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Variability of the Traits of Cones and Seeds in Different Larch Clones I. The Influence of the Provenance

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Abstract. Phenotypic variability of the cones and seeds was studied on seven larch clones that were obtained through grafting from plus trees, selected from natural and artificial populations from Romania. Also, correlations between several characteristics such as cones weight (g), cone length and width (cm), seed weight (mg), seed length and width (mm) were studied. **A** wide variation was observed for the weight of cones, ranged between 1.97-4.93 g, the average for all clones being 3.50 g. The coefficient of variability for cones' weight oscillated, depending on the provenance, from 11.1% to 21.2%. Seeds weight varied between 54.4-74.4 mg, with a mean value of 61.9 mg. The weight of cones was positive correlated with all traits, except width of cones and seeds' length. Weight of seeds was strong correlated with all traits, the biggest value of the coefficient of correlation being registered with the weight of cones (0.835). A very strong correlation (+0.939) was registered between the germination energy and germination capacity of seeds, but germination of seeds was negative linked with all traits of cones and seeds, not statistically correlated. The heritability in broad sense had high values, comprised between 0.943 (width of cones) and 0.993 (weight of cones). The results had illustrated that the peculiarities of the cones and seeds have a strong genetic determinism, influenced especially by the genotype and in a relatively small extent by the environment.

Keywords: genus *Larix*, variability, seeds, cones, provenances

INTRODUCTION

Genus *Larix* (*Pinaceae*) comprises around ten species of deciduous trees whose importance differs depending on the geographical area (Bobrov, 1972). For instance, *L. sibirica* and *L. gmelinii* are a main component of the Siberian forest, whereas the natural range of *L. decidua* is mostly limited to the mountainous areas of western and central Europe.

European larch (*Larix decidua* Mill.) has a scattered natural area in Europe, and is present in four geographic zones (Alps, Sudetan Mounts, Carpathians and Central Poland), where the local European larch got sometimes the status of subspecies or races (Biswas, 1997).

Along with the Norway spruce [*Picea abies* L. (Karst)] and silver fir (*Abies alba* Mill.), the most important tree species of Europe (Curtu *et al.*, 2009), larch (*Larix decidua*) is also a representative species for European economy (Wenfang *et al.*, 2008) for its high wood quality (Nawrot *et al.*, 2009), high rate of growth (Wang *et al.*, 2006), great productivity (Lukkarinen *et al.*, 2010), and for its valuable ornamental traits (Nagaike *et al.*, 2010). Larch (*Larix* sp.) is much appreciated for its mechanical properties of wood, its colour and texture, and its natural durability. Its strength and resistance to decay make it well suited for several uses such as floor planking, building skids, pilings, posts and poles.

Larch species are unique among conifers because they are needles are deciduous. The trees are valued for their light green hues in spring and shades of yellow to gold during fall. The crown is usually pyramidal with spreading branches. The height within all ten species varies a lot, influenced also by elevation and site conditions. Western larch is the tallest larch species of the world and can reach about 61 m (Schmidt and Shearer, 1990).

Male and female flowers of the larch grow on the same tree. Cones are scattered throughout the non-shaded crown, in some cases with seed cones positioned higher in the crown and pollen cones more frequent lower in the crown (Eis *et al*., 1983), whereas they usually overlap. They occur randomly with the leaves on the sides of twigs or branches and open few days before needle elongation. The male flowers are solitary, yellow, globe-to-oblong bodies that bear wingless pollen. The female flowers are small, usually short-stalked, erect, red or greenish cones and ripen the first year. Seed cones and pollen cones are usually differentiated in terminal positions on short-shoot axes that complete at least 1 cycle of annual growth (Worrall, 1993).

Ripe cones become brownish and have woody scales; each of them bears two seeds at the base (Fins and Reedy, 1992). The seed has a crustaceous, light-brown outer coat, a membranaceous, pale chestnut-brown, lustrous inner coat, a light-coloured female gametophyte, and a well-developed embryo (Gierlinger *et al.*, 2004; Dallimore, 1967). Occasionally, atypical cones are found on larch.

Larch seeds are winged, nearly triangular in shape, and chiefly wind dispersed. Empty cones may remain on trees for an indefinite period. The number of seeds produced by a single cone may vary from 30 to 70 (Shearer *et al*., 1999; LePage, 1995; Kosiński, 2003). Larch often have a high proportion of hollow seeds, as reported by Shearer (1990), Trenin and Chernobrovkina (1984).

The average number of seeds per kilogram varies with the length of the cone such as: the weight of 1000 seeds from the largest cones was 2.3 times higher than the weight of seeds from the small cones, and 1.4 times higher than the weight of the middle ones. The average weight of 1000 wing seeds was 5.6 g and 5.1 g for the un-wing seeds (Rubţov, 1976). The time of pollination is critical for the development of viable and high-quality western larch seeds (Owens *et al.*, 1994).

In practical forestry, the provenance problem in essence is to find the genotypes of which the seed will grow forests, that are well adapted to their environment and that produce more seeds valuable to obtain quality seedlings.

MATERIALS AND METHODS

Seeds and cones of seven larch clones from Baciu orchard, administrated by O.S. Cluj, Forest Direction Cluj-Napoca (Romania), were collected and used for analysis. The orchard is located at 46°8' latitude, 23°52' longitude and has an average altitude of 357 m.

The larch clones were obtained through grafting, from plus trees, selected from different natural or artificial larch populations in Romania (Gura Humorului, Valea Cetatii, Sacele, Valea Popii, Sinaia, Anina and Latorita - Fig. 1).

The most important traits of cones and seeds, respectively cone height (g), cone length and width (cm), seed weight (mg), seed length and width (mm) were analyzed, these being correlated with the energy of germination and capacity of germination (%), following ISTA and FAO (http://www.fao.org/DOCREP/006/AD232E/AD232E10.htm) recommendation and other studies (Kang, 1991; Li *et al.*, 1992; McComb, 1955).

Data were processed as mean values, calculating the variability of the analyzed traits. In this sense, a statistical analysis of variation (ANOVA) was performed, using the “t” test and considering the average of experience as control (Ardelean *et al.*, 2007).

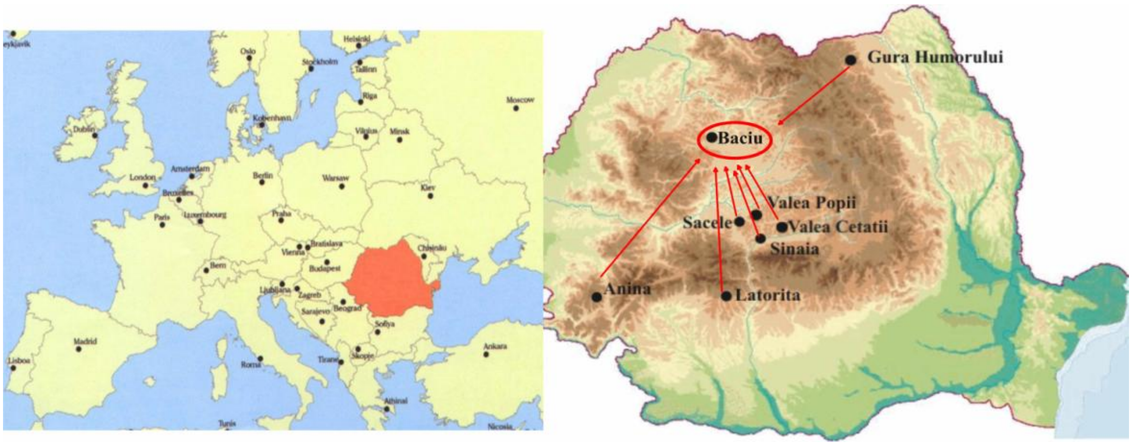

Fig. 1. The provenance of larch clones situated in Baciu orchard, Romania

RESULTS AND DISCUSSION

The main characteristics of cones and seeds, influencing the quality and quantity of seed production in forest trees, are important for identifying the various origins of larch and for understanding their influence upon germination and their capacity to produce quality seedlings.

Cones weight vary significantly within the provenances (Tab. 1) ranging from 1.97 g for Latoriţa provenance to 4.93 g for Sinaia provenance. The highest values for cones weight, comparing with the mean of experience (3.50 g), were observed for Sinaia provenances (4.93 g) and Bv. Valea Popii (4.79 g). Cones with the lowest weight were observed for Latoriţa provenances (1.97 g) and Bv. Valea Cetăţii (2.69 g), with significant negative deviations from the mean of experience.

Cones weight variability had an average value with a lowest coefficient of variability of 11.1% for Sinaia provenance and a highest percentage of 21.2% for Latoriţa provenance. Variation in cones length within all provenances is presented in (Tab. 1) with a mean value of 3.13 cm, where the minimum value was 2.52 cm in Latoriţa and the maximum was 3.69 cm observed in Sinaia provenance.

Tab. 1

Coefficient of variability and the significance of the differences between cones weight, length and width

Nr.	Variant	Cones weight (g)			Cones length (cm)			Cones width (cm)		
		Mean	Signif.	CV%	Mean	Signif.	CV%	Mean	Signif.	CV%
1.	Gura Humorului	3.51	-	12.0	3.62	***	9.5	2.17	-	9.4
2.	Bv. Valea Cetăţii	2.69	ooo	20.9	2.90	ooo	8.4	2.16	-	11.9
3.	Săcele	3.32	-	15.9	2.85	ooo	8.3	2.06	-	9.8
4.	Bv. Valea Popii	4.79	***	11.4	3.26	-	11.9	2.21	*	10.4
5.	Sinaia	4.93	***	11.1	3.69	***	8.4	2.09	-	8.9
6.	Anina	3.28	-	14.1	3.05	-	12.5	2.22	**	9.4
7.	Latoriţa	1.97	ooo	21.2	2.52	ooo	7.8	1.78	ooo	8.5
Mean of experiment		3.50	-	15.2	3.13		9.6	2.10		9.7

*, **, ***/ $^{o, oo, ooo}$ Significant at P<0.05; 0.01 and 0.001 (*, **, *** positive, $^{o, oo, ooo}$ negative)

Significantly high values were obtained in all of the analyzed provenances, resulting in a coefficient of variability ranging from CV=7.8% for Sinaia provenance to CV=12.5% for Anina provenance.

Cones width showed a wide variation within the provenances, with limits between 1.78 cm for Latoriţa provenance and 2.22 cm Anina provenance (Tab. 1). The highest values regarding the cones width were observed in Anina provenance and Bv. Valea Popii, compared with the mean of 2.10 cm, while the lowest values were found in Latoriţa provenance. The maximum coefficient of variability for cones width was observed in Bv. Valea Cetăţii (CV=11.9%) and the minimum of CV=8.5% was found in Latoriţa provenance.

The average of seeds weight for overall provenances was 61.9 mg (Tab. 2). The observed variation vary between 54.4 mg in Bv. Valea Cetăţii provenance and 74.4 mg in Sinaia provenance.

Tab. 2

Weight, length and width seeds, significance values* and coefficient of variability (CV%)

Nr. crt.	Variant	Seeds weight (mg)			Seeds length (mm)			Seeds breadth (mm)		
		Mean	Signif.	CV%	Mean	Signif.	CV%	Mean	Signif.	CV%
1.	Gura Humorului	64.6	-	20.8	4.30	***	12.1	2.43	*	17.7
2.	BV. Valea Cetăţii	54.4	ooo	17.0	3.93	**	12.8	2.32	-	13.3
3.	Săcele	59.4	-	16.2	3.33	o	18.6	2.23	-	11.4
4.	BV. Valea Popii	67.0	*	17.9	3.72	-	11.5	2.30	-	13.5
5.	Sinaia	74.4	***	16.1	3.95	***	9.0	2.50	**	16.6
6.	Anina	67.7	*(*)	14.9	3.72	-	14.9	2.28	-	13.7
7.	Latoriţa	46.2	ooo	14.1	2.45	ooo	15.5	1.68	ooo	14.6
Mean of experiment		61.9	-	16.7	3.63	-	13.5	2.25	-	14.4

*, **, ***/ $^{o, oo, ooo}$ Significant at P<0.05; 0.01 and 0.001 (*, **, *** positive, $^{o, oo, ooo}$ negative)

In regard to the seed weight, the highest values, when compared with the control (61.9 mg) (mean of the experiment), were observed for Sinaia provenance (74.4 mg), Anina (67.7 mg), Bv. Kings Valley (67.0 mg). The lowest values were noted for Latoriţa provenance (46.2 mg) and Bv. Valea Cetăţii (54.4 mg).

The seeds weight variability among all provenances had a mean value except for Gura Humorului provenance, which showed a high variability (CV=20.8%).

Variations of seed length were observed in all provenances, with the lowest value for Latoriţa (2.45 mm), while clones of Gura Humorului, Sinaia, Bv. Valea Cetăţii, Bv. Valea Popii and Anina provenances had higher values than the mean value of 3.63 mm. Among all provenances, the coefficient of variability for seed length had an average value of 13.5%, but a high variability was observed for this trait in Săcele provenance (CV=18.6%)

Variation was observed also among the seeds' width, trait that ranged from 1.68 mm in Latoriţa provenance and had the upper limit of 2.50 mm in Sinaia provenance.

Considering the coefficient of variability for overall studied characters/traits, the maximum values were recorded for seeds weight (16.7%), followed by cones weight (15.2%), seeds width (14.4%) and seeds length (13.5%) respectively, while the minimum values were recorded for cones length (9.6%) and cones width (9.7%) (Fig. 2). High variability means an efficient selection and promising genetic gains (Paques *et al.*, 2010).

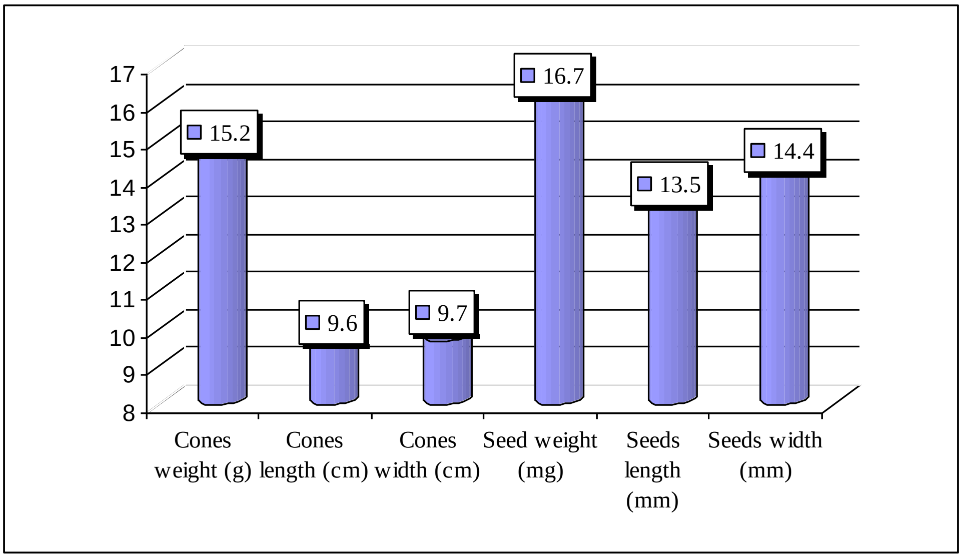

Fig. 2. Coefficient of variability for the cones and seeds of seven clones of larch

Correlation coefficients between cones traits and seeds traits were calculated for all the larch clones (Tab. 3) showing significant differences, which suggest that seeds' development is influenced by the characteristics of the cones.

Weight of cones was positive correlated with all the traits, except width of cones and seeds length. Weight of seeds was strongly correlated with all the traits, the biggest value of coefficient of correlation being registered with the weight of cones (0.835**).

Significant correlations were reported earlier between the weight and mean length of the cones and the weight of 1000 seeds, Carlson (1994). In general, these characters are strongly influenced by diseases and pests, as well as by different crop management views (Weiskittel *et al.*, 2006).

Tab. 3

Phenotypic correlations among the traits of larch cones and seeds

Trait	Cones length	Cones width	Seed weight	Seeds length	Seeds width	Germination (%)	
						Energy	Capacity
Cones weight (g)	0.798*	0.566	0.894**	0.568	0.724*	-0.286	-0.219
Cones length (cm)	-	0.589	0.857**	0.817*	0.837**	-0.500	-0.446
Cones width (cm)	-	-	0.708*	0.869**	0.851**	-0.159	0.093
Seed weight (mg)	-		-	0.709*	0.835**	-0.586	-0.471
Seeds length (mm)	-	-	-	-	0.947***	-0.345	-0.135
Seeds width (mm)	-	-	-	-	-	-0.480	-0.255
Germin. energy (%)	-	-	-	-	-	-	0.939***

r5% = 0.707; r1% = 0.834; r0,1% = 0.925

Between the germination energy and germination capacity of the seeds it was registered a very strong correlation (+0.939***), but the germination of the seeds was negative linked with all traits of cones and seeds, not statistically correlated.

Coefficient of heritability in broad sense (H^2) was calculated for all the traits (Tab. 4). Heritability is a genetic parameter that showed to what extend a genetic character is transmitted to the next generation (Jaquish, 1998).

Tab. 4

The heritability of the studied peculiarities

No. of entry	The studied traits	Coefficient of heritability in broad sense (H^2)
1.	Cones weight (g)	0.993
2.	Cones length (cm)	0.983
3.	Cones width (cm)	0.943
4.	Seeds weight (mg)	0.959
5.	Seeds length (mm)	0.978
6.	Seeds width (mm)	0.951

The heritability in broad sense showed values of 0.943 for cones width and 0.993 for cones weight. It can be concluded that all the analyzed traits have a powerful genetic determinism, strongly influenced by genotype and in a relatively small extent influenced by the environment (ecotype).

CONCLUSIONS

A data base consisting of morphologically descriptions of characters of larch seeds and cones belonging to different provenances and respectively clones, could be useful to identify quality genotypes for breeding programs, as well for forest restoration programmes. In the present experiment, the seeds' energy of germination and the capacity of germination were not influenced by the morphological traits of cones and seeds.

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