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Variability of old Scots pine *Pinus sylvestris* L. vegetative progeny from the Augustowska Primeval Forests

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Abstract. This study was carried out in the clone archive of old Scots pine Pinus sylvestris L. trees located in the Augustowska Primeval Forest. The aim of the study was to determine the intra-clonal diversity among quantitative and qualitative traits of the vegetative progeny of Scots pine trees older than 200 years. Our analyses included traits such as survival rate, height and diameter at breast height (DBH), stem straightness, length and width of the crowns as well as branch thickness and growth angle. There was no significant correlation between the age of mother trees and the traits of their vegetative progeny. However, mother trees did affect the survival of the progeny. In overall, the survival rate of grafts in the archive is high (about 80% at the age of 13 years) and there have been no significant fluctuations in recent years. Nevertheless, the variability of quantitative traits among vegetative progeny was high with the average height ranging from 2.16 m up to 6.71 m, and in the case of DBH, ranging from 3.23 cm to 12.1 cm. Both, height of trees and their DBH, were significantly different among the analysed clones. These intra-clone differences in growth traits indicate a high environmental impact on the growth and performance of clones. However, the diversity of quantitative and qualitative traits is comparable to the differences observed in the economic seed orchards with seedlings at a similar age. Most of the genotypes planted in the archive are fully viable and have matured to the stage of seed production. The clone archive can thus be viewed as both, a conservation effort and to obtain valuable seeds from the point of view of tree breeding. Therefore, establishing archives of tree clones using valuable genotypes is an effective method of conserving individual genotypes even of very old individuals.

Keywords: Old trees, clonal archive, grafts, vegetative progeny, conservation of genotypes

1. Introduction

One of the most important challenges of Polish forestry in the coming period will be the protection of biological diversity, including genetic diversity, which will condition the possibility of conducting continuous and sustainable forest management as the climate changes. Protecting genetic diversity is conducted as a long-term program of the State Forests (Barzdajn 2011). Ad hoc measures are also taken to protect endangered species, populations or even individual genotypes. One of the most valuable activities in this field was the initiative to protect old trees, the remaining natural populations growing in forests. In 1985, an inventory was begun of old, over 200-year-old trees in the oldest forests growing in north-eastern Poland, which included the Augustów Primeval Forest. These are most probably seed trees of about 8−12 trees/ha left in clearcuts in the 19th century for supplementary sowing in accordance with the Hartig method (Brody 1984, 1988 after Korczyk 2008a). These trees are especially valuable due to the management practices of the past (natural renewal), which enabled the gene resources of the populations growing there to survive. The trees in question are relics of native, wild populations formed in the process of natural selection, so they are highly adaptable because they represent the genotypes growing in this area before intensive forest management began (Sokołowski, 2006). Therefore, it is extremely important to make an inventory of old trees and preserve their genetic resources for future generations (Korczyk 1997).

The inclusion of old trees, not only to protect genetic variability, but also for selective forest tree breeding programs is extremely important. Activities relating to the conserva-

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tion of the genetic resources of these genotypes should include several successive stages: conducting an inventory of the trees, the vegetative reproduction of selected genotypes, planting them in an archive (archives) and determining the detailed characteristics of the vegetative variability of the progeny of the protected genotypes (Korczyk, Matras 2006).

The only known technique for the long-term conservation of these genotypes is their vegetative propagation and planting the obtained progeny in clonal archives (Bednarek 2003). Single trees aged over 200 years were also found in the Augustowska Primeval Forest (Korczyk 1997). Dr. A. Korczyk inventoried the old pines in this area, and then took measures for their vegetative propagation (grafting). In 1999, a clonal archive was established in the Pomorze Forest Inspectorate in the Rygol (branch 960ab) and Wiłkokuk Forest Districts (section 637d).

2. Aim of the work

The aim of the study was to assess the variability of the quantitative and qualitative traits of the vegetative progeny of *Pinus sylvestris* L. Scots pine genotypes from the Augustów Primeval Forest located in the clonal archive of the Rygol Forest District.

3. Materials and methods

3.1. Study subject

Studies on the variability of the quantitative and qualitative traits of the vegetative offspring of old Scots pine trees from the Augustów Primeval Forest were conducted in the clonal archive established in unit 960ab of the Rygol Forest District. The archive covers an area of 3.4 ha and is divided by a forest path into two parts. Maps of the area show the distribution of individual grafts, among others, those included in the studies of Korczyk and Myszczyńska (2012) and Matras (2012). The archive was established in fresh coniferous habitat, on brunic arenosols made of loose sands. The archive contains 60 offspring of selected trees representing three main habitats in which pine grows in the Augustów Primeval Forest (fresh coniferous – Bśw, fresh mixed coniferous – BMśw, fresh deciduous – LMśw). These habitats are not equally represented. Most of the old trees are from the BMśw habitat (39 individuals), many fewer from the Bśw (17) habitat and only 4 from the LMśw habitat. The highest age diversity of mother trees occurs in the Bśw habitat (208−319), slightly lower diversity in the BMśw habitat (221−292 years), and distinctly lower in the LMśw site (212−252 years). The variability of individual growth characteristics of the mother trees is significant. Even though the average diameter at breast height of the trees from different habitats is almost identical, you can see a clear increase in average tree height as the fertility of the habitat increases. The main criterion for selecting trees for the archive was age, initially defined by using data from the forest management plan, and then verified on the basis of bores. Selected trees were characterized in detail and described in an information card. The study by Korczyk and Myszczyńska (2012) provides the scope of the measurements and observations of mother trees, information on the production of the vegetative progeny and detailed data on the established clonal archive, including surface maps, distribution scheme and the number of clones planted in the area.

The archive was founded in the autumn of 1999. Grafts were planted in 5 × 7 m spacings in sites with manually prepared soil. In subsequent years, the soil was hoed, the spacings were weeded, and emerging basal shoots and seedlings of deciduous species were removed.

3.2 Measurements and field observations

The grafts in the experimental plot were measured in terms of their survival, height and DBH, stem straightness, crown length and width, as well as branch thickness and growth angle.

The height of the grafts was measured with measuring patches to an accuracy of 5 cm, the DBH of the saplings was measured with a millimetre graduated diameter gauge with an accuracy of 1 mm. Qualitative traits were estimated on a four-point scale similar to the one used for the characteristics chosen to preserve the parent trees. This scale was partially modified to take into account the variability of the assessed traits of individual trees occurring in the plot. An important modification of the scale assessing the progeny was the distinction of a group of grafts having a shrubby form, which were excluded from further assessment of qualitative traits. The scale of evaluation of the individual features was determined in the plot, taking into account their maximum range. Next, the grafts were classified into individual groups categorized by the highest, the lowest and the intermediate value of a given feature. In the case of crown length, the group with the highest value were grafts with crowns clearly longer than half of the height of the trees, the group with the lowest value of crown length were clearly shorter than half the height of the trees and the group with an average value of this feature were trees with crowns of a similar length to half of their height. Table 1 presents the description of the applied quality assessment scale.

The qualitative characteristics were assessed during the growing season, and the quantitative characteristics were measured in the autumn of 2012 after the end of the tree growth season.

3.3. Statistical analysis of the study results

The diversity of the quantitative features was estimated with one-way analysis of variance and the significance of

Table 1. Artificial scale for estimation the qualitative characters of Scots pine clones

Character \ Scale	0	1	2	3
Straitness of stem	bushy form	many crooks in different direction	crooks in one direction	stright
Lenght of crown	bushy form	short >>1/2H*	intermediate 1/2H	long <<1/2H
Width of crown	bushy form	wide w/l>1**	intermediate w/l 1	narrow w/l.<1
Thickness of branches	bushy form	thick <1/2d***	intermediate ½ d	thin >1/2d
Angle of branches	bushy form	less than 45º	between 45–90º	close by 90º

*proportion the lenght of crown to total height, ** proportion the width to length of crown, *** proportion thickness of branches to thickness of stam in the same of whorl

differences in mean values of the analysed features was determined by using Tukey's post-hoc LSD test to distinguish homogeneous groups.

4. Findings

4.1. Quantitative features

4.1.1. Survival

Results of the assessment of graft survival in the study plots are presented in Table 2 and Figures 1 and 2. The diversity of clones in terms of survival was relatively high, and the observed differences were statistically significant. Tukey's test allowed us to distinguish 6 homogeneous groups. The average survival rate of the clones was 78.65% and ranged from 41.67% in the case of clone number 18 to 100% in the case of clones with the numbers 7, 15, 264, 286, 293, 294, 298, 316, 325 and 390. The greatest changes in survival were observed in the first period of graft growth. From 2006 to 2012, a relatively small (under 4%) average decrease in survival was mainly due to a significant decrease in the value of this feature in three clones, numbers 18, 300 and 388. Of the 60 clones analysed, 9 (15%) were still characterized by a survival rate of 100%, 17 had a rate of above 90% and 7 a rate below 60%. The survival of the grafts was significantly influenced by, among others, the growing conditions of the mother trees. Higher survival rates of the grafts were observed as the fertility of the habitat increased, both after 6 and 12 years of the progeny growing in the archive (Fig. 2).

4.1.2. Height

The variation in the height of the grafts in the study plots is shown in Table 2 and Figure 3. This differentiation has a very high statistical significance (Table 3). The distribution of this trait in the plots ranged from 1.55 m to 7.85 m, and its average values for the clones was from 2.16 m (clone no. 295) to 6.71 m (clone no. 389). The analysis of variance resulted in 5 homogeneous groups with different representativeness being distinguished. Groups with extreme values, including the best and worst clones, were relatively few, while intermediate groups had a large number of clones. The best-growing clone, number 389, was significantly better than the next in the ranking, clone no. 1. Similarly, the worst clone, no. 295, was significantly worse than the next clone, no. 303. The fact that the height of the analysed clones is diversified is of interest. In this case, it is also possible to distinguish groups of clones with a low and high differentiation, both in the group of clones growing well, as well as those with poor growth.

4.1.3. Diameter at breast height

The DBH diversity of the clones in the study plots is presented in Table 2 and Figure 4. As in the case of heights, the observed variation has a very high statistical significance (Table 3). The total range of DBH measurements of the grafts ranged from 1.55 to 15.5 cm, and the average values of this attribute for the clones was from 3.23 to 12.1 cm. On the basis of the performed analysis of variance, 6 homogeneous groups with differing representativeness were distinguished. Groups with extreme values, including the clones with the best and worst growth, were relatively small, while the intermediate groups

Table 2. The mean value of qualitative and quantitative characters of the Scots pine clones growth in clonal archives in Rygol

Nr of clone	No of ramets	Survival rate 2006 year	Survival rate 2012 year	Height [m]	Height standard error	Diameter	Diameter standard error	Straitness of stem	Lenght of crown	Width of crown	Thicknees of branches	Angle of branches
1	11	92.3	84.6	6.21	0.216	11.67	0.432	2.64	3.00	2.27	1.82	3.00
2	13	76.5	76.5	4.85	0.347	7.88	0.855	2.46	2.86	1.85	2.08	1.92
3	12	100.0	92.3	4.60	0.352	7.99	0.847	2.17	2.75	2.08	2.17	1.83
4	10	83.3	83.3	4.98	0.312	9.93	0.844	2.40	2.80	2.10	1.90	1.90
7	12	100.0	100.0	5.17	0.292	8.61	0.767	2.42	2.83	2.00	2.25	2.25
9	9	69.2	69.2	5.65	0.436	9.40	0.964	3.00	2.89	2.11	2.11	2.11
11	7	66.7	58.3	3.92	0.367	7.26	0.778	2.57	2.57	2.00	2.14	1.71
13	9	81.8	81.8	4.41	0.464	7.74	1.095	2.78	3.00	2.11	2.11	2.00
14	12	100.0	91.7	4.83	0.305	9.52	0.844	2.55	2.91	2.09	2.09	1.91
15	11	100.0	100.0	4.93	0.318	8.19	0.739	2.46	2.82	2.64	2.73	1.73
16	10	83.3	83.3	3.90	0.311	6.07	0.766	2.00	2.89	1.67	2.00	1.78
17	9	66.67	66.7	4.43	0.398	7.70	0.857	2.78	2.67	1.89	2.00	1.89
18	5	83.33	41.7	5.28	0.249	10.06	0.535	2.40	3.00	1.60	1.80	1.80
74	10	83.33	83.3	5.02	0.268	8.21	0.580	2.70	2.90	2.10	2.40	2.10
180	10	91.67	83.3	4.93	0.477	9.03	1.025	2.40	2.80	1.60	1.60	1.90
262	11	100.0	91.7	5.47	0.304	10.41	0.761	2.46	2.82	1.46	1.55	2.18
263	11	83.3	83.3	5.31	0.257	9.65	0.427	2.55	2.91	1.73	1.73	2.18
264	13	100.0	100.0	5.67	0.194	10.79	0.339	1.62	2.846	1.39	1.54	1.77
265	9	76.9	69.2	5.97	0.424	8.98	0.832	2.67	2.667	2.22	2.33	1.67
266	9	76.9	69.2	5.40	0.349	8.97	0.668	2.67	2.778	2.11	2.22	2.00
267	8	75.0	66.7	4.67	0.251	8.28	0.845	2.63	2.625	2.13	2.13	1.75
269	11	92.3	84.6	4.91	0.228	8.28	0.545	2.73	2.727	2.27	2.27	1.73
271	12	85.7	85.7	4.87	0.447	8.08	0.961	2.67	2.667	2.42	2.33	1.83
276	7	53.6	53.9	4.71	0.527	7.71	0.870	2.57	2.429	2.29	2.43	1.71
284	11	91.7	91.7	5.33	0.174	9.06	0.490	2.36	2.818	1.82	1.91	2.09
285	11	84.6	84.6	5.61	0.254	10.36	0.719	2.91	2.818	1.46	1.91	1.64
286	13	100.0	100.0	5.38	0.278	9.27	0.730	2.69	2.615	1.85	1.85	2.00
288	10	83.3	83.3	4.59	0.384	8.15	0.976	2.50	2.6	2.20	2.3.0	2.30
290	6	63.6	54.6	4.75	0.544	9.53	0.958	3.00	2.833	1.83	2.17	1.83
293	11	100.0	100.0	4.39	0.250	8.56	0.840	2.18	2.636	1.64	1.55	1.91
294	11	100.0	100.0	4.24	0.292	7.06	0.722	2.18	2.727	2.18	2.18	1.91
295	6	54.6	54.6	2.24	0.184	3.58	0.423	0.00	2.8	1.20	2.80	2.80

Nr of clone	No of ramets	Survival rate 2006 year	Survival rate 2012 year	Height [m]	Height standard error	Diameter	Diameter standard error	Straitness of stem	Lenght of crown	Width of crown	Thicknees of branches	Angle of branches
296	9	83.3	75.0	3.80	0.260	6.68	0.721	1.11	2.778	1.56	2.22	1.89
297	9	81.8	81.8	5.30	0.213	9.71	0.652	2.22	2.444	2.11	2.33	2.00
298	11	100.0	100.0	5.05	0.409	9.027	0.986	2.00	2.818	1.46	1.64	1.91
300	7	100.0	63.6	5.32	0.226	10.09	0.851	2.86	3.00	2.00	1.71	1.86
302	10	91.7	83.3	5.51	0.313	9.54	0.955	2.70	2.80	2.20	2.30	2.20
303	10	90.9	90.9	2.56	0.208	3.75	0.486	0.40	2.90	1.40	2.70	2.20
304	7	80.0	70.0	5.30	0.309	9.90	0.899	2.71	2.714	2.27	2.286	1.86
305	7	63.6	63.6	5.14	0.452	8.83	1.301	2.43	2.714	2.00	2.00	1.71
307	6	63.6	54.6	5.17	0.169	9.25	0.699	2.50	2.667	2.33	2.50	1.67
309	7	63.6	63.6	5.28	0.286	9.11	0.825	2.14	2.71	2.29	1.86	1.86
310	6	60.0	60.0	5.02	0.579	8.66	1.209	2.43	2.62	2.33	2.13	1.86
313	10	90.9	90.9	5.41	0.231	9.72	0.788	2.40	3.00	1.90	1.70	2.40
316	11	100.0	100.0	5.17	0.287	9.21	0.816	2.27	2.82	1.82	1.73	1.82
317	7	77.8	77.8	4.81	0.522	8.27	1.070	2.57	2.71	2.29	2.14	2.14
324	7	63.6	63.6	5.24	0.525	9.56	1.166	2.43	2.43	1.43	1.71	1.71
325	11	90.9	90.9	5.65	0.341	8.86	0.796	2.18	2.46	1.55	2.09	2.18
326	5	62.5	62.5	4.48	0.527	7.23	0.720	1.80	2.60	2.40	2.20	1.40
328	7	70.0	70.0	5.13	0.398	8.29	0.996	2.43	2.43	2.14	2.00	2.57
383	8	81.8	72.7	4.70	0.194	8.26	0.765	2.63	2.38	2.13	2.00	1.75
384	7	63.6	63.6	5.38	0.672	9.51	1.326	2.57	3.00	1.71	2.00	2.14
85	10	90.9	90.9	5.61	0.285	10.00	0.513	2.60	3.00	1.80	1.90	1.70
386	10	91.6	83.3	4.92	0.240	8.24	0.648	2.00	2.90	1.90	1.80	2.20
387	9	81.8	81.8	6.21	0.324	11.37	0.805	2.67	2.89	1.56	1.22	2.11
388	7	81.8	63.6	5.40	0.608	9.30	1.339	2.86	3.00	1.86	2.29	2.14
389	7	58.3	58.3	6.71	0.237	12.09	0.636	2.29	2.86	1.57	1.43	1.86
390	11	100.0	100.0	4.91	0.234	9.62	0.684	2.18	3.00	1.36	1.82	1.46
394	9	75.0	75.0	5.41	0.488	9.96	1.098	2.44	2.89	1.44	1.33	2.22
396	8	72.7	72.7	4.68	0.387	7.65	0.646	2.27	2.77	1.83	2.19	2.17
LMśw	53	84.4	81.4	5.16			9.14	2.42	2.77	2.09	1.99	2.25
BMśw	349	83.2	78.7	4.98			8.76	2.43	2.77	1.95	2.04	1.93
Bśw	151	79.4	76.3	4.99			8.77	2.22	2.79	1.79	2.00	1.98

LMśw – fresh mixed broadleaved forest, BMśw – fresh mixed coniferous forest, Bśw – fresh coniferous forest

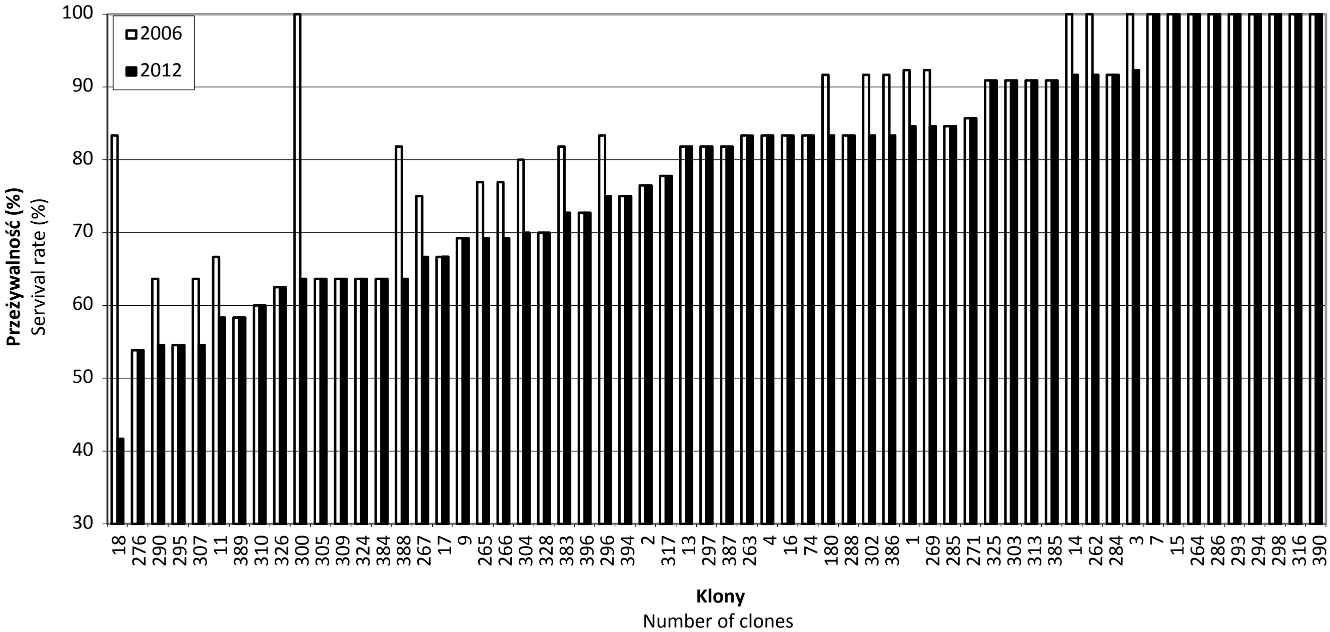

Figure 1. Servival rate of tres in clones in 2006 and 2012 years in Rygol clonal archive

contained a large number of clones. The clone with the best DBH growth was clone no. 389, but it did not exhibit such domination as with the height measurements, while the two weakest clones, nos. 295 and 303, had significantly smaller DBHs than the next, third one, clone no. 296. The ranking of the clones in terms of mean height and DBH is very similar.

4.2. Qualitative features

To estimate the variability of the qualitative features of clones in the archive, the stem straightness, crown width and length, branch thickness and growth angle of the grafts were assessed.

The greatest variation among the quantitative features was observed for stem straightness (Table 2). The grafts assessed in the clonal archive were characterized by relatively good qualitative characteristics of the stem. Out of 550 assessed grafts, only 26 (4.7%) were classified as '0' with the shrubby form and clones numbered 295, 303 and 296 were exceptionally negative in this respect. When omitting the '0' class, the average value of this feature was 2.49 in the three-point straight stem rating scale. This is relatively high, which is a positive sign of the straightness of most of the pine trees' stems. However, the clones also exhibited high variability for this trait, mainly in terms of the participation of individuals in particular classes. Of the 60 clones analysed, only individuals with numbers 2 and 290 were included in the best quality class. In the case of 13 clones, particular individuals were

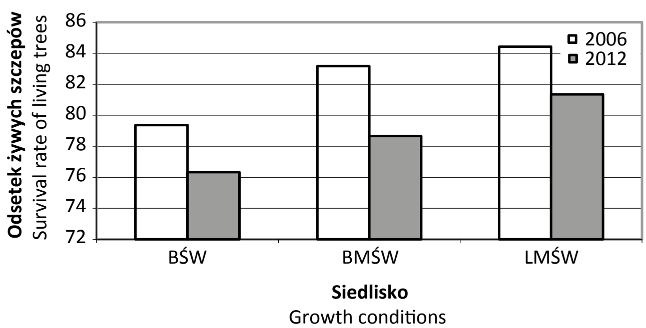

Figure 2. Change in survival rate of the Scots pine clones in time and conditions of growth of mother trees

classified to three quality classes, and the remaining clones were in two classes of stem quality. Particularly noteworthy are the clones with a high proportion of individuals having completely straight stems assessed as class '3'.

The vegetative progeny of mother trees growing in the clonal archive were characterized by relatively long crowns. The variability of this feature was relatively low, and the average value of the crown length index for all analysed individuals was exceptionally high, amounting to 2.78 in the three-point rating scale. Of the 550 grafts assessed, 425 individuals (85%) were classified to class '3'.

The grafts assessed in the experimental plot were characterized by a relatively large variation in crown width, with a predominance of individuals having wide crowns. The aver-

Table 3. Results of statistical analyses qualitative characters of the Scots pine clones in archive Rygol

Results of statistical analyses					
	df	SS	MS	F	Pr(>F) P
Diameter					
Clones	59	1184.	20.072	3.197	1.72e-12***
Error	493	3095.0	6.278		
Height					
Clones	59	273.7	4.639	4.222	<2e-16 ***
Error	493	541.7	1.099		
Level of differences: 0 '***'					

age value of the crown width index of 550 individuals was 1.915 and was the lowest of all analysed qualitative traits. There were as many as 152 individuals in the group classified to class '1'. Of the 60 analysed clones, there was not a single one with all of its individuals having only narrow crowns. The assessment of crown characteristics estimated in the archive plots clearly characterizes the natural properties of the mother trees in terms of these features, since the spacing of the progeny planting was conducted in such a way that enabled them to grow without being affected by their neighbours for the entire period up to the moment of taking the last measurements.

The average values of the clones' branch thickness are presented in Table 2. The assessed grafts in the experimental plots were characterized by average branch thickness characteristics. Of the 550 grafts assessed, there were respectively 134 in class 1 (thick), 276 in class 2 (moderately thick) and 141 in class 3 (thin). The average value of this characteristic of the clones is also confirmed by the average index for the plot of 1.98 in the three-point rating scale.

As in the case of branch thickness, the grafts were found to have average values of branch growth angle (1.98 in the three-point rating scale), and its variability was small.

4.3. The influence of the characteristics of mother trees on the growth and development of their vegetative progeny

Having at our disposal data on the age and quantitative features of the mother trees (Korczyk, Myszczyńska 2012; Matras 2012), an attempt was made to assess them depending on the quantitative characteristics of their progeny in the clonal archive. In most cases, the correlation coefficients of the mother trees' characteristics and their progeny were minimal (close to zero). The age of the mother trees on the survival of the grafts was also not confirmed. Information about the lack of a correlation of growth traits of the vegetative progeny with the age of mother trees is valuable, although not entirely consistent with the general thesis on the negative influence of age on the dynamics of progeny growth, also vegetative. The lack of a negative impact of the mother trees' age on progeny growth suggests the possibility of

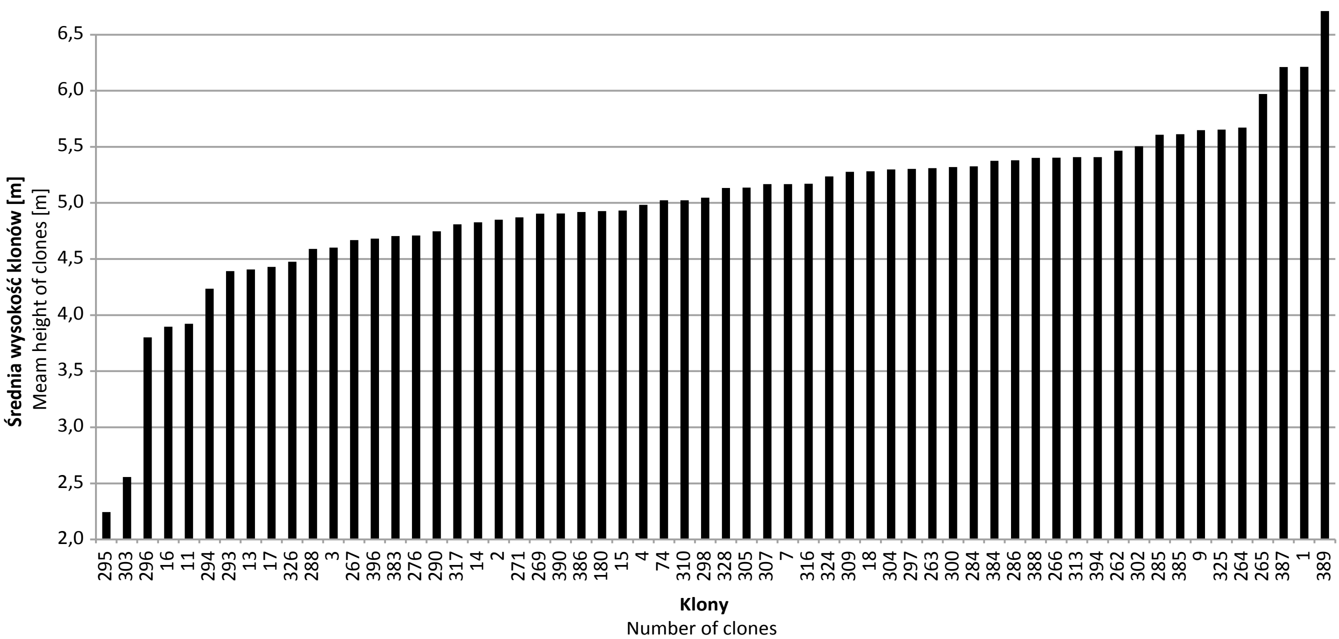

Figure 3. Mean height [m] of clones in clonal archive Rygol

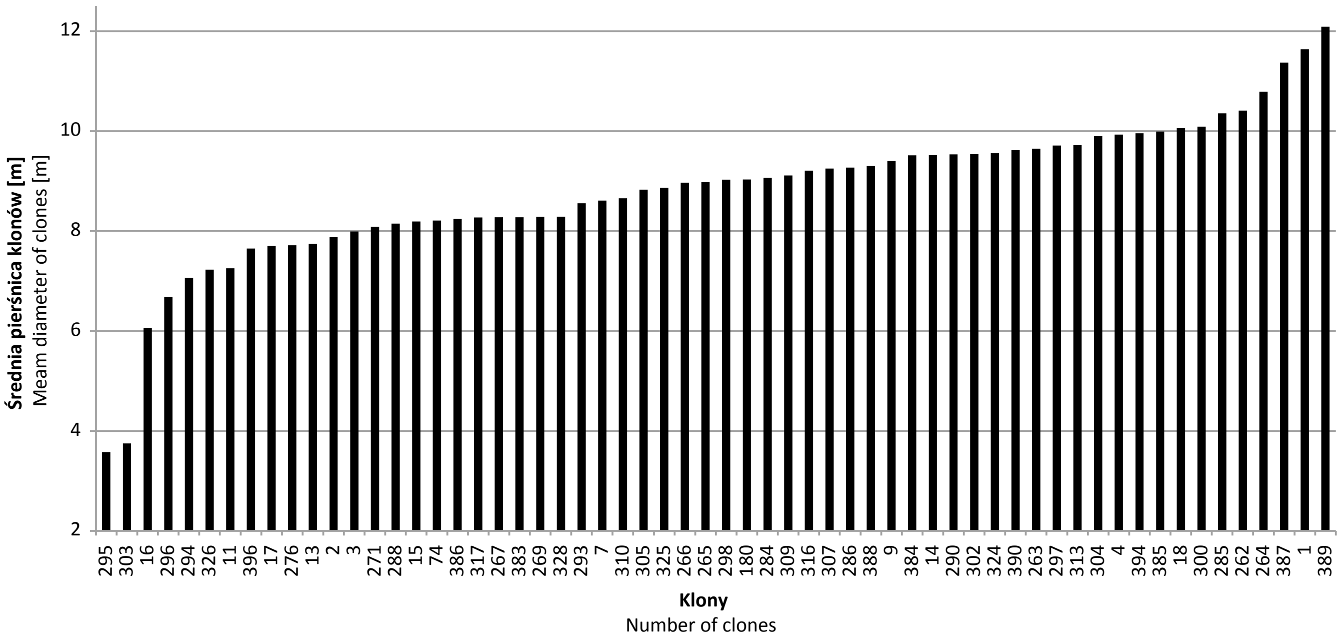

Figure 4. Mean diameter [cm] of clones on experimental plot Rygol

using vegetative reproduction by grafting for both selective breeding as well as the conservation of genetic resources of even very old Scots pine trees.

The observed dependencies between the mother trees and their progeny were observed only in terms of the conditions of growth and survival of the progeny. This indicates the need to precisely select the location of archives in order to create optimal conditions (not only soil conditions) for their growth.

5. Summary and discussion

The average survival rate of pine grafts after 13 years of growth in the experimental plots of Rygol Forest District was 78.65%, which was relatively high. The greatest changes in survival were observed at the initial stage of graft growth. Most data in the literature on the survival of grafts concern seed orchards that collect grafts grown from much younger mother trees. The survival of grafts in Scots pine seed orchards is usually high and ranges between 80–90% (Wilczkiewicz 1975; Kocięcki 1988; Matras 1996; Trojakiewicz, Burczyk 2005; Bobriniev, Pak 2007; Kanak et al. 2009; Kroon et al. 2009; Šejkina, Lebedeva 2010). In the first few years after planting, a relatively high (94–98%) survivability of fir grafts was observed in conservation seed orchards of this species established in the Sudety Mountains under the 'Sudety Mountain fir restitution program' (Bednarek 2003; Niemczyk 2005); however, this case concerns relatively young mother trees. The survival of grafts grown from old, over 200-year-old pines differs. According to Korczyk (2010), on the basis of observations from the archives of clones in the Augustów, Białowieża and Knyszyńska Forests, as the age of mother trees increases, the survivability of the grafts obtained from them generally decreases, which can significantly impact the effects of grafting and the subsequent growth of the grafts. Undoubtedly, other factors, including genetic ones, significantly influence the growth and development of grafts. As was shown in the case of the Rygol plots, the habitat of the mother trees also influenced the survival of the grafts grown from them.

The diversity of quantitative traits of the grafts – diameter at breast height and height – was very high in the analysed plots and fluctuated in the case of average height from 2.16 m to 6.71 m, and in the case of DBH from 3.23 cm to 12.1 cm. The analysed clones differed very significantly in terms of DBH and height. The intra-clonal diversity of the growth traits indicates the high impact of habitat on the growth and development of clones. Other factors, such as the rootstock or making the graft properly may undoubtedly modify the growth and development of grafts significantly. Additionally, in this case, the clones represent various populations growing in different habitat conditions.

Niemczyk (2005) also observed high, statistically significant differences in the growth of fir grafts in the first few years after planting, both between clones in the plots, between individual plots, as well as between the years of the observation in the conservation seed orchards of silver fir.

Similar statistically significant differences were observed in the conservation seed orchard of fir established in the Kamienna Góra Forest Inspectorate under the 'Fir Restitution Program' (Bednarek 2003) and small-leaved lime at the seed orchard in the Susz Forest Inspectorate (Ludwikowska et al. 2011). The differentiation of the grafts' growth confirmed in the plots is not an isolated phenomenon. Relatively large differences are observed in economic plantations, and not only ones of pine. In this case, as in the case of hereditary studies, intra-clonal variability is often greater than inter-clonal variability. Similar differences were observed by Korczyk (1997, 2008a, b, 2010) on other plots with clones representing other forest complexes established to conserve old trees.

The grafts assessed in the experimental plots were characterized by relatively good qualitative characteristics of the stem and crown length as well as average features of crown width, branch thickness and growth angle.

The literature on the issue under discussion lacks detailed characteristics of the qualitative traits of grafts, so it is difficult to refer the obtained results to published information. In the seed orchards operating within the seed base of the State Forests, the qualitative characteristics of grafts are assessed when planning and determining cuts. Although these data cannot be directly compared, the scale of the variation in the qualitative traits found in the economic plantations of Scots pine is similar to what was observed in the clonal archive of the Rygol Forest District.

6. Conclusions

The diversity of the quantitative traits of grafts in the clonal archive of Rygol Forest District is high and statistically significant for most traits. Large variation occurs both between the clones being analysed and within the clones themselves, which is evidence of its genetic and environmental character.

In the first years of growth (up to 6 years of age) of the progeny of mother trees, significant changes in the survival of individual clones were observed. In the next period (6−12 years of age), changes in this trait were small and rather random (impact of game animals).

The lack of a negative correlation between age and the quantitative features of mother trees with the growth of their progeny in the archive indicates the possibility of applying this breeding method both for selective forest tree breeding as well as for the conservation of the genetic resources of forests.

Establishing archives of valuable clones, for various reasons, genotypes of forest trees, even of very old individuals, seems to be a sufficiently effective method of protecting individual genotypes.

Conflict of interest

The authors declare the lack of potential conflicts of interest.

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Authors' contribution

M.M.-Z. – study concept, preparation of the manuscript, corrections; M.M.-Z., A.Z. – fieldwork, development of the methodology, A.Z. – literature review.

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