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Testing Romanian seed sources of Norway spruce (*Picea abies*): results on growth traits and survival at age 30

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Abstract. Growth traits and survival rate were evaluated in two field trials consisting of 33 provenances (seed stands) spread across the entire natural distribution range of Norway spruce in Romania. Total tree height, diameter at breast height (DBH) and survival rate were measured at 30 years after planting. Both growth and adaptation traits show substantial genetic variation among the tested seed stands. The amplitude of variation depends markedly on trait and testing site. This fact suggests that the best performing seed stands for growth and adaptation traits at each testing site can be selected. Two groups of valuable populations from Romanian Carpathians - the Northern and Western part (Apuseni Mountains) - were identified. Survival rate was negatively correlated with growth traits, the average values in the two field trials were 68% and 70%. By analyzing growth and adaptation traits together with stem and wood qualitative traits, the best performing populations will be considered as tested seed sources and the forest reproductive material they can provide will be recommended for use in the regions of provenance where the two field trials are located.
Keywords *Picea abies*, seed stands, genetic variability, quantitative traits, survival rate, Norway spruce.

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Introduction

In Romania, the distribution range of Norway spruce (*Picea abies*) comprises about 1.479.000 ha (INS 2008), which represent 77% of the area occupied by conifers and 23.4% of the forest cover. The Norway spruce forms alone an entire vertical vegetation belt in the Carpathian Mountains. It can also be found at lower altitudes, in mixed stands with silver fir and common beech (Şofletea & Curtu 2007).

IUFRO (International Union of Forest Research Organizations) coordinated the establishment of three series of experiments with Norway spruce: first in 1938/1939, the 2nd in 1964/1968 and the last one in 1972. All the published data afterwards in Europe show favorable results related to Romanian provenances, both in growth traits and adaptation ability, the most valuable provenances being Marginea and Moldovița (Giertych 1993, Naapola 1997, Alexandrov & Stancova 1997, Karlsson & Hogberg 1998, Mihai 2003, Skroppa 2005, Ujvari & Ujvari 2006).

Norway spruce seed stands (populations) located over the entire natural distribution range of Norway spruce in Romania were selected for testing in different fields trials. Within each population, morphologically valuable trees were selected as seed trees. The seed stands are phenotypically valuable populations of identified origin, but untested from the genetic point of view. Therefore, the purpose of the study is to identify and prove the genetic value of some of the Norway spruce seed stands in multi-site trials and furthermore to establish tested seeds sources (Enescu & Contescu 1984), based on genotypic selection. The results will allow creating the streamline for the practice decisions regarding the aforestation works by using the most suitable forest reproductive materials depending on environmental conditions, which will lead to stands that are more productive and durable to disruptive environmental factors. As a consequence, the national and European regulations regarding the production and use of the forest reproductive materials will also be implemented (Pârnuță et al. 2010).

The main quantitative and adaptation traits of the Norway spruce [*Picea abies* (L.) Karst.], are analyzed taking into account the data obtained in two field trials (Avrig and Brețcu) of the multisite experiment established in Romania in 1980.

The most valuable populations (seed stands) resulting from the evaluations will be designated as tested sources, and the stands where they originate from will be nominated as Norway spruce seed sources recommended to be used in similar ecological conditions as the ones of the two trials.

Materials and methods

The two field trials (Avrig and Brețcu) were established using seedlings resulted from the open pollination of 10 seed trees identified in each of the 33 seed stands (table 1).

The Avrig field trial is placed outside the natural Norway spruce area, at 615 m altitude (45°39'36" N, 24°26'12" E) and the Brețcu field trial was established in the ecological optimum of the species, at an altitude between 980 and 1240 m (mean altitude 1100 m, 45°58'16" N 26°24'12" E).

The experimental design for both field trials is an incomplete balanced square grid design, with 3 replications and 49 seedlings per plot, planted at 2 by 2 m spacing, each population being composed by descendents obtained from bulked seeds harvested from 10 trees from each of the seed stand tested in this experiment (Enescu & Contescu 1984).

The methodology recommended by I.U.F.R.O. for the field measurements was adopted. Thus, 10 trees were randomly measured from a single plot totalizing 30 trees measured for each population per field trial. The data obtained were analyzed using STATISTICA software (Statistica 8.0). According to the experimental design and the type

Table 1 Origin location of the tested populations (seed stands)

Code	Population	Alt./lat./long.	Code	Population	Alt./lat./long.
1	Coşna (SV)	1025/47°28'/25°10'	18	Braşov (BV)	1020/45°35'/25°35'
2	Dorna Cândreni (SV)	990/47°17'/25°05'	19	Azuga (PH)	1210/45°28'/25°40'
3	Frasin (SV)	755/47°28'/25°48'	20	Domneşti (AG)	650/45°11'/24°49'
4	Marginea (SV)	670/47°49'/25°50'	21	Orăştie (HD)	680/45°43'/23°16'
5	Moldovița (SV)	855/47°39'/25°34'	22	Bistra (AB)	1350/45°35'/23°45'
6	Stulpicani (SV)	985/47°22'/25°46'	23	Voineasa (VL)	1410/45°17'/23°55'
7	Năsăud (BN)	1210/47°28'/24°25'	24	Retezat (HD)	970/45°27'/22°51'
8	Prundul Bârgăului (BN)	1290/47°05'/24°45'	25	Bozovici (CS)	600/44°57'/21°59'
9	Rodna (BN)	890/47°26'/24°50'	26	Văliug (CS)	940/45°12'/22°02'
10	Sânmartin (HG)	900/46°13'/25°57'	27	Beliş (CJ)	1210/46°32'/23°02'
11	Toplița (HG)	910/46°45'/25°20'	28	Turda (CJ)	1200/46°33'/23°02'
12	Gurghiu (MS)	1225/46°45'/24°50'	29	Beiuş (BH)	520/46°52'/22°23'
13	Sovata (MS)	1190/46°40'/25°05'	30	Dobreşti (BH)	510/46°53'/22°20'
14	Tarcău (NT)	930/46°54'/26°06'	31	Sudrigiu (BH)	1050/46°31'/22°35'
15	Comandău (CV)	1150/45°45'/26°20'	32	Câmpeni (AB)	1237/46°25'/23°10'
16	Nehoiu (BZ)	1120/45°37'/26°30'	33	Gârda (AB)	1295/46°29'/22°55'
17	Nehoiaşu (BZ)	1080/45°30'/26°10'			

Note: In paranthesis of the "Population" column is noted the county abbreviation, Alt. - altitude (m), lat. - latitude N, long. - longitude E.

of biological material used, the most suitable ANOVA test (Nanson 1970, White et al. 2007) was used in order to analyze the total variance of the traits.

The total variance was divided in variance components: variance determined by populations effect, variance determined by replications, and the residual variance. The following mathematic model was used:

$$X_{ijk} = m + \alpha_i + \beta_j + \varepsilon_{ij}$$

where: m - overall average, α_i - component of i populations (i = 1...a), β_j - component of j repetitions in i populations (j = 1...b), ε_{ij} - random error affecting ij plots.

Fisher (F) and multiple t tests were used to establish the level differences' significance for the transgression probability of 5%, 1% and 0.1%. For populations ranking and their distribution in homogeneous groups, Duncan test for the transgression probability of 5% (Duncan 1955, Ujvari & Ujvari 2006) was used. Correlations among traits were calculated, as well as the correlations among traits and the ecological gradients of the seed stands' origin.

Results

Breast height diameter

The amplitude of variance for breast height diameter (DBH) in Avrig trial indicates a moderate population x environment interaction. The average value of the DBH is 19.3 cm, resulting 0.64 cm annual average diameter increment. The highest growths were determined in the populations 28-Turda – 22.0 cm, 15-Comandău - 21.4 cm and 13-Sovata - 21.0 cm, while the lowest were achieved by 24-Retezat and 14-Tarcău – both of 17.2 cm. Compared to the overall average of the field trial, the Turda population achieved a 14% higher diameter while the Retezat and Tarcău populations showed a lower value by 11%.

In the Brețcu field trial, the low value of the amplitude of variance for DBH indicates a reduced population x environment interaction. The DBH average value is 20.6 cm, with 1.3 cm (7%) higher than in the field trial Avrig. The best performing populations are 12-Gurghiu - 22.4 cm, 32-Câmpeni - 22.3 cm and 21-

Orăştie - 21.7 cm. The lowest value for growth was 19.5 cm, being registered by populations 14-Tarcău and 31-Sudrigiu. Compared to the overall average of the trial, the best performing population achieved a growth higher by 8.7%, while the two least performing populations showed a value lower by 5.3%.

The analysis of variance (Table 2) reveals the existence of highly significant ($p < 0.001$) differences among the populations in the field trial Avrig, while the differences in the field trial Breţcu are insignificant.

The populations ranking and their homogenous groups' distribution are outlined in figures 1 and 2. The populations with the lowest diameter growth in the field trial Breţcu are placed close to the average value in the field trial Avrig. This situation may be the result of the trials' location (low altitude outside the natural distribution range of the Norway spruce for Avrig trial, ecological optimum for Norway spruce in the case of Breţcu trail). On the other hand, if we compare the populations' ranking in the two trials, we identify situations of

Table 2 ANOVA results for the breast height diameter, total height and survival rate

Source of variance	Sum of squares	*DF*	Mean square (s^2)	F_{value}	*p*	$F_{5\%}$	$F_{1\%}$	$F_{0.1\%}$
DBH								
Avrig								
Replication	49.8	2	24.9	1.15	0.3161	3.00	4.62	7.00
Population	1527.5	35	43.6	2.02***	0.0005	1.44	1.66	1.95
Error	22518.9	1042	21.6					
Total	24096.2	1079	-					
Breţcu								
Replication	77.8	2	38.9	1.80	0.1666	3.00	4.62	7.00
Population	871.1	35	24.9	1.15	0.2552	1.44	1.66	1.95
Error	22574.3	1042	21.7					
Total	23523.1	1079	-					
Total height								
Avrig								
Replication	3.8	2	1.9	0.49	0.6151	3.00	4.62	7.00
Population	519.3	35	14.8	3.78***	0.0000	1.44	1.66	1.95
Error	4086.5	1042	3.9					
Total	4609.6	1079	-					
Breţcu								
Replication	0.7	2	0.4	0.10	0.8713	3.00	4.62	7.00
Population	168.7	35	4.8	1.84**	0.0023	1.44	1.66	1.95
Error	2731.3	1042	2.6					
Total	2900.7	1079	-					
Survival rate								
Avrig								
Replication	155	2	77	1.80	0.1736	3.00	4.62	7.00
Population	42892	35	1225	27.80***	0.0000	1.44	1.66	1.95
Error	45938	1042	44					
Total	88985	1079	-					
Breţcu								
Replication	29579	2	14789	405.00***	0.0000	3.00	4.62	7.00
Population	33043	35	944	25.90***	0.0000	1.44	1.66	1.95
Error	37995	1042	36					
Total	100616	1079	-					

Note: * - significant at $p < 0.05$, ** - distinctly significant at $p < 0.01$, *** - highly significant at $p < 0.001$, *DF* - degrees of freedom

similar positions for some of them (the case of 12-Gurghiu and 32-Câmpeni populations with active growths, respectively 14-Tarcău and 18-Braşov with reduced growth) but also large fluctuations from one trial to another. For example, the populations Turda and Comandău, the first two positions in the Avrig field trial, rank only positions 27th, respectively 19th in the Brețcu field trial. The populations 21-Orăştie and 8-Prundul Bârgăului, 3rd and 4th positions in the Brețcu trial can be found on 27th and respectively 30th positions in the Avrig trial.

The average differences between the DBH in each of the 33 populations in the two trials is 1.8 cm (9%). The DBH were bigger in Brețcu field trial compared to Avrig field trial for 79% of the evaluated seed sources, most of them (52%) originated from the Eastern Carpathians. The biggest difference between the two experiments was determined for population 24-Retezat (Southern Carpathians), which recorded in Brețcu test a 25% higher value than the one from Avrig. The smallest differences between the two test locations were registered by the population 25-Bozovici, with only 0.5% higher in Avrig test.

Total height

The average value for total tree height in Avrig trial is 18.8 m, with a variation amplitude much smaller than that recorded for breast height diameter. The populations with the highest mean height are 12-Gurghiu - 20.1 m, 4-Marginea - 20.0 m, 25-Bozovici - 19.9 m and 5-Moldovița - 19.8 m. The lowest heights are in populations 24-Retezat and 18-Braşov (17.4 m), followed by 23-Voineasa and 14-Tarcău – 17.9 m (Figure 3).

The mean height of the 1080 trees measured

Seed stand	Mean (cm)	Homogeneous groups for the transgression probability of 5%					
28	22.0	****					
15	21.4	****	****				
13	21.0	****	****	****			
4, 12	20.7	****	****	****	****		
27, 32	20.3	****	****	****	****	****	
5	20.2	****	****	****	****	****	
25	20.1	****	****	****	****	****	
3, 31	19.9	****	****	****	****	****	****
29	19.8	****	****	****	****	****	****
30	19.7	****	****	****	****	****	****
11	19.5	****	****	****	****	****	****
8	19.4	****	****	****	****	****	****
2, 23	19.1		****	****	****	****	****
1, 19, 26	19.0		****	****	****	****	****
20	18.9		****	****	****	****	****
10, 22	18.8		****	****	****	****	****
7	18.7		****	****	****	****	****
17	18.6		****	****	****	****	****
18, 21	18.1			****	****	****	****
6, 16	18.0				****	****	****
9	17.8				****	****	****
33	17.7					****	****
14, 24	17.2						****

Figure 1 Duncan test for the breast height diameter in Avrig field trial

Seed stand	Mean (cm)	Homogeneous groups for the transgression probability of 5%			
12	22.4	****			
32	22.3	****	****		
21	21.7	****	****	****	
9, 17	21.6	****	****	****	
24	21.5	****	****	****	
2, 8, 22	21.4	****	****	****	****
4, 7, 11	21.1	****	****	****	****
19	21.0	****	****	****	****
29	20.9	****	****	****	****
33	20.8	****	****	****	****
1	20.7	****	****	****	****
16	20.6	****	****	****	****
6	20.6	****	****	****	****
15, 23	20.5	****	****	****	****
30	20.3	****	****	****	****
10, 13, 20	20.2	****	****	****	****
3	20.1	****	****	****	****
25, 28	20.0	****	****	****	****
5	19.9	****	****	****	****
26	19.8	****	****	****	****
14, 31	19.5		****	****	****
18	18.8			****	****
27	18.5				****

Figure 2 Duncan test for the breast height diameter in Brețcu field trial

in Brețcu trial is 17.0 m and the variation amplitude is, as in Avrig trial, much smaller than that recorded for breast height diameter. The populations with the highest mean height are: 7-Năsăud - 17.9 m, 32-Câmpeni and 24-Retezat - 17.6 m, 12-Gurghiu - 17.5 m, but all values are under the average value recorded in Avrig trial (18.8 m). The lowest heights are registered by populations 26-Văliug - 16.0 m, 27-Beliş - 16.1 m and 18-Braşov - 16.4 m (Figure 4).

ANOVA reveals the existence of significant differences between populations in both trials, for this trait. Duncan test for total tree height confirms the differences between populations established by ANOVA test (figure 3 and 4). The existence of a large number of homogenous groups it is very useful in obtaining superior results, by selecting populations with high growth potential for height.

The most valuable homogeneous group includes about half of the 33 populations, group that covers relatively uniform the Norway spruce's distribution range in our country; more frequent being the populations from the Eastern Carpathians and Apuseni Mountains. Referring to total height, there were found some populations which registered active height growth in one trial, but very weak in the other (population 24-Retezat ranks 2 in Brețcu field trial, but only 32nd in Avrig trial). For a better ranking of the tested population, they should be evaluated according to the average volume per tree, achieved in each of the field trials (Figure 5 and Figure 6).

The average difference for total height in each of the 33 populations in the two field trials is 1.9 m (11%). The total height is larger in Avrig compared to Brețcu for 32 of the evaluated seed sources (except for 24- Retezat). The biggest difference between the two experiments was found for the population 25-Bozovici (Southern Carpathians), which recorded in Avrig test a 19% higher value than the one from Brețcu. The smallest differences between the two test locations were registered by the population 24-Retezat, with only 1% higher in Brețcu test.

Seed stand	Mean (m)	Homogeneous groups for the transgression probability of 5%						
12	20.1	****						
4	20.0	****						
25	19.9	****	****					
5	19.8	****	****	****				
13,15,28	19.5	****	****	****	****			
7, 29	19.4	****	****	****	****			
32	19.2	****	****	****	****			
2, 8, 30	19.1	****	****	****	****	****		
11,20,22,27	19.0	****	****	****	****	****	****	
1,3,19	18.7		****	****	****	****	****	
9	18.6			****	****	****	****	
10,16,31	18.5				****	****	****	****
6,17	18.4				****	****	****	**** ****
26	18.3				****	****	****	**** ****
21,33	18.0					****	****	**** ****
14,23	17.9					****	****	**** ****
18,24	17.4							**** ****

Figure 3 Duncan test for the height tree in Avrig field trial

Seed stand	Mean (m)	Homogeneous groups for the transgression probability of 5%						
7	17.9	****						
24, 32	17.6	****	****					
12	17.5	****	****	****				
1, 2, 21, 22	17.3	****	****	****	****			
5, 19, 29	17.2	****	****	****	****	****		
30	17.1	****	****	****	****	****	****	
4,9,11,13,16,33	17.0	****	****	****	****	****	****	****
17,20,23	16.9	****	****	****	****	****	****	****
8,15,25,28	16.8		****	****	****	****	****	****
10, 14	16.7		****	****	****	****	****	****
3, 6, 31	16.6		****	****	****	****	****	****
18	16.4				****	****	****	****
27	16.1					****	****	****
26	16.0							****

Figure 4 Duncan test for the height tree in Brețcu field trial

Survival rate

The average survival rate for Avrig trial is 68%, with a large variation amplitude (from 77% for population 20-Domneşti, to 52% for population 28-Turda), while in Brețcu trial it is 70%, also with a high amplitude of variation (from 82% for population 21-Orăştie, down to 54% for population 12-Gurghiu).

ANOVA underlines the existence of significant differences between populations, in both field trials. In addition, in Brețcu comparative trial, there are significant differences between replications, which may be the result of the site variation.

The biggest difference between the two experiments was registered for population 27-Beliș (Occidental Carpathians), which recorded in Brețcu test a 36% higher value than the one from Avrig. The smallest differences between the two test locations were registered by the populations 1-Coşna, 9-Rodna, 2-Dorna Cândreni, 8-Prundul Bârgăului, with only 1% higher in Avrig test (first two), and Brețcu test (last two).

The correlation between the latitude corrected by altitude and the survival rate is negative and significant (r = - 0.18*** in Avrig trial, respectively r = - 0.13*** in Brețcu field trial - table 3) meaning that the survival rate decreases as we go to the North on latitude.

Seed stand	Mean (mc)	Homogeneous groups for the transgression probability of 5%						
28	0.373	****						
15	0.363	****	****					
4	0.354	****	****	****				
13	0.351	****	****	****				
12	0.349	****	****	****				
5	0.338	****	****	****	****			
32	0.329	****	****	****	****	****		
25	0.328	****	****	****	****	****		
27	0.327	****	****	****	****	****		
29	0.324	****	****	****	****	****	****	
30	0.316	****	****	****	****	****	****	
3	0.307	****	****	****	****	****	****	
11	0.303	****	****	****	****	****	****	****
31	0.302	****	****	****	****	****	****	****
8	0.299	****	****	****	****	****	****	****
2	0.291	****	****	****	****	****	****	****
22	0.289	****	****	****	****	****	****	****
23	0.286	****	****	****	****	****	****	****
20	0.285	****	****	****	****	****	****	****
19	0.283	****	****	****	****	****	****	****
7	0.280	****	****	****	****	****	****	****
1	0.276		****	****	****	****	****	****
26	0.275		****	****	****	****	****	****
10	0.272		****	****	****	****	****	****
17	0.266			****	****	****	****	****
16	0.248				****	****	****	****
21	0.246				****	****	****	****
6, 9	0.244				****	****	****	****
18	0.242					****	****	****
14	0.234					****	****	****
33	0.231						****	****
24	0.211							****

Figure 5 Duncan test for the average volume per tree in Avrig field trial

Seed stand	Mean (mc)	Homogeneous groups for the transgression probability of 5%		
32	0.346	****		
12	0.345	****		
21	0.325	****	****	
24	0.323	****	****	
2, 22	0.313	****	****	****
9	0.310	****	****	****
7, 29	0.309	****	****	****
17	0.308	****	****	****
8	0.303	****	****	****
15, 19, 33	0.296	****	****	****
11	0.295	****	****	****
1, 4	0.293	****	****	****
16, 30	0.291	****	****	****
23	0.289	****	****	****
6	0.284	****	****	****
13	0.283	****	****	****
28	0.279	****	****	****
5, 20	0.273	****	****	****
3	0.272	****	****	****
31	0.270	****	****	****
25	0.269	****	****	****
10	0.266	****	****	****
14	0.261		****	****
26	0.259		****	****
18	0.247		****	****
27	0.237			****

Figure 6 Duncan test for the average volume per tree in Brețcu field trial

Table 3 Correlation coefficients between growth traits, adaptability and environmental gradients

Variables	Total height	Survival rate	Latitude (N)	Latitude corrected by altitude	Longitude (E)	Altitude (m)
Avrig						
Breast height diameter	0.87***	- 0.14***	0.04	0.020	- 0.02	0.004
Total height		- 0.11**	0.11**	0.003	0.00	- 0.040
Survival rate			- 0.29***	- 0.180***	- 0.01	- 0.010
Brețcu						
Breast height diameter	0.86***	- 0.09*	0.02	0.030	0.01	0.030
Total height		- 0.05	0.05	0.040	0.00	0.020
Survival rate			- 0.29***	- 0.130***	- 0.11**	- 0.020

Note: * - significant at $p < 0.05$, ** - distinctly significant at $p < 0.01$, *** - highly significant at $p < 0.001$

Discussion

The results reflect the importance of long term multisite experiments, as they offer very useful information for identifying of the best populations according to the very different environmental conditions of the Norway spruce's natural area in Romania.

Comparing the results obtained at the age of 30 years with those at the age of 15 (Enescu & Ioniță 2002) we observe that, in the field trial Avrig, the 24-Retezat population remains on the last position of the ranking, followed by 14-Tarcău, while at the top of the ranking, the population 28-Turda moved from 2nd position to the first one, displacing the 26-Văliug population, now on position 18.

At the age of 30, we can remark that the height growths are superior in Avrig trial, while in Brețcu trial the diameter growths are higher. In fact, divergent results in various site conditions of the same type of biological material were noticed also in Finland (Raiskila et al. 2006).

The experimental data obtained for diameter and height growths, revealed the existence of very significant and positive correlation between these quantitative traits (Table 3). Similar results were obtained through other studies made for Norway spruce field trials (Enescu & Ioniță 2000, 2002, Glen 1994, Mihai 2000, 2002, 2009, Pacalaj et al. 2002, Pârnuță 2001, 2008, Ujvari & Ujvari 2006).

The correlation between growth traits and survival rate is negative and significant to highly significant (r = -0.09* in Brețcu, respectively r = -0.14*** in Avrig – both for breast height diameter). This result is similar to data published by Kowalczyk (2007) and Pacalaj (2002), although other previous evaluations made in field trials in Romania did not reach to a similar result (Mihai 2002, Pârnuță 2008).

The population 22-Bistra (original from Sothern Carpathians), the closest to the Avrig site, is on the 22nd position in the ranking of the best performing seed stands tested in this location for DBH and on 16th for total height. Among the populations located close to Brețcu trial we can outline 15-Comandău, which ranks 19th for DBH and 23rd for total height and 10-Sânmartin 22nd for DBH and 26th for total height. These results show that the local provenances are not the best such as in order to obtain superior stands, in the future afforestation works it is necessary to include other valuable Norway spruce populations within the same ecological conditions as the ones met in the two testing sites.

15 out of the 33 seed stands tested in the Romanian experiment have been also tested in two experiments in France (Besançon and Nancy). The French experiments showed that,

at the age of 10 years, the Romanian populations have a high adaptability capacity and a better growth compared to the local populations, and therefore they have been recommended for use in France in similar site conditions as the ones of the experiment (Héois & Van de Sype 1991).

Conclusion

The results obtained after processing the field data for the two trials have revealed that, concerning both growth and adaptation traits, there is inter-populations genetic variation with a wider or narrower amplitude, depending on the analyzed trait and the testing site. This fact suggests that the best performing populations from the growth and adaptation traits point of view may be selected for each of the testing sites as it follows: for Avrig trial the populations 12-Gurghiu, 4-Marginea, 25-Bozovici, 5-Moldoviţa, 13-Sovata, 15-Comandău and 28-Turda and for Breţcu trial the populations 7-Năsăud, 32-Câmpeni, 24-Retezat, 12-Gurghiu, 1-Coşna, 22-Bistra, 21-Orăştie and 2-Dorna Cândreni.

The populations from the Eastern Carpathians and Apuseni Mountains regularly are on top, while the ones from the Sothern Carpathians and cooler mountainous depressions have registered the lowest results.

Analyzing the growth and adaptation traits together with the stem and wood qualitative traits, the best performing populations will be considered as tested seed sources (seed stands) and the forest reproductive material that they provide will be recommended for use in the regions of provenance C140 and B120, where Avrig and respectively Breţcu trials are located.

If we report the present results to the previous published data (Enescu & Ioniţă 2002), we observe that the variation amplitude is larger for all the traits except the survival rate, and that the populations ranking modified as the time went by. Therefore, we can conclude that periodical evaluations must also continue after the age of 30.

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References

Alexandrov A., Stankova T., 1997. Norway spruce provenance trials in Bulgaria. IUFRO Norway spruce symposium, Stara Lesna, Slovakia, 8 p.

Duncan D.B., 1955. Multiple range and multiple F tests, Biometrics, 11: 1–42.

Enescu V., Contescu L., 1984. Teste de descendenţe în faza de pepinieră la molid din rezervaţii de seminţe [Nursery tests of Norway spruce seed stands progenies]. ICAS, Series II, Bucureşti, 48 p.

Enescu V., Ioniţă L., 2000. Variaţia genetică a unor populaţii de molid testate în cultura comparativă Cheile Vâlsanului-Argeş [Genetic variation of Norway spruce populations tested in Cheile Vâlsanului-Argeş field trial]. Revista Pădurilor 3: 4-10.

Enescu V., Ioniţă L., 2002. Variaţia genetică inter şi intrapopulaţională a unor resurse genetice de molid (*Picea abies* (L) Karst.) [Inter and intra populations genetic variation of some Norway spruce (*Picea abies* (L) Karst) Forest Genetic Resources]. Annals of Forest Research 45: 67-77.

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

Glen W., 1994. Norway spruce in Prince Edward Island. Management notes, nr. 5.

Héois B., Van de Sype H., 1991. Variabilité génétique de quinze provenances roumaines d'épicéa commun (*Picea abies* (L) Karst). [Genetic variability of 15 Romanian provenances of Norway spruce (*Picea abies* (L) Karst.). First results]. Annals of Forest Science 48: 179-192.

INS, 2008. Institutul Naţional de Statistică, Seria Silvicultură [National Institute for Statistics, Silviculture Series].

Karlsson B., Hogberg K.-A., 1998. Genotypic parameters and clone x site interaction in clone tests of Norway spruce. Forest Genetics 5: 21-30.

Kowalczyk J., Nowakowska J., Sulkowska Ml., 2007. Norway spruce in the conservation of forest ecosystems in Europe. In: IUFRO W.P.S. 2.02.11: Norway spruce provenances and breeding, Warsaw, 21 p.

Mihai G., 2000. Variabilitatea genetică interpopulațională a molidului pentru principalele caractere de interes silvo-economic. I. Variabilitatea genetică a caracterelor de creştere [Norway spruce inter populations genetic variability for the main silvo-economic traits. I. Genetic variability of the growth traits]. Revista Pădurilor 5: 15-20.

Mihai G., 2000. Variabilitatea genetică interpopulațională a molidului pentru principalele caractere de interes silvo-economic. II. Variabilitatea genetică a caracterelor adaptive şi de calitate a lemnului [Norway spruce inter populations genetic variability for the main silvo-economic traits. Genetic variability of the adaptive and wood quality traits]. Revista Pădurilor 6: 15-20.

Mihai G., 2002. Cercetări de provenienţe de molid (*Picea abies* (L.) Karst.) în culturi comparative multistaţionale, Teză de Doctorat [Researches of Norway spruce multisite provenances comparative trials, PhD Thesis], Transilvania University Publishing House, Braşov, 287 p.

Mihai G., 2003. Researches of Norway spruce interpopulational genetic variability. Annals of Forest Research 46: 131-139.

Mihai G., 2009. Surse de seminţe testate pentru principalele specii de arbori forestieri din România [Tested seed sources for the main forest tree species from Romania]. Editura Silvică, Bucureşti, 281 p.

Naapola M.L., 1997. The growth and adaptation of the IUFRO 1964/1968 Norway spruce provenance material in Finland, IUFRO Norway spruce Symposium. Stara Lesna, Slovakia, 17 p.

Nanson A., 1970. L'héritabilité et le gain d'origin génétique dans quelques types d'expériences. Silvae Genetica 19(4): 113-121.

Pacalaj M., Longauer R., Krajmerová D., Gömöry D., 2002. Effect of site altitude on the growth and survival of Norway spruce (*Picea abies* L.) provenances on the Slovak plots of IUFRO experiment 1972. Journal of Forest Science 48(1): 16-26.

Pârnuţă Gh., 2001. Variabilitatea genetică a unor caractere ale descendenţelor biparentale de molid pendula şi comun, testate în culturi multistaţionale [Genetic variability for some traits of common and narrow crowned Norway spruce progenies tested in multisite trials]. Annals of Forest Research 44: 23-28.

Pârnuţă Gh., 2008. Variabilitatea genetică şi ameliorarea arborilor de molid cu coroană îngustă în România [Genetic variability and amelioration of narrow Norway spruce tree in Romania]. Editura Silvică, Bucureşti, 181 p.

Pârnuţă Gh., Lorenţ A., Tudoroiu M., Petrilă M., 2010. Regiunile de provenienţă pentru materialele de bază din care se obţin materialele forestiere de reproducere din România [Regions of provenances of basic materials for forest reproductive materials in Romania]. Editura Silvică, Bucureşti, 122 p.

Raiskila S., Saranpää P., Fagerstedt K., Laakso T., Löija M., Mahlberg R., Paajanen L., Ritschkoff A-C., 2006. Growth rate and wood properties of Norway spruce cutting clones on different sites. Silva Fennica 40(2): 247-256.

Skroppa T., 2005. *Ex situ* conservation methods. In: Geburek T., Turok J. (eds.), Conservation and management of forest genetic resources in Europe. Arbora Publishers, Zvolen, pp. 567-583.

Şofletea N., Curtu L.A., 2007. Dendrologie [Dendrology]. Transilvania University Publishing House, Braşov, 540 p.

STATISTICA 8.0, 2008. StatSoft Inc., Tulsa, OK, USA.

Ujvari E., Ujvari F., 2006. Adaptation of progenies of a Norway spruce provenance test (IUFRO 1964/68) to local environment. Acta Silvatica Lignignaria Hungarica 2: 47-56.

White TW., Adams W.T., Neale D.B., 2007. Forest genetics. CAB International, CABI Publishing, Cambridge, USA, 682 p.