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Stone Pine (*Pinus cembra* L.) Provenance Experiment in Romania

I. Nursery Stage at Age 6 [1])

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Summary

The paper reports results of a stone pine (*Pinus cembra* L.) provenance study conducted in a 4-replicated complete block design nursery provenance test. At age 6, total height growth, height increment in the 6-th year, diameter at root-collar and number of buds around the leader bud were statistically analysed. Highly significant ($p < 0.001$) differences between provenances were noticed for all tested traits. DUNCAN's test suggested a major gap between genetically isolated populations within the natural range of the species. After 6 years of testing, one can not conclude whether the species is characterized by a continuous or a discontinuous distribution pattern. Fast growing and slow growing provenances were found in populations in both the Alps and Carpathians, suggesting that the improvement by selection would be profitable.

Key words: *Pinus cembra*, population, provenance, variation, correlation.

FDC: 165.5; 232.1; 174.7 *Pinus cembra*; (498).

Introduction

The natural distribution of the stone pine (*Pinus cembra* L.) is restricted to the high altitudes of the Alps and Carpathians (SOMORA, 1959; HOLZER, 1963; CRITCHFIELD and LITTLE, 1963). In the Alps, the species ranges between 1200 m and 2500 m elevation (CONTINI and LAVARELO, 1982) but the main zone is between 1500 m and 2000 m (HOLZER, 1975). In Romania, stone pine ranges between 1350 m and 1880 m elevation in the northern Carpathians (GUBESH, 1971) and between 1350 m and 1986 m in the southern Carpathians (BELDIE, 1941; TATARANU and COSTEA, 1952; OARCEA, 1966).

The stone pine is important for:

– reforestation of the subalpine zone to raise the timberline, where it plays a leading part in watersheds, for stabilizing avalanche areas and for reducing the effects of the flash floods (HOLZER, 1972, 1975);

– spruce – larch – cembra mixed stands creation at high elevation in order to increase their windbreak resistance (BLADA, 1996);

–its dense – brown – reddish wood useful for handicrafts (CONTINI and LAVARELO, 1982);

– its high resistance to blister – rust caused by *Cronartium ribicola* FISCH. ex. RABENH. (BINGHAM, 1972; HOLZER, 1975; HOFF et al., 1980; BLADA, 1982, 1987, 1990, 1994);

– landscaping purposes due to its conic – oval shape when grown as single tree (BLADA, 1996).

Investigations concerning stone pine variability revealed that:

– a phenotypical variability in crown shape and stem form was noticed (RIKLI, 1909; HOLZER, 1975);

– in 2 trials with half-sib progenies, HOLZER (1975) found a good correlation between height growth and the elevation of the seed source, i.e. at low altitudes the provenances from the lowest elevation grew best and the progenies of trees selected near the timber line grew better at higher elevations;

– very high variation in both the number of seeds per cone and weight of seeds per cone was found within each investigated population, but variation in 1000 seed weight was moderate (BLADA and POPESCU, 1992);

– highly significant differences between provenances for growth traits were found (BLADA, 1987);

– the *P. cembra* x *P. monticola* DOUGL. F_1 hybrid displayed heterosis for growth traits, at age 11 while *P. cembra* x *P. wallichiana* JAKS. hybrid was intermediate between the 2 parents (BLADA, 1994);

– a recent diallel analysis (BLADA, 1995) within a natural population from the Carpathian, showed highly significant differences in growth traits for CGA, SCA, MAT and REC effects. The conclusion was that within the species *P. cembra* parents could be found with a good general combining ability, which could be used in a breeding programme;

This paper reports some results concerning genetic variation among – and within – 12 stone pine provenances at age 6.

[1]) A modified form of this paper will be presented at the XI World Forestry Congress, Antalya, Turkey, October 13 to 22, 1997.

Materials and Methods

The nursery test consisted of 12 provenances (*Table 1*) including 7 seedlots sampled from Romanian Carpathians and 5 seedlots from Austrian, Switzerland and French Alps. The populations represented a range of stone pine natural populations, ranging from 4°36' in latitude (45°12'N to 49°48'N) to 20°29' in longitude (4°48'E to 25°17'E), and from 1520 m to 2175 m in elevation.

Table 1. – Origin of *Pinus cembra* provenances involved in this study.

Code	Provenance	Lat.(°N)	Long.(°E)	Alt.(m)
1.Ge.	Gemenele (S.C.)	45°35'	22°50'	1780
2.Ptr.	Pietrele (S.C.)	45°23'	22°52'	1650
3.St.R.	Stana de Rau (S.C.)	45°25'	23°03'	1680
4.Cal.	Calimani (N.C.)	47°07'	25°17'	1650
5.La.	Valea Lalei (N.C.)	47°33'	25°05'	1520
6.Pet.	Pietrosul (N.C.)	47°37'	24°40'	1770
7.Pap.	Papusa-Iezer (S.C.)	45°29'	25°05'	1480
8.Elv.	Grachen Wallis (SA)	45°12'	7°52'	2140
9.A.7	Blunbach Grunalpe (AA)	47°27'	13°06'	1575
10.A.34	Imst-Roppen (AA)	47°10'	10°51'	1950
11.Zi.21	Sirnitz-Gilendorfer (AA)	46°55'	13°56'	1740
12.Fr.	Bois des Ayes (FA)	49°48'	4°48'	2175

SC = Southern Carpathians; NC = Northern Carpathians;
SA = Swiss Alps; AA = Austrian Alps; FA = French Alps

Seedlots were sown in early November, 1990 in individual polyethylene pots (22 cm x 18 cm) in potting mixture consisting of spruce humus. Based on results of previous local experiments (BLADA, 1996) by sowing *P. cembra* seed during the autumn, almost all seeds germinate in the next spring avoiding the complicated and costly 180 days long stratification period as KRIEBEL (1973) recommended. If sowing is done in the autumn control measures against seed predation by mice in the nursery beds is compulsory.

The nursery was near Sinaia city at 45°20'29" latitude, 25°33'14" longitude and 730 m in elevation.

After sowing, the pots were placed in nursey beds and arranged in a complete block design. Each of 12 provenances was represented by a 36-seedling plot in each of 4 blocks.

During the whole testing period, the seedlings remained in the same pots and they grew in normal nursery conditions without fertilisation or any other particular care.

Four traits were measured at age 6, including: total height growth (H.6), height increment in the 6th year (h.6), diameter at root-collar (DRC) and number of buds arround the leader bud (NB).

The plot means comprised the basic data for 2-way analysis of variance.

Results

Result of the analysis of variance showed highly significant ($p < 0.001$) differences between provenances for total height growth, height increment in the 6th year, diameter at root-collar and number of buds around the leader bud (*Table 2*). These results suggest that: (1) the differences had a genetic origin; (2) the improvement of the growth traits by selection of some valuable provenances is possible even if the species is a very slow growing one.

Total height growth showed large variation, ranging from 10.2 cm to 27.5 cm with a mean of 16.8 cm. The top 4 provenances were: Pietrele, Blünbach Grünalpe, Gemenele and Calimani (*Table 3*). They grew 64%, 36%, 29%, and 24%, respectively, faster than the trial mean and 170%, 125%, 113% and 104%, respectively (*Fig. 1*), faster than the slowest one in the rank. Three poorest provenances were Pietrosul from northern Carpathians, Sirnitz and Bois des Ayes from Austrian and French Alps, respectively.

According to DUNCAN's (1955) multiple range test, the total height growth was distributed into 6 homogeneous groups (*Table 3*). The first group comprised only one provenance originating in the Pietrele (Code 2) population from the southern Carpathians. This source grew considerably faster than any of the others. The second group comprised 3 provenances, i.e. Gemenele (Code 1) and Calimani (Code 4) both from the Carpathians and Blünbach Grünalpe (Code 9.A.7) from the Austrian Alps. The last provenance in the rank – Pietrosul (Code 6) – from the Carpathians was also statistically different from the others.

Height increment in the 6th year ranged from 3.2 cm to 12.3 cm with a mean of 6.7 cm. Again, Pietrele, Blünbach Grünalpe, Gemenele and Calimani ranked as the top 4 provenances.

Diameter at root-collar ranged from 6.6 mm to 11.1 mm with a mean of 8.6 mm. Once more, Blünbach Grünalpe, Pietrele, Calimani and Gemenele were in the top 4 provenances.

In the ranking of provenance means for number of buds arround the leader bud, the same 4 provenances were in the top group.

The lack of overlap in growth traits, as indicated by DUNCAN's (1955) multiple range test (*Table 3*), suggested that major gaps separated provenances within the natural range of the species, i.e. in both Alps and Carpathians genetically distinct populations could be found. The data from table 3 suggests a discontinuous pattern of distribution, but it has not been possible to draw a valid conclusion yet, because: (a) the provenances were only 6 year old; (b) the number of provenances, particularly those from Alps, seemed to be small.

High to very high variation coefficients were found within provenance for all traits (*Table 4*). For example, for total height growth, the phenotypic coefficient of variation ranged from 14% within Sirnitz population to 35% within Pietrele.

Phenotypic correlations between traits are listed in *table 5*.

There were highly significant ($p < 0.001$) positive correlations between H.6 and h.6, H.6 and DRC, H.6 and NB; h.6 and DRC, h.6 and NB; DRC and NB. This suggests that growth improvement using indirect selection is possible, i.e. selection for one easy measurable trait, such as diameter, will cause a simultaneous improvement for others.

Table 2. – Results of the analysis of variance of *P. cembra* provenance trial.

Source of variation	DF	H.6 MS	H.6 F	h.6 MS	h.6 F	DRC MS	DRC F	NB MS	NB F
Blocks	3	2.26	0.91	0.08	0.11	0.34	1.06	0.13	0.87
Prov.	11	115.21	46.27***	32.21	42.38***	9.66	30.19***	2.31	15.40***
Error	33	2.49		0.76		0.32		0.15	

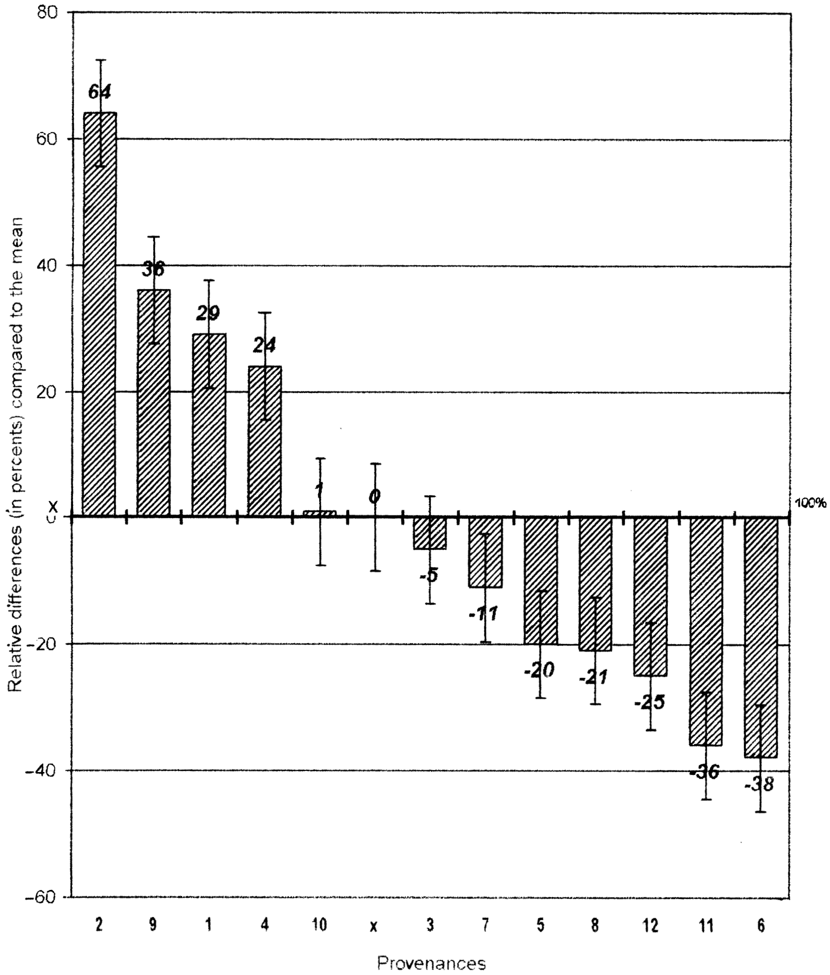

Fig. 1. – Performances of the provenances above/below general mean and their limits of variation.

Table 3. – Distribution of the provenances into homogeneous groups according to DUNCAN's test ($p < 0.05$).

H.6			h.6			DRC			NB		
Prov.	Mean	Duncan test	Prov.	Mean	Duncan test	Prov.	Mean	Duncan test	Prov.	Mean	Duncan test
2	27.51		2.	12.33		9.	11.10		2.	3.69	
9	22.90		9.	9.74		2.	11.00		9.	3.61	
1	21.69		1.	9.47		4.	9.94		1.	3.55	
4	20.83		4.	8.72		1.	9.78		4.	3.25	
10	17.02		10.	6.60		3.	8.74		3.	2.54	
3	15.91		3.	6.34		8.	8.63		10.	2.48	
7	14.94		7.	6.23		10.	8.52		7.	2.34	
5	13.41		5.	5.15		7.	8.09		5.	2.14	
8	13.29		12.	4.68		5.	7.40		12.	1.89	
12	12.63		11.	3.82		12.	7.11		6.	1.88	
11	10.82		8.	3.75		11.	6.75		8.	1.80	
6	10.10		6.	3.23		6.	6.60		11.	1.67	
Mean	16.80			6.70			8.60			2.60	

Table 4. – Within provenance variation coefficients.

Provenances	Variation coefficients			
	H.6	h.6	DRC	NB
1.Ge.	23	39	19	29
2.Ptr.	35	45	26	49
3.St.R.	23	31	22	41
4.Cal.	16	22	15	41
5.La.	30	39	27	52
6.Pet.	17	38	24	39
7.Pap.	18	22	18	27
8.Elv.	24	28	21	51
9.A.7	28	35	16	20
10.A.34	29	45	26	50
11.Zi.21	14	22	28	41
12.Fr.	29	47	34	50
Mean	24	34	23	41

Table 5. – Phenotypic correlations among traits (Df = 10).

Traits	h.6	DRC	NB	Lat.	Long.	Alt.
H.6	0.99***	0.95***	0.96***	-0.41	0.23	-0.32
h.6		0.91***	0.97***	-0.44	0.30	-0.39
DRC			0.93***	-0.40	0.14	-0.27
NB				-0.45	0.33	-0.40
Lat.					–	–
Long.						–

No significant correlations were found, at nursery stage, between growth traits and any geographical co-ordinates of the origin of the provenances. This result needed to be confirmed from long – term juvenile – adult correlations and correlations with additional characters of both economic and ecologic value. However it must be stressed that HOLZER (1975) found a good correlation between height growth and the elevation of the seed source.

Conclusions

Though *P. cembra* is a slow-growing species, these results demonstrated the existence of intraspecific significant variation in growth traits;

– The significant variability was present between and within populations.

– The best provenances, for use in Romania, in growth traits were Pietrele, Gemenele and Calimani from Carpathians and Blünbach Grünalpe from Alps.

– The pattern of distribution seemed to be a discontinuous one; however, results at age 6 were too early to get a valid result; also, the number of provenances, particulary those from Alps, was too small.

– Improvement of the growth traits is possible by using the best provenances and the best individuals within provenances.

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