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Genetic variability of European larch (*Larix decidua* Mill.) in provenance trials established in Romania

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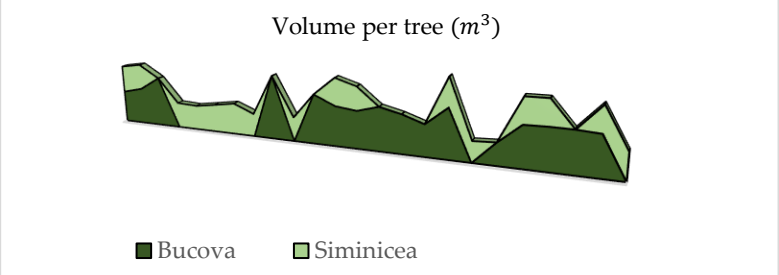
HIGHLIGHTS

- European larch is an important conifer tree species in Romania.
- Large among population genetic variation was observed.
- The study is important to establish appropriate conservation strategies of breeding.

GRAPHICAL ABSTRACT



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ABSTRACT

European larch is one of the most important coniferous species in Romania. It is a fast-growing tree used frequently in reforestations along the Romanian Carpathians. Its natural distribution area in Romania is discontinuous and very limited, representing only 0.3% of the forest area. A series of common garden experiments using European and local larch provenances was established in 1982. The objective of our study was to assess the genetic variability of economic and adaptive traits among European larch provenances, tested in two field trials, to select the best provenances in terms of growth traits, stem straightness, and survival. We also investigated the phenotypic correlations among traits and genotype vs. environment interaction. The analyzed traits included total height, diameter at breast height, volume per tree, pruned height, stem straightness, and survival percentage. The results indicate a large genetic variation within the populations of European larch. The Romanian provenances have a lower growth compared to those from Central Europe but very good stem straightness. The environment factor was significant, therefore the response of the species to climate change will depend on the environmental conditions of the planting site.

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1. INTRODUCTION

The European larch is distributed discontinuously from eastern France to central and south-eastern Italy, and to the mountains of Southern, Central, and Eastern Europe [1]. The Alps are the natural and largest continuous habitat of the European larch. Native stands are located mostly at high altitudes (1000-2900 m), up to the **treeline**, in the Eastern Alps. The best growth is recorded at the altitudes of 1400-1500 m, while at higher altitudes European larch grows less vigorously and faces less competition from other tree species. Larch forests have been estimated to account for around 4% of Europe's total coniferous forest and for less than 1% of the total forest [2]. In Romania, European larch covers around 30,000 ha [3], with the natural distribution area concentrated into five centers: Ceahlău, Ciucaş, Bucegi, Lotru, and Apuseni Mountains**,** totaling approximately 4500 ha.

European larch is a fast-growing species with high-quality wood and high air-pollution resistance. It is particularly shade intolerant compared to other conifers, but it can cope with poor soil and less water availability [4-6]. European larch has double the photosynthesis rates of higher nitrogen levels inside the leaf and a greater leaf area, resulting from less investment in structural tissue and a more carbon-efficient crown shape and canopy structure [7,8].

The European larch, which has a significant level of genetic variation in terms of major economic traits, is one of the most studied forest tree species in Europe. International provenance experiments have identified the best European larch populations regarding growth traits, resistance to diseases and abiotic factors. There is large genetic differentiation within and among local larch populations, which has led to a strong geographic variation in their economic and adaptive traits, as a species with a fragmented distribution [9]. As a result, this genus has been intensively studied since the beginning of the large provenance experiments coordinated by the International Union of Forestry Research Organizations (IUFRO). In 1944, R. Schober organized the first international experiment on this species, followed, in 1958, by further studies [10,11]. In Romania, European larch breeding program started in 1978 and 1982 by establishing two series of common garden experiments through international collaboration (six geographic locations), using Romanian and foreign larch provenances [12]. Afterwards, 26 seed orchards (134 ha) have been established in Romania of which three (15 ha) are of interspecific hybridization (*Larix* x *eurolepis*), and more than 300 plus trees have been grafted [13].

Despite the economic importance of European larch for some populations of *sudetica* and *polonica* varieties [4-6,11,14] and alpine and Romanian Carpathians larch [15], genetic variation of the traits has also been highlighted. The findings showed that, among the European larch progeny from the same provenance, there were significant differences in their growth characteristics, adaptability and wood quality [16-19]. Genetic variability has also been found in resistance to canker disease (*Lachnellula willkommii*), which is harmful in European larch. The European larch has shown significant genetic variation throughout the species range related to sensitivity to drought [20].

Knowledge of the geographical genetic variation of the European larch populations in Romania is becoming increasingly important in the context of climate change, in order to establish

the appropriate strategies for the conservation of forest genetic resources, improve species adaptability to climate change, and continue the European larch breeding program [17,18].

The objective of this study was to investigate 1) genetic variability of the economic and adaptive traits among European larch provenances tested in field trials, 2) phenotypic correlations among traits and 3) genotype-environment interaction, in order to select the best provenances, in terms of growth traits, stem straightness and adaptive capacity, as valuable germplasm sources for reforestation and breeding programs.

2. MATERIALS AND METHODS

The material for this study consisted of 16 European larch provenances - seven Romanian and nine foreign, from Germany (three), Austria (two), Belgium (one), and Slovakia (three) (**Table 1**). The provenances tested originated from seed orchards, plantations, and natural stands. Out of the total number, eight provenances are common in both trials: 30 (Harbker, Hanau 11, seed orchard) and 31 (Hanau 11, seed orchard) from Germany; 54, 55 (Bicaz, artificial stand), 59 (Sinaia, artificial stand) and 62 (Brașov, artificial stand) from Romania; and 63 (Zilina-Hradok), 65 (Keimarok-Lubica) from Slovakia [21]. Romanian provenances come from five natural populations (native to the Romanian Carpathians), five artificial stands of unknown origin, and two seed orchards. The Furnicoși seed orchard is an interspecific hybridization (*Larix decidua* x *L. leptolepis*) seed orchard and plus trees of European larch originated from Brașov, Sinaia, and Latorița forest districts (Curvature and Southern Carpathians). Plus, trees tested in Hemeiuși seed orchard come from the Eastern Carpathians and Apuseni Mountains.

The provenance trials analyzed in this study were established in 1982 in two locations - Bucova (southwest of the country) and Siminicea (northeast of the country). The experimental design consisted of square grids comprising 4 × 4 provenances, with 25 trees per plot and three repetitions. Both experimental trials were established outside the larch's natural distribution area in Romania, in the mountain European beech and oak layer, respectively. The site conditions and location of field trials are presented in **Table 2**.

In each trial, 10 trees from the category of dominant or codominant were measured in each plot and each of the three repetitions. The traits analyzed were categorized as follows: growth traits - total height (m), diameter at breast height (cm), volume per tree (m^3); wood quality traits - pruned height (m), stem straightness (index), and adaptive traits - survival (%). The stem straightness was evaluated using an index, where 1 = straight stem, 2 = minor defects, and 3 = sinuous stem. Tree diameter measurements were made using a caliper at a height of 1.30 m from the ground. The measurement of tree height is very important for determining the volume and other shape parameters. A Vertex III was used for this, following well-established procedures. The observations and measurements of these characteristics were made in 2021, at age 39.

Microsoft Office Excel and SPSS software were used to process the data from field measurements. Data analysis was done by simple and multifactorial analysis of variance with the following sources of variation: provenance, repetition, locality, and the interaction between them.

Table 1. Provenances of *Larix decidua*

No.	Code	Provenance	Country	Lat. N	Long. E	Altit.
1	30	Harbker, Hanau 11 – seed orchard	Germany	-	-	-
2	31	Hanau 11 – seed orchard	Germany	-	-	-
3	32	West Sudd. Mittelgeb Berkel – seed orchard	Germany	-	-	-
4	33	Reichenau / Kärnten	Austria	46°51′	13°58′	1550
5	35	Wienerwald-Lammerau-seed orchard	Austria	-	-	-
6	45	Haldensleben Oberforsterei Bischofswald	Germany	52°20′	11°15′	105
7	47	Halle – seed orchard	Belgium	-	-	-
8	50	Reghin – artificial stand	Romania	46°40′	24°50′	450
9	51	Mihăeşti, Furnicoşi - seed orchard	Romania	-	-	-
10	52	Bacău, Hemeiuși I – seed orchard	Romania	-	-	-
11	53	Bacău, Hemeiuşi II - seed orchard	Romania	-	-	-
12	54	Bicaz – artificial stand	Romania	46°49′	25°52′	1100
13	55	Bicaz – natural stand	Romania	46°57′	25°58′	1500
14	56	Baia de Criş – natural stand	Romania	46°25′	23°30′	1100
15	57	Comăneşti – artificial stand	Romania	46°15′	26°12′	710
16	58	Latoriţa – natural stand	Romania	45°12′	23°55′	1100
17	59	Sinaia – artificial stand	Romania	45°15′	25°30′	690
18	60	Sinaia – natural stand	Romania	45°20′	25°30′	1600
19	61	Sinaia – natural stand	Romania	45°10′	25°40′	1300
20	62	Braşov – artificial stand	Romania	45°30′	25°30′	670
21	63	Zilina - Hradok	Slovakia	49°00′	19°56′	650
22	64	Poprad-Hranovnica	Slovakia	48°59′	20°11′	900
23	65	Keimarok - Lubica	Slovakia	49°07′	20°28′	720
24	66	Presov	Slovakia	49°00′	21°06′	550

Table 2. Location and site conditions of larch provenances trials established in 1982

No.	Trial name Forest District P.U., m.u.*	Region of Prov.	Mean annual temperature (^{0}C)	Total annual precip. (mm)	Lat. N	Long. E	Altit.	Vegetation layer	Soil type
1.	Bauțar Bauțar U.P. VIII, u.a. 1A	D2	2.55	1030	45°29′	22°40′	650	Mountain European beech	brown forest soil
2.	Siminicea Fălticeni U.P. VI, u.a 45 C	G1	5.42	594	47°30′	26°20′	350	Mixture of oak species	brown forest soil

The statistical analysis was based on the individual tree measurements using the following mathematical model [22]:

$$Y_{kil} = \mu + P_k + R_i + L_l + e_{ikl} \quad (1)$$

where Y_{kil} = performance of the k^{th} provenance in the i^{th} repetition and l^{th} locality; μ = overall mean; P_k = effect of the k^{th} provenance; R_i = effect of the i^{th} repetition; L_l = effect of the l^{th} locality and e_{kil} = random error associated with the kil^{th} trees. Pearson's correlations based on provenance means were also calculated to examine phenotypic correlations and relationships between traits.

3. RESULTS

3.1. Genetic Variability

The analysis of variance for each site revealed significant statistical differences among the European larch provenances tested in the 1982 series in terms of growth characteristics (**Table 3**). The provenance factor significantly influenced all characters studied in the Bucova trial, while only for height (total and pruned) and stem straightness in the Siminicea trial.

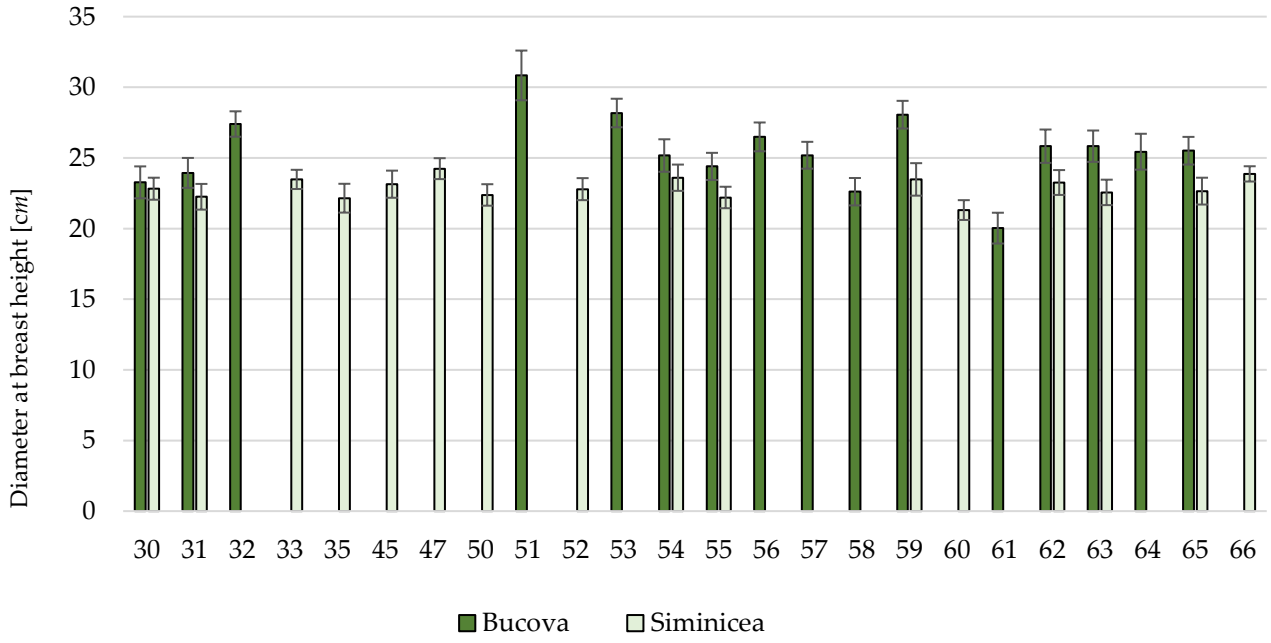
Table 3. Analysis of variance for studied traits in the European larch provenance trials at age 39

Source of variation	S^2						
	D.F	Volume/tree	DBH	Total height	Pruned height	Stem straightness	Survival
Siminicea field trial							
Provenances	15	0.040	16.144	22.257***	33.652***	0.888***	254.99
Repetitions	2	0.095	16.134	133.103	394.280	0.613	1335.44
Error	30	0.030	19.187	4.668	4.498	0.284	1335.44
Bucova field trial							
Provenances	15	0.521**	148.267***	38.236***	12.509***	1.892***	134.733*
Repetitions	2	0.034	13.262	12.496	13.781	1.507	22.333
Error	30	0.107	34.387	5.548	2.987	0.573	22.333

Notes: *p < 0.05; **p < 0.01; ***p < 0.001

The largest diameters at breast height were obtained in the Bucova trial ($\bar{x}$=25.5 cm). The best performing provenances in this trial were: 51 (Mihăeşti, Furnicoşi, seed orchard), Romania; 53 (Bacău, Hemeiuşi II, seed orchard), Romania; 59 (Sinaia, artificial stand), Romania; and 32 (West Sudd. Mittelgeb Berkel, seed orchard), Germany. In the Siminicea trial, the mean on the experiment was $\bar{x}$=22.9 cm and the best provenances were: 47 (Halle, seed orchard), Belgium; 66 (Presov),

Slovakia; 54 (Bicaz, artificial stand), Romania; 33 (Reichenau, Kärnten), Austria; and 45 (Haldensleben), Germany (**Figure 1**). The lowest values for diameter at breast height were registered by the provenances: 61 (Sinaia, artificial stand), Romania in the Bucova trial, and 60 (Sinaia, natural stand) also Romania in the Siminicea trial.



whiskers [*error bar*] represent standard error [*SE*]

Figure 1. Variation of the diameter at breast high in provenance trials

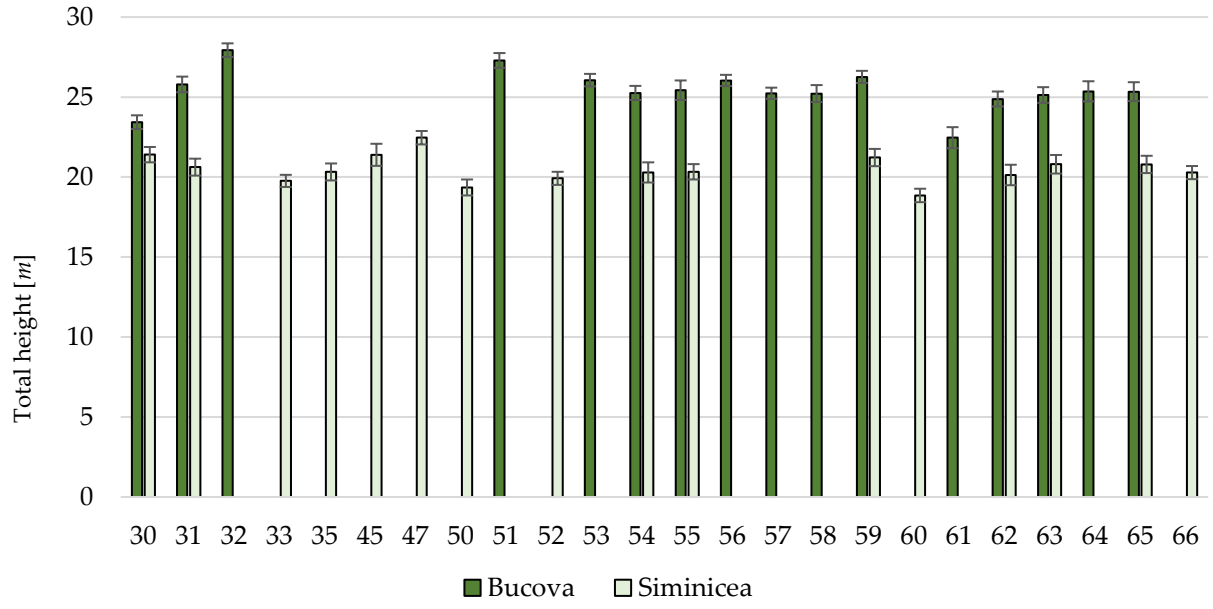


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Figure 2. Variation of total height in provenance trials

The highest total heights (**Figure 2**) have been recorded in the Bucova trial ($\bar{x}$ =25.5 m) by the following provenances: 32 (Berkel, seed orchard, Germany), 51 (Mihăeşti, Furnicoşi, seed orchard, Romania), 53 (Bacău, Hemeiuşi II, seed orchard, Romania), 59 (Sinaia, artificial stand, Romania) and 56 (Baia de Criş, natural stand, Romania). In the Siminicea trial ($\bar{x}$=20.5 m) the provenances with the highest values of total heights were: 47 (Halle, seed orchard, Belgium), 30 (Harbker, Hanau 11, seed orchard, Germany), 45 (Haldensleben Oberforsterei Bischofswald, Germany) and 59 (Sinaia, artificial stand, Romania). The lowest values for the total heights were obtained by the provenances 60 (Sinaia, natural stand, Romania at the Siminicea trial) and 61 (Sinaia, artificial stand, Romania at Bucova trial).

The greatest volume per tree (**Figure 3**) was recorded in the Bucova trial, where the mean of the experiment was $\bar{x}$=0.65 m^3, compared to Siminicea trial where the mean of the experiment was $\bar{x}$=0.41 m^3. In the Bucova trial, the best provenances in terms of volume per tree were: 51 (Mihăeşti, Furnicoşi, seed orchard), Romania; 32 (Berkel, seed orchard), Germany; 59 (Sinaia, artificial stand), Romania; 53 (Bacău, Hemeiuşi II, seed orchard), Romania; and 56 (Baia de Criş, natural stand), Romania. The lowest volumes per tree in this trial were recorded: 61 (Sinaia, natural stand), Romania; 58 (Latoriţa, natural stand), Romania and 30 (Harbker, Hanau 11, seed orchard), Germany. In the Siminicea trial, the following provenances recorded the highest volumes per tree: 47 (Halle, seed orchard), Belgium; 59 (Sinaia, artificial stand), Romania; 45 (Haldensleben Oberforsterei Bischofswald), Germany; and 54 (Bicaz, artificial stand), Romania. The lowest values have obtained: 60 (Sinaia, natural stand), Romania; 55 (Bicaz, natural stand), Romania; and 50 (Reghin, artificial stand), Romania.

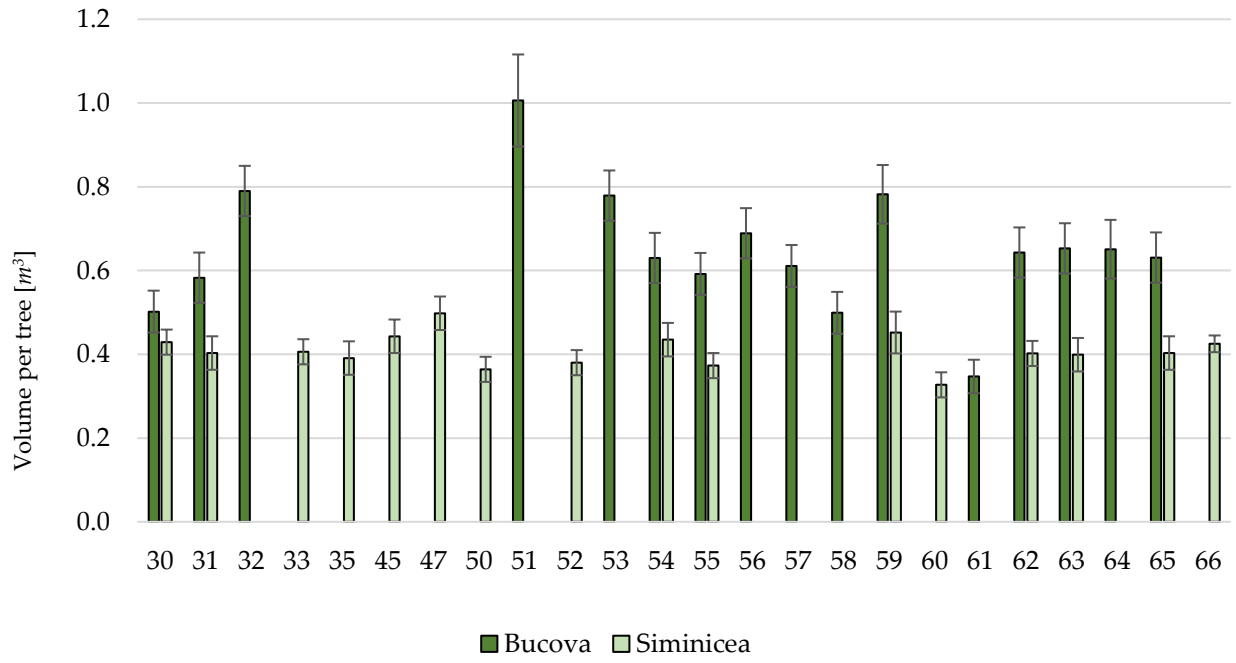

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Figure 3. Variation of the volume per tree

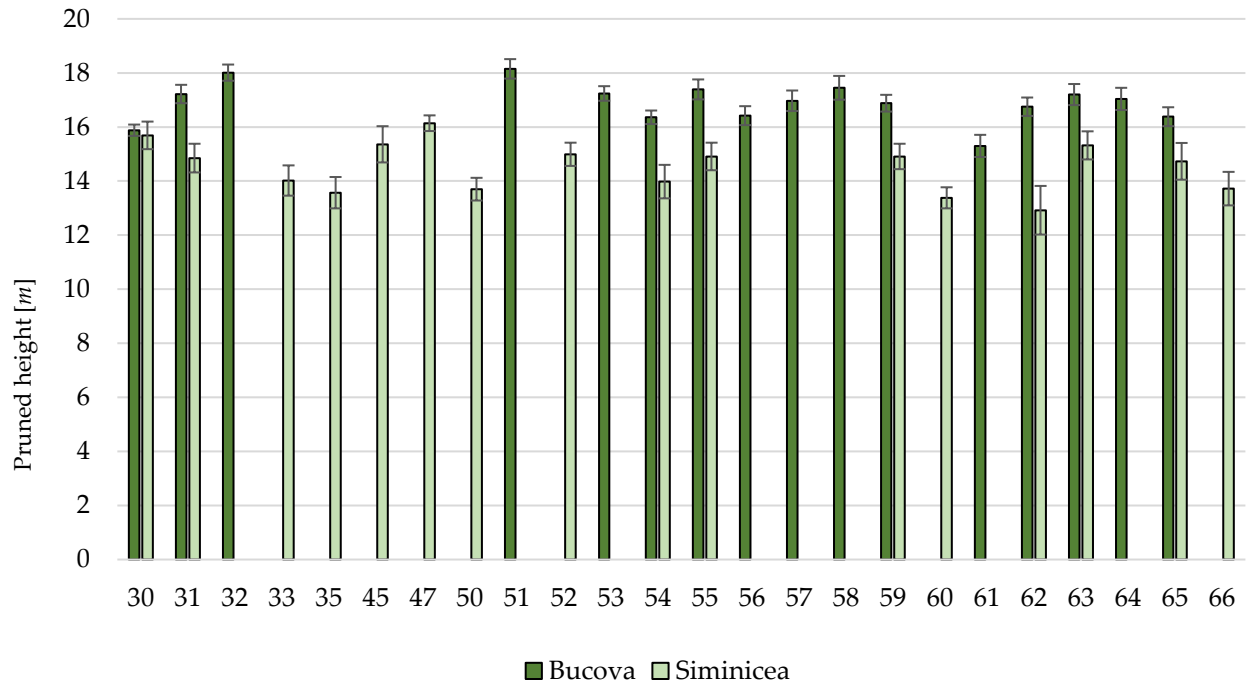

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Figure 3. Variation of pruned height in the provenance trials

The highest value for pruned height (**Figure 4**) has been recorded in the Bucova trial by provenance 51 (Mihăeşti, Furnicoşi, seed orchard), Romania. In Siminicea trial, the highest pruned height was obtained by provenance 59 (Sinaia, artificial stand, Romania). The lowest values were registered by the provenances 60 (Sinaia, natural stand, Romania) and 61 (Sinaia, artificial stand, Romania).

The most defects in the stem shape were observed in the Bucova trial ($\bar{x}$=1.73), with lesser amounts recorded in the Siminicea trial ($\bar{x}$=1.45), but with only a slight difference (**Figure 5**). In Bucova trial, the provenances with the most stem defects were: 56 (Baia de Criş, natural stand, Romania), 55 (Bicaz, natural stand, Romania) and 54 (Bicaz, artificial stand, Romania), 64 (Poprad, Hranovnica, Slovakia), while in the Siminicea trial were: 50 (Reghin, artificial stand, Romania) and 59 (Sinaia, artificial stand, Romania) and 66 (Presov, Slovakia). The fewest defects were recorded by 61 (Sinaia, natural stand, Romania) and 58 (Latoriţa, natural stand, Romania) at Bucova trial and 54 (Bicaz, artificial stand, Romania), 62 (Braşov, artificial stand, Romania) and 60 (Sinaia, natural stand, Romania) at Siminicea trial.

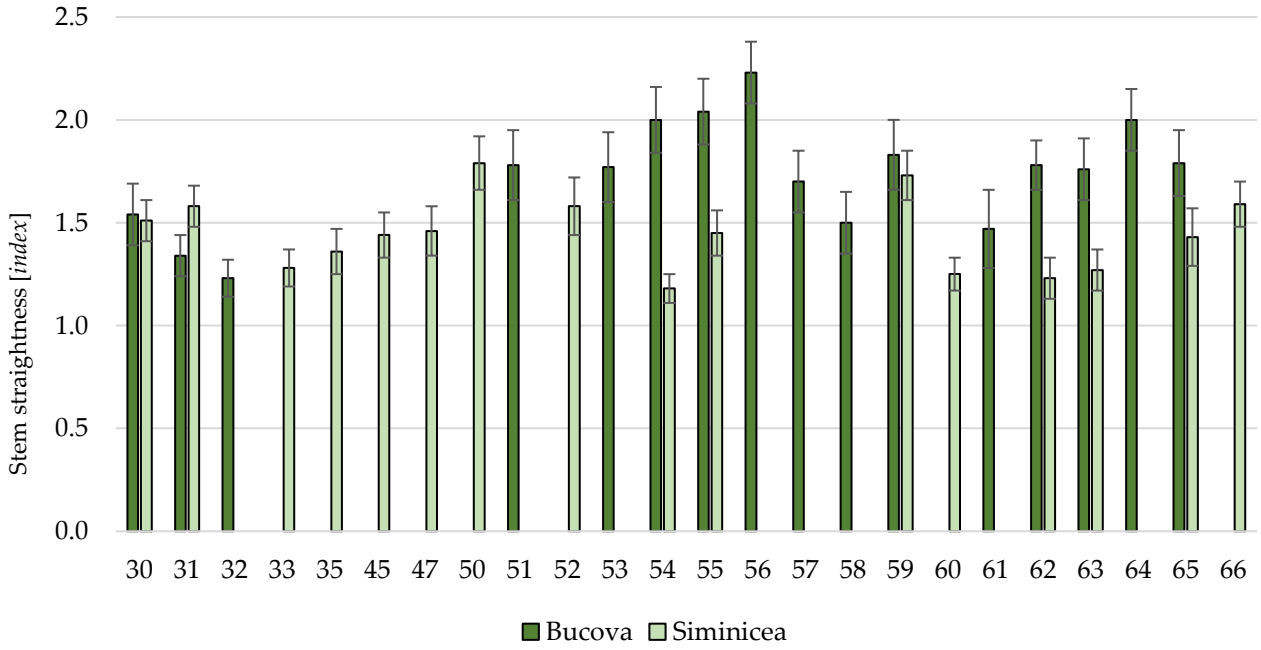

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Figure 5. Variation of stem straightness in the provenance trials

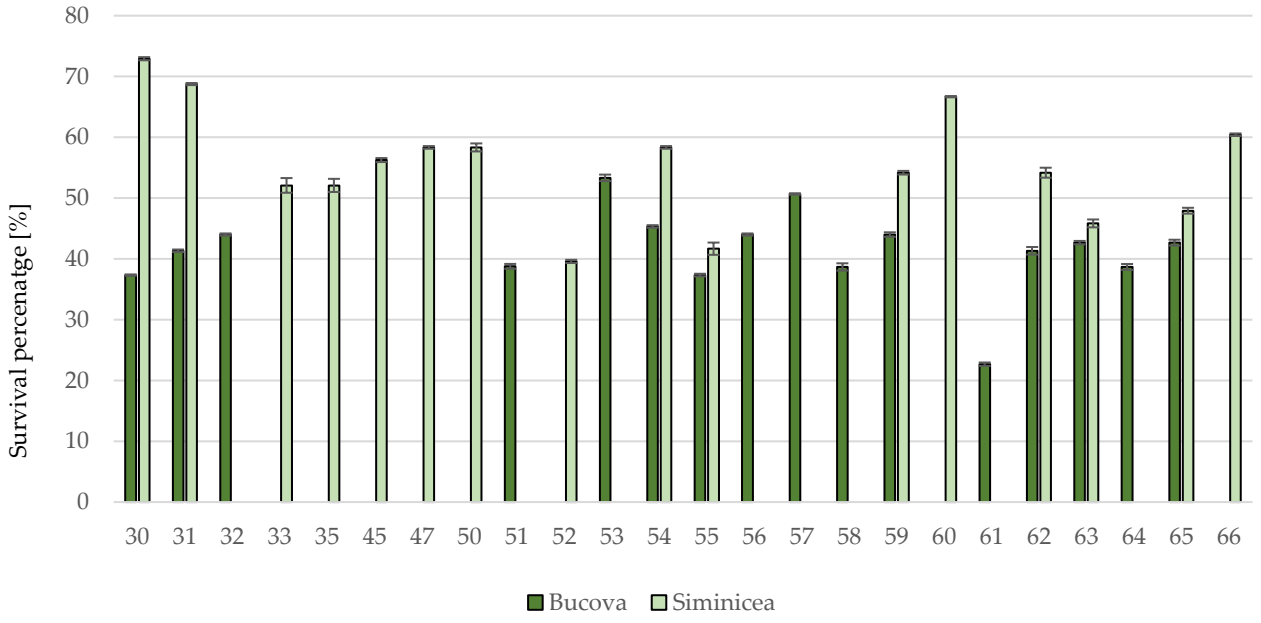

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Figure 6. Variation of stem straightness in the provenance trials

At age 39, the survival rate varied considerably among the experimental trials and provenances. The highest percentage of survival was recorded at Siminicea ($\bar{x}$=55%) and the lowest at Bucova ($\bar{x}$=41%) (**Figure 6**). The provenances with the highest survival percentage in the Bucova trial were: 53 (Bacău, Hemeiuşi II, seed orchard, Romania), 54 (Bicaz, artificial stand, Romania), and 57 (Comăneşti, artificial stand, Romania). At Siminicea trial, the best adaptability was recorded by 30 (Harbker, Hanau 11, seed orchard, Germany), 31 (Hanau 11, seed orchard, Germany), and 60

(Sinaia, natural stand, Romania). The lowest survival percentage was recorded in provenances 30 (Harbker, Hanau 11, seed orchard, Germany), 55 (Bicaz, natural stand, Romania), and 61 (Sinaia, natural stand, Romania) at the Bucova trial, while at the Simincea trial, the lowest survival was found at the provenances 63 (Zilina-Hradok, Slovakia), 55 (Bicaz, natural stand, Romania) and 52 (Bacău, Hemeiuşi I, seed orchard, Romania).

3.2. Phenotypic Correlations Between Traits

Phenotypic correlations among studied traits are presented in **Tables 4** and **5**. Analyzing both filed trials, it can be observed that more significant correlations have been obtained in Bucova trial compared to Siminicea trial.

Table 4. Pearson correlations of traits in Bucova trial, 2021

Variable	Pruned height	DBH	Volume/tree	Stem straightness	Survival rate
Total height	0.844***	0.824***	0.860***	0.042	0.577*
Pruned height		0.644***	0.703**	-0.119	0.416
Diameter at 1.30 m			0.989***	0.287	0.603*
Volume per tree				0.219	0.527*
Stem straightness					0.216

Notes: *p < 0.05; **p < 0.01; ***p < 0.001

Table 5. Pearson correlations of traits in Siminicea trial, 2021

Variable	Pruned height	DBH	Volume/tree	Stem straightness	Survival rate
Total height	0.793***	0.563*	0.881***	0.143	0.077
Pruned height		0.247	0.562*	0.263	-0.049
Diameter at 1.30 m			0.854*	0.056	-0.025
Volume per tree				0.104	0.142
Stem straightness					0.084

Notes: *p < 0.05; **p < 0.01; ***p < 0.001

In both trials, positive significant correlations were obtained between growth traits and pruned height. Also, in Bucova trial there are positive significant correlations between survival rate and total height, diameter at the breast height, and volume per tree, respectively (**Table 4**). In the Siminicea trial, no significant correlations were obtained between growth traits and survival (**Table 5**). No correlations have been obtained in the provenance trials between growth traits and stem straightness.

3.3 Provenance - environment interaction

At age 39, the analysis of variance across sites did not indicate a significant statistical influence of the provenance factor for the studied traits (**Table 6**). The site conditions strongly

influenced the variation of all studied traits. The interaction between provenance and site conditions was not significant for growth traits, wood quality, and survival rate.

Table 6. Analysis of variance for studied traits in the two provenance trials at age 39

Source of variation	s^2						
	D.F.	Volume/ tree	DBH	Total height	Pruned height	Stem straightness	Survival
Provenance (P)	7	0.011	4.909	1.828	2.780	0.079	178.330
Location (L)	1	0.556***	55.922***	277.152***	82.268**	1.245**	2341.512**
Interaction P x L	7	0.009	2.568	1.951	3.374	0.168	203.628
Error	32	0.009	3.611	4.340	6.006	0.109	172.190

4. DISCUSSION

The studied material included 16 European larch provenances, originating from three categories of genetic resources: natural populations, artificial stands, and seed orchards, which cover a large part of the geographical distribution of species in Central and Eastern Europe. A high level of genetic variability for growth traits, stem straightness, and survival rate at the provenance level was observed in each site. Across sites, the provenance factor was not significant and the environment factor had the greatest influence. These findings suggest that environmental conditions can exert a variety of impacts on European larch characteristics, particularly in the context of climate change. The lack of significance of provenance-environment interaction indicates high spatial stability in terms of growth and adaptive performance of the European larch provenances.

The best growth performances were recorded in Bucova trial located in the southwest of the country, in the European beech mountain layer at 650 m altitude, in a mild climate with Mediterranean influences. Siminicea trial is located in the Moldova Plateau (northeast of the country), in the sessile oak layer at 350 m altitude, in a continental climate. In the last 30 years, the Moldova Plateau was one of the most affected regions by climate change, in Romania. In this region, the mean annual temperature has increased by 1.02 °C in the last three decades [16] and the total annual precipitation is very low (594 mm), being below the vegetation optimum for *Quercus robur*. As opposed to Siminicea site conditions, at Bucova the mean annual temperature has increased by 0.45 °C in the last three decades and the total annual precipitation is around 1030 mm, being situated in optimal climatic conditions for European beech.

At age 39, in both trials, the highest volumes per tree were recorded by 2 seed orchards: 51 (Mihăeşti, Furnicoşi, seed orchard, Romania at Bucova trial) and 47 (Halle, seed orchard, Belgium at Siminicea trial). At the Bucova trial, volumes above mean on experiment have obtained also Berkel seed orchard from Germany, Hemeiuși seed orchard from Romania, 63-Zilina-Hradok and 64-Poprad from the Tatra Mountains, and the Romanian provenances 59-Sinaia (artificial stand) and 56-Baia de Criș (natural stand). At the Siminicea trial, the Romanian seed orchard (52-Hemeiuși) and natural populations are placed at the end of the ranking of growth traits. In this trial site, the highest wood production has obtained the following provenances: 59 (Sinaia, artificial stand) and 54 (Bicaz,

artificial stand) from Romania, and 45 (Haldensleben Oberforsterei Bischofswald) and 30 (Harbker, Hanau 11, seed orchard) from Germany.

Comparing the provenances ranking for the growth traits at this age with those previously obtained at age 25 [15] a high similarity could be seen for the Siminicea trial, while at the Bucova trial some changes in the provenances standing have occurred. Thus, if at the 25 years old all Romanian natural populations (except 61 - Sinaia) and seed orchards have been situated above the experimental mean, at present all natural populations (except 56 from Apuseni Mountains) have dropped below the mean. The seed orchards: 51-Furnicoşi and 53-Hemeiuşi from Romania and 32-Berkel from Germany, have maintained their position within ranking emphasizing a high growth and adaptive capacity.

Selection for the most productive provenances would bring significant genetic gains in timber production. Generally, fast-growing provenances have the highest mortality rates. Our results highlighted a positive significant correlation between growth traits and survival, in the Bucova trial. The provenances that combine both high wood production and survival rate are 53 (Hemeiuşi, seed orchard), 56 (Bicaz, natural stand), 59 (Sinaia, artificial stand) Romania; 63 (Zilina-Hradok, 650-m), Slovakia, and 32 (Berkel, seed orchard), Germany.

The good growth performances of the provenances 59-Sinaia and 54-Bicaz, artificial stands of unknown origin, could be explained by their non-local origin, most likely from the Tyrolean Alps [19,23]. Results from IUFRO experiments have demonstrated that the provenances from the south-eastern Alps had moderate growth and good adaptability [10,24]. The Romanian provenances have a lower growth compared to those from Central Europe but very good stem straightness.

5. CONCLUSIONS

Our findings indicate a large within-population genetic variation in European larch. Substantial genetic variability was also observed for the quantitative traits (volume per tree, diameter at breast height, total height, and pruned height) among the European larch provenances in each field trial. The environmental factor was also significant. Consequently, the response of this species to climate change will depend on the environmental conditions of the planting site and also on the provenance. Generally, the seed orchards have obtained the best growth, stem shape, and adaptability, which demonstrates the genetic improvement of this forest reproductive material, as result a of phenotypic selection at the population and plus trees level. However, the genetic composition of the seed orchards is important as the best growth and additive performances have been recorded by 51-Furnicoşi and 53-Hemeiuși, Romania; 32-Berkel and 30-Harbker, Germany, and 47-Halle, Belgium, respectively. Provenance trials represent forest genetic resources that can provide important information about the intraspecific genetic variation, the most valuable seed sources, and the adaptive genetic potential of species in the context of climate change. These genetic resources should be maintained and managed in a sustainable manner. Further efforts to conserve genetic resources of European larch should lead to an integrated conservation strategy, considering both *ex-situ* and *in-situ* approaches.

SUPPLEMENTARY MATERIALS

Not the case.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

APPENDIX

Not the case.

EXTENDED ABSTRACT – REZUMAT EXTINS

Titlu: *Variabilitatea genetică a laricelui (Larix decidua MILL.) în culturi de proveniențe instalate în România.*

Introducere: *Laricele are un areal discontinuu din estul Franței spre centrul și sudul - estul Italiei, munții din sudul, centrul și estul Europei. Alpii sunt cel mai mare habitat natural și continuu al laricelui. Se estimează că pădurile de larice european reprezintă aproximativ 4% din totalul pădurilor de conifere și mai puțin de 1% din totalul pădurilor din Europa. În Romania, laricele vegetează spontan în cinci centre montane Ceahlău, Ciucaş, Bucegi, Lotru și Apuseni. Laricele este o specie cu creștere rapidă, cu lemn de înaltă calitate și rezistență ridicată la poluarea aerului. Această specie are un nivel ridicat de variabilitate genetică pentru caracteristicile economice majore, fiind una dintre cele mai studiate specii din Europa. Laricele este o specie forestieră importantă în România, iar programul său de ameliorare genetică a început în anii 1960. Obiectivul principal al acestui program a fost de a îmbunătăți rezistența la factorii biotici și de mediu, și de a crește producția și calitatea lemnului. Cunoașterea variației genetice geografice a populațiilor de larice devine din ce în ce mai importantă în contextul schimbărilor climatice, pentru stabilirea unor strategii adecvate de conservare a resurselor genetice forestiere, pentru a îmbunătăți adaptabilitatea speciei la schimbările climatice și pentru a continua programul de ameliorare genetică în România. Obiectivele acestui studiu au fost de a evalua variabilitatea genetică la nivelul proveniențelor de larice testate în culturi experimentale, de a studia corelațiile dintre caractere și de a investiga interacțiunea genotip - mediu, cu scopul selecției celor mai bune proveniențe, în ceea ce privește caracterele de creștere, formă a fusului şi supraviețuirea, ca surse valoroase de germoplasmă pentru programele de reîmpădurire și ameliorare.*

***Materiale şi metode**: Materialul acestui studiu constă din 16 proveniențe de larice, 7 românești și 9 străine, din următoarele țări: Germania (3), Austria (2), Belgia (1) și Slovacia (3). Proveniențele 30, 31, 54, 55, 59, 62, 63, 65 sunt comune în ambele culturi. Materialul testat provine din plantaje de larice, arborete artificiale și arborete naturale. Culturile cu proveniențe de larice analizate în acest studiu au fost instalate în anul 1982, în două locații (Bucova și Siminicea), iar dispozitivul experimental este grilaj pătrat de tip 4 × 4 cu 3 repetiții. În fiecare cultură au fost măsurați 10 arbori (din categoria dominant sau codominant) pe parcela unitară, în fiecare dintre cele 3 repetiții. Măsurătorile în suprafețele experimentale au fost efectuate la vârsta de 39 de ani, iar metoda de evaluare în teren a constat în măsurători biometrice și observații cu privire la înălțimea totală, diametrul la 1.30 m, volumul mediu pe arbore, înălțimea elagată, forma fusului și supraviețuirea. Programele Excel și SPSS au fost utilizate pentru prelucrarea şi analiza statistică a datelor și a observațiilor din teren.*

***Rezultate şi discuții:** Analiza variației în fiecare loc de testare a evidențiat diferențe statistice semnificative între proveniențele de larice testate, în ceea ce privește caracterele analizate. Cele mai mari valori pentru diametrul la 1,30 m au fost obținute în cultura comparativă Bucova. În cultura Bucova, cele mai mari creșteri în diametru au înregistrat proveniențele : 51 - Furnicoşi (plantaj, România), 53 - Hemeiuși II (plantaj, România), 59 - Sinaia (arboret artificial, România) şi 32 - Berkel (plantaj, Germania). Cele mai mari valori pentru înălțimea totală au fost înregistrate, de asemenea, în cultura Bucova, iar în topul clasamentului au fost situate proveniențele : 32 - Berkel (plantaj, Germania), 51 - Furnicoşi (plantaj, Romania) și 59 - Sinaia (arboret artificial, Romania). În cultura comparativă Siminicea, proveniențele care au obținut cele mai mari valori ale înălțimii totale au fost : 47 - Halle (plantaj, Belgia), 30 - Harbker, Hanau (plantaj, Germania) și 45 - Haldensleben Oberforsterei Bischofswald (Germania). În cultura comparativă Bucova s-au înregistrat cele mai bune rezultate în ceea ce privește volumul mediu pe arbore, în topul clasamentului situându-se plantajul 51 - Furnicoși, România, în timp ce în cultura comparativă Siminicea în topul clasamentului se situează plantajul 47 - Halle, Belgia. De asemenea, în cultura comparativă Bucova s-au înregistrat cele mai mari înălțimi elagate, dar şi cele mai multe defecte de formă ale fusului. În ambele locuri de testare, cea mai bună formă a fusului o prezintă proveniențele din Romania și Austria. Cele mai mari procente de supraviețuire, la vârsta de 39 de ani de la plantare au fost înregistrate în cultura comparativă Siminicea (55%), iar cele mai reduse în cultura comparativă Bucova (41%). Proveniențele cu cea mai bună supraviețuire în ambele locuri de testare sunt: 54 - Bicaz și 59 - Sinaia (arborete artificiale). Corelații pozitive semnificative între caracterele de creștere şi supraviețuire au fost obținute doar în cultura comparativă Bucova. Interacțiunea proveniență - localitate a fost nesemnificativă pentru caracterele de creștere, de calitate a lemnului și supraviețuire, sugerând o stabilitate spațială mare a performanțelor proveniențelor de larice. Analiza multifactorială a variației, evidențiază o influență mai mare a condițiilor staționale comparativ cu factorul proveniență pentru caracterele studiate.*

***Concluzii:** Rezultatele acestui studiu indică o variabilitate genetică ridicată la nivelul proveniențelor de larice în ambele culturi comparative. Performanțele proveniențelor de larice sunt influențate, în primul rând, de condițiile staționale ale locului de testare. Cele mai bune performanțe de creștere au fost obținute în cultura comparativă Bucova, situată în etajul făgetelor montane, într-un climat mai blând cu influențe mediteraneene. În general, plantajele au obținut cea mai bună creștere, formă a fusului și adaptabilitate, fapt care dovedește superioritatea materialului obținut prin ameliorare, ca urmare a selecției fenotipice la nivel de populații și arbori plus. Cu toate acestea, compoziția genetică a plantajelor contează, prin urmare, cele mai bune performanțe de creștere şi adaptare au înregistrat plantajele: 51-Furnicoşi şi 53-Hemeiusi, România, 32-Berkel și 30-Harbker, Germania și 47-Halle, Belgia.*

***Cuvinte cheie:** larice, variabilitate genetică, resurse genetice forestiere, provenanțe, corelații fenotipice.*

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