean value, whiskers – standard error; p – significance level)

Table 1. Growth characteristics and survival of Norway spruce at age 10 years in Chrosno experiment

Family No.	Index W_f	Number of measured trees	Survival at age 10 (%)	Height increment (from age 5 to 10) (cm)	Height at age 10 (cm)	DBH at age 10 (mm)	Stem form (1–5)	Branch angle (1–5)
2 Z	0.264	23	94.4	229.5	428.7	47.35	2.3	2.5
3 Z	–1.506	12	90.0	213.9	370.0	31.50	2.3	2.3
4 Z	0.160	12	88.2	264.6	443.7	42.33	3.5	3.5
5 Z	0.066	21	79.1	233.9	419.7	45.62	2.5	2.3
6 Z	–0.115	19	85.7	235.6	426.1	42.21	2.5	2.3
8 Z	0.184	25	86.4	258.5	446.3	46.63	2.5	2.8
9 Z	0.229	27	88.6	230.1	426.6	47.11	2.8	2.8
10 Z	–0.189	27	86.4	242.6	427.2	44.35	3.0	3.0
11 Z	–0.006	25	85.7	242.2	421.8	43.96	2.3	2.5
12 Z	–1.061	23	76.7	206.5	373.0	37.57	2.5	3.0
13 Z	0.183	21	75.0	248.9	438.6	47.90	2.3	2.0
14 Z	–	9	88.9	273.0	491.3	52.38	2.8	2.5
15 Z	0.051	26	88.4	253.3	443.8	46.76	2.8	3.0
16 Z	0.189	27	88.6	237.8	427.9	46.04	2.5	3.0
17 Z	–	6	66.7	214.0	379.0	38.67		
18 Z	–	8	75.0	223.9	419.4	45.38		
19 Z	0.697	17	89.3	266.4	487.1	51.31	2.8	3.3
20 Z	–0.303	25	85.7	225.7	407.9	42.48	2.3	1.8
21 Z	–	6	75.0	253.2	477.0	51.80		
22 Z	0.188	21	88.6	223.3	426.0	46.95	2.5	2.8
23 Z	–0.720	24	84.1	207.3	383.4	40.83	3.0	3.0
24 Z	–0.497	20	74.4	245.0	406.7	39.10	2.3	3.0
25 Z	–0.055	21	77.3	268.5	447.3	44.60	2.5	3.3
26 Z	0.387	24	86.4	241.6	434.0	47.79	2.3	2.3
27 Z	0.150	22	91.7	233.4	425.3	46.05	2.8	2.8
28 Z	–0.114	27	88.6	232.2	428.1	47.50	2.8	3.0
29 Z	–0.062	27	84.1	243.0	421.9	43.15	2.5	2.0
30 Z	–0.657	24	81.8	220.5	386.3	40.71	2.5	2.8
31 Z	–0.643	16	79.4	243.8	402.1	37.75	2.3	2.5
32 Z	0.679	24	88.4	260.7	468.6	51.30	2.8	3.0
33 Z	0.007	10	68.4	245.5	424.0	43.70	2.3	3.0
42 Z	0.165	28	90.9	249.5	436.8	46.70	2.5	2.8
43 Z	–0.122	27	90.7	250.9	450.2	46.80	2.5	3.0
44 Z	0.270	21	75.0	228.0	433.2	46.90	2.3	2.3
45 Z	–	6	100.0	199.7	364.2	38.50		
46 Z	–	6	100.0	254.7	438.5	48.83		
47 Z	–	5	77.8	269.6	452.8	44.00		
49 Z	0.737	19	90.9	266.4	490.2	53.83	2.3	2.8
50 Z	–0.577	27	90.7	219.0	395.0	40.74	2.8	3.0
52 Z	–0.466	12	85.0	217.5	405.0	41.00	2.5	2.8
57 Z	0.152	19	86.1	229.1	422.6	46.63	3.0	3.0
58 Z	–0.036	19	80.6	232.2	440.7	46.94	2.8	3.0
59 Z	0.576	10	94.7	251.8	456.0	47.00	2.5	2.5
60 Z	0.330	12	84.6	257.2	445.0	44.83	2.5	3.2
61 Z	–0.720	17	85.3	228.4	391.8	38.76	2.3	2.5
63 Z	–0.471	27	88.4	235.3	401.4	40.59	3.0	3.0
65 Z	0.302	23	78.6	239.5	428.5	47.43	2.0	2.8
66 Z	0.855	12	100.0	261.3	466.7	49.00	2.3	3.0
67 Z	0.406	15	85.7	267.3	459.7	43.47	2.5	2.8

Family No.	Index W_f	Number of measured trees	Survival at age 10 (%)	Height increment (from age 5 to 10) (cm)	Height at age 10 (cm)	DBH at age 10 (mm)	Stem form (1–5)	Branch angle (1–5)
68 Z	0.046	16	88.9	247.0	434.3	42.81	2.8	3.0
69 Z	0.222	24	79.5	237.1	435.1	45.58	2.6	2.8
70 Z	0.942	21	77.3	248.3	468.6	50.52	2.5	2.8
71 Z	–	4	66.7	192.8	417.5	54.50		
73 Z	–0.702	21	81.0	214.2	391.3	39.71	3.0	2.8
74 Z	–	10	90.0	269.1	487.8	49.67	3.3	3.0
79 Z	–	5	75.0	256.6	418.6	42.40		
80 Z	0.301	16	82.1	250.8	436.3	45.88	2.5	3.0
82 Z	–0.146	15	82.1	231.3	412.8	43.73	2.5	2.5
86 Z	–	2	42.9	214.0	398.5	40.00		
87 Z	–0.434	19	88.6	237.3	407.5	40.21	2.5	2.8
88 Z	–0.079	11	80.0	211.0	417.3	45.00	3.3	2.8
89 Z	0.989	17	88.9	263.3	467.4	50.65	3.0	3.0
91 Z	–0.061	17	92.9	237.6	420.1	43.65	2.3	2.5
92 Z	–0.106	10	80.0	237.1	419.0	43.20	2.8	3.0
93 Z	–	8	80.0	216.0	416.3	45.50	3.0	2.8
95 Z	–0.102	12	95.0	259.6	430.8	40.67	3.0	2.5
96 Z	–0.791	16	86.2	205.7	382.4	40.06	2.8	2.8
98 Z	–	8	75.0	244.0	462.5	50.38	3.0	3.0
99 Z	–	3	71.4	205.3	418.3	51.67		
100 Z	–0.382	25	89.7	235.6	408.1	40.92	2.5	2.8
101 Z	–	3	88.9	292.0	510.0	50.80	3.0	3.5
102 Z	–0.192	16	96.3	237.1	422.5	41.56	3.3	3.3
104 Z	–	7	81.8	286.2	497.2	51.33		
105 Z	0.024	23	94.4	248.0	422.7	44.00	3.0	3.0
106 Z	0.049	30	84.7	246.9	435.5	44.72	2.1	2.9
107 Z	0.612	11	85.0	263.0	457.3	46.82	2.8	2.8
108 Z	–	5	87.5	238.4	396.8	39.80		
109 Z	–	9	70.0	254.7	457.8	46.67	3.0	3.5
110 Z	0.991	10	90.0	260.4	469.0	50.60	2.8	3.0
111 Z	0.695	16	89.3	240.4	450.6	49.88	2.8	2.5
112 Z	–	5	87.5	257.8	418.8	42.20		
113 Z	–0.380	11	95.0	255.9	457.0	45.90	2.3	2.3
114 Z	–0.819	10	85.0	216.0	387.0	38.60	2.3	2.5
128 Z	0.526	19	83.3	263.8	476.7	50.61	3.0	2.8
130 Z	0.630	12	78.6	247.9	447.9	49.00	2.8	2.8
131 Z	–	9	70.0	215.8	388.9	39.56	2.0	2.8
132 Z	1.224	11	90.0	273.1	480.9	51.64	2.5	3.0
135 Z	0.332	15	85.7	241.3	441.9	46.00	2.3	2.3
136 Z	–	4	75.0	171.3	374.8	43.25		
137 Z	1.637	11	90.0	268.0	498.2	55.27	2.8	3.0
138 Z	–	5	87.5	242.8	400.2	40.80		
139 Z	–0.051	20	82.9	239.3	427.0	42.80	2.8	2.5
140 Z	0.268	21	88.9	235.3	434.5	46.38	3.0	2.8
141 Z	–0.070	18	100.0	239.8	430.8	42.00	3.3	2.8
143 Z	0.331	21	82.4	250.5	446.5	44.95	2.5	2.5
144 Z	–0.062	17	77.1	222.1	411.6	45.47	2.3	2.3
145 Z	–0.166	21	91.7	230.8	418.2	42.76	9.5	2.3
146 Z	0.177	15	96.2	242.7	427.3	45.73	2.0	2.3
201 B	–0.067	18	80.6	239.1	418.9	43.67	2.8	3.0

Family No.	Index W_f	Number of measured trees	Survival at age 10 (%)	Height increment (from age 5 to 10) (cm)	Height at age 10 (cm)	DBH at age 10 (mm)	Stem form	Branch angle
							(1–5)	(1–5)
202 B	–0.015	15	92.6	232.9	417.3	44.87	2.5	2.5
203 B	–	9	100.0	277.6	452.5	42.38	2.5	2.5
204 B	0.181	14	81.5	248.1	461.0	50.85	2.8	2.0
205 B	–0.047	18	74.3	282.6	472.8	49.19	2.3	2.8
206 B	–0.363	20	69.8	233.1	401.3	42.20	2.8	2.8
207 B	–0.038	13	78.6	228.8	417.7	44.69	2.8	2.5
208 B	–0.812	18	77.8	218.6	379.6	39.56	3.3	3.0
209 B	–0.440	21	80.6	234.7	405.0	40.57	2.5	2.5
210 B	–	5	100.0	213.8	374.4	41.00	3.0	2.0
211 B	0.523	22	88.6	246.8	447.5	47.64	3.0	2.5
212 B	0.709	11	95.0	261.6	458.2	48.09	3.0	2.8
213 B	0.842	11	90.0	262.5	477.3	47.36	2.8	3.0
214 B	–0.209	17	89.3	232.0	415.1	42.53	3.0	2.8
215 B	–0.927	14	81.5	203.2	381.5	38.43	3.3	3.3
216 B	0.421	21	88.9	242.3	437.9	47.71	3.0	2.8
217 B	–0.299	10	94.7	246.2	420.0	40.00	2.8	3.0
218 B	–0.765	21	86.5	226.6	395.3	37.76	2.8	3.0
220 B	–0.356	27	79.5	236.9	408.3	41.19	3.0	3.3
221 B	–1.381	15	88.9	204.3	362.9	34.60	2.5	2.8
222 B	–0.459	12	85.7	220.4	397.8	41.92	3.0	3.0
223 B	0.241	22	86.1	236.5	433.7	46.05	3.0	2.8
224 B	0.721	12	90.0	271.8	459.2	47.67	2.8	2.5
225 B	–0.144	21	79.1	243.5	445.0	45.75	2.8	2.8
226 B	0.626	18	80.6	242.2	453.7	48.44	2.3	2.5
227 B	0.084	27	88.6	239.6	424.0	45.04	3.0	2.5
228 B	0.959	29	93.0	254.9	476.9	53.79	2.5	3.3
229 B	–0.369	21	71.4	224.5	399.4	42.76	2.3	2.8
230 B	–0.757	20	86.1	202.2	385.1	40.35	2.0	2.5
231 B	0.155	17	89.3	233.8	419.9	46.82	2.5	2.8
232 B	0.072	26	88.4	241.1	427.2	45.84	3.0	2.8
233 B	–0.286	24	80.0	231.7	422.9	45.43	3.3	3.3
234 B	–0.194	12	95.0	223.0	420.0	42.50	1.8	2.8
235 B	–	6	77.8	224.5	421.5	47.17		
236 B	1.402	12	100.0	267.3	502.5	51.50	3.3	2.8
237 B	–	6	87.5	215.0	396.8	43.33		
240 B	–0.479	17	77.8	249.4	438.3	43.25	2.0	2.8
241 B	–	9	80.0	270.1	492.2	50.89	2.3	2.3
242 B	0.745	12	95.0	256.4	475.8	46.50	2.8	3.3
243 B	–	4	75.0	279.8	501.5	55.25		
244 B	1.081	12	100.0	275.3	475.8	50.25	2.5	3.0
245 B	0.911	15	89.3	246.2	463.6	50.87	2.5	2.8
246 B	0.816	21	80.6	256.0	462.2	49.29	2.5	2.5
247 B	–	6	100.0	227.5	410.5	45.00		
248 B	–0.163	16	92.6	241.1	405.6	44.00	2.3	2.5
249 B	0.150	19	82.9	268.7	454.7	46.61	2.8	2.8
251 B	0.274	17	72.2	252.9	450.9	47.81	2.0	2.5
252 B	–0.911	14	72.4	226.6	425.5	42.00	2.5	2.8
253 B	0.683	25	79.5	262.1	470.0	49.21	2.5	2.3
254 B	0.405	21	88.6	251.4	446.0	46.00	2.8	2.5
255 B	–	5	85.7	237.2	456.6	49.80		

Family No.	Index W_f	Number of measured trees	Survival at age 10 (%)	Height increment (from age 5 to 10) (cm)	Height at age 10 (cm)	DBH at age 10 (mm)	Stem form	Branch angle
							(1–5)	(1–5)
256 B	0.409	23	72.7	271.1	449.8	44.65	2.8	2.3
257 B	0.896	25	84.1	274.5	485.3	53.00	3.0	2.8
259 B	–0.336	24	79.5	229.1	404.1	42.38	2.8	3.3
260 B	0.322	25	81.8	228.7	425.6	48.60	2.8	2.5
261 B	–1.115	27	86.0	240.0	419.1	42.75	3.3	2.8
262 B	0.214	26	79.1	254.5	433.5	44.88	2.3	3.3
263 B	–0.178	25	81.8	224.8	413.7	43.48	2.3	3.0
264 B	0.637	26	83.3	253.5	446.9	48.96	2.3	2.3
265 B	–0.654	22	83.7	224.4	389.6	40.14	2.8	2.3
266 B	0.098	25	86.4	234.2	426.6	45.12	3.3	3.0
267 B	0.388	25	84.1	253.0	448.5	49.38	2.3	2.5
268 B	–0.252	21	70.5	220.6	407.1	43.52	3.0	1.8
269 B	0.123	21	78.0	224.6	417.7	47.10	2.8	2.8
270 B	–1.081	26	88.6	224.0	401.2	39.71	3.0	2.8
271 B	–	4	75.0	253.0	450.0	48.50		
272 B	–0.072	21	69.8	233.6	421.0	43.57	1.8	2.3
273 B	0.060	24	79.5	245.8	426.3	44.13	1.8	1.8
274 B	–0.024	23	83.3	237.9	425.5	43.43	2.0	2.8
275 B	–0.235	24	79.1	234.0	416.4	41.92	2.5	2.5
276 B	–0.800	25	83.7	232.6	405.0	40.63	2.3	2.8
277 B	–0.875	23	83.7	223.7	380.4	38.35	2.5	2.8
278 B	–0.318	27	86.0	252.2	453.9	47.24	2.8	2.5
279 B	–0.380	28	95.3	226.1	408.0	41.39	3.0	2.8
280 B	0.479	26	86.0	252.2	449.6	46.50	2.5	2.0
281 B	0.093	24	81.4	246.0	429.0	44.21	2.0	2.8
282 B	0.190	15	85.7	233.5	434.4	45.40	2.0	1.5
284 B	0.030	26	88.4	232.7	426.3	44.31	2.5	2.3
285 B	0.383	12	95.0	227.2	432.5	48.58	2.8	2.8
287 B	0.268	25	84.1	252.4	435.4	45.48	2.0	2.0
288 B	0.421	24	88.1	248.0	448.2	46.08	3.0	2.8
289 B	–1.091	26	84.1	215.2	373.1	36.73	2.5	2.3
290 B	–0.192	27	84.1	242.8	427.0	44.62	2.8	3.5
291 B	–0.457	20	75.0	234.3	400.6	40.95	2.5	2.8
292 B	–0.277	27	86.4	231.5	412.8	41.93	2.3	2.5
293 B	0.114	21	78.6	240.4	421.4	45.76	3.0	3.0
294 B	–0.115	26	79.5	237.5	432.1	44.36	3.0	3.3
295 B	0.203	20	72.7	234.2	427.6	46.45	3.3	3.0
296 B	–0.352	17	70.0	233.5	407.8	41.47	3.0	3.3
297 B	0.579	23	83.7	252.7	451.1	47.65	2.8	2.8
298 B	–	9	89.5	255.4	445.6	44.11	3.0	2.3
299 B	–0.247	21	85.4	248.8	437.1	45.30	3.0	3.0
300 B	0.045	18	92.9	242.2	445.3	48.29	2.0	3.0
Zwierzyniec								
Σ		1579						
μ			84.5	240.5	430.9	45.1	2.7	2.7
Bliżyn								
Σ		1765						
μ			84.2	240.9	430.2	45.0	2.6	2.7
Total								
Σ		3344						
μ			84.4	240.7	430.6	45.1	2.7	2.7

Table 2. Individual and family heritability (± standard error) and additive genetic coefficients of variation (CV_A) for analysed traits of Norway spruce from Bliżyn and Zwierzyniec Lubelski

Trait	Mean	Single tree heritability h_S^2	Family heritability h_F^2	CV_A (%)	Variance explained by family (%)
Height at age 1 (cm)	34.02 ± 0.13	0.47 ± 0.05	0.84 ± 0.02	22.40	11.6
Height at age 2 (cm)	54.65 ± 0.19	0.42 ± 0.13	0.82 ± 0.01	18.72	10.3
Height at age 3 (cm)	82.21 ± 0.30	0.16 ± 0.03	0.58 ± 0.01	11.81	4.1
Height at age 4 (cm)	116.90 ± 0.46	0.14 ± 0.03	0.54 ± 0.01	11.76	3.6
Height at age 5 (cm)	182.80 ± 0.69	0.12 ± 0.02	0.50 ± 0.01	10.64	3.1
Height increment from age 4 to 5 (cm)	68.34 ± 0.20	0.07 ± 0.02	0.22 ± 0.08	6.94	1.4
Height at age 10 (cm)	422.90 ± 1.67	0.05 ± 0.02	0.18 ± 0.08	4.96	1.2
Height increment from age 5 to 10 (cm)	237.00 ± 1.10	0.01 ± 0.00	0.03 ± 0.01	0.00	1.4
DBH at age 10 (mm)	44.43 ± 0.20	0.10 ± 0.02	0.32 ± 0.02	9.00	2.3
Survival at age 10 (%)	81.54 ± 0.52	0.00 ± 0.00	0.00 ± 0.00	0.00	0.0
Survival at age 5 (%)	88.70 ± 0.57	0.00 ± 0.00	0.00 ± 0.00	0.00	0.0

Table 3. Coefficients of genetic correlation (below diagonal, bolded) and phenotypic correlation (above diagonal) between analysed traits of Norway spruce

Trait	Height at age 1	Height at age 2	Height at age 3	Height at age 4	Height at age 5	Height increment from age 4 to 5	Height increment from age 5 to 10	DBH at age 10	Height at age 10
Height at age 1		0.8948	0.4831	0.4667	0.4476	0.3342	0.1371	0.4096	0.3372
Height at age 2	**0.9551**		0.5926	0.5765	0.5482	0.4008	0.1321	0.4672	0.3894
Height at age 3	**0.6617**	**0.7537**		0.9583	0.9096	0.6621	0.2959	0.7814	0.6967
Height at age 4	**0.6357**	**0.7299**	**0.9758**		0.9618	0.7227	0.3148	0.8135	0.7380
Height at age 5	**0.6309**	**0.7106**	**0.9378**	**0.9693**		0.8843	0.3590	0.8413	0.7882
Height increment from age 4 to 5	**0.5077**	**0.5447**	**0.6945**	**0.7345**	**0.8788**		0.3696	0.7365	0.7313
Height increment from age 5 to 10	**0.1466**	**0.2078**	**0.3901**	**0.4265**	**0.4460**	**0.4031**		0.6109	0.8574
DBH at age 10	**0.5087**	**0.5882**	**0.8331**	**0.8504**	**0.8681**	**0.7455**	**0.6282**		0.8668
Height at age 10	**0.4537**	**0.5364**	**0.7768**	**0.8168**	**0.8462**	**0.7503**	**0.8543**	**0.8781**	

matic changes (Eriksson et al. 2006), therefore, having a substantial variation around the mean value would ensure that there will always be some genotypes well adapted to the conditions existing at the time of regeneration. This is a compromise between high adaptability in the short term and the potential for flexible response to the changes in the long term.

Conclusions

1. Norway spruce populations from Zwierzyniec Lubelski and Bliżyn exhibit a wide within-population variation, but the differences between the two populations are statistically nonsignificant.
2. The wide within-population variation provides the potential for response to the changes in growth conditions in the long term or for seed transfer to other seed zones.
3. Survival did not depend on family in the environmental conditions of the experiment.
4. The best-growing families: 137 Z, 236 B, 132 Z, 244 B, 110 Z, 89 Z, and 228 B were 10% better for height and 15% better for DBH than the general mean of the experiment.
5. The results should be considered as preliminary because of the young age of trees and the unstable components of variance.

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