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CORRELATIONS BETWEEN THE GERMINATION CAPACITY AND SELECTED ATTRIBUTES OF EUROPEAN LARCH SEEDS (*LARIX DECIDUA* MILL.)

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K e y w o r d s: European larch seeds, separation properties, germination.

A b s t r a c t

The critical transport velocity, basic dimensions (thickness, width and length), the angle of sliding friction and weight of European larch seeds from three batches were determined. The values of shape factors, cross-sectional area, volume and density were calculated for all seeds. The seeds were germinated, and germination time was determined. The investigated attributes were compared by single classification analysis of variance and correlation analysis. The germination capacity of seeds from the same stand varied between harvest years, and germination time was most highly correlated with critical transport velocity and density. The lightest seeds should be separated from the batch to improve germination capacity, and seeds of the heaviest fractions should be used to promote even germination.

Symbols:

F – seed cross-sectional area, mm^2,
m – seed weight, mg,
S – standard deviation of trait,
T, W, L – seeds thickness, width and length, mm,
T_n – time required to produce a healthy germ, day,
T_o – time of germination test, day
W_k – germination time,
v – critical transport velocity of seeds, m · s^{-1},
V – seed volume, mm^3,
V_s – coefficient of trait variability, %,
x, $x_{\max}$, $x_{\min}$ – average, maximum and minimum value of trait,
α, β – Donev's shape factors,
γ – angle of sliding friction, °,
ε_k – germination capacity, %,
ε_w – separation efficiency of non-germinating seeds, %,
ρ – seed density, g · cm^{-3}.

Introduction

The European larch (*Larix decidua* Mill.) is a tree that reaches 50 m in height and 200 cm in diameter at breast height (BHD). The species, which thrives in sunny and wind-shielded habitats, is tolerant of cold and vast temperature fluctuations and shows a preference for open spaces. The European larch avoids dry habitats, and it grows best on deep and medium-compact soils (JAWORSKI 2011, JOHNSON, MORE 2011, MURAT 2002, PIRC 2006). In Poland, larch trees do not form dense stands that cover extensive areas, and they are mostly encountered in the form of clusters (FONDER et al. 2007).

European larch seeds can be harvested when trees growing in open spaces reach 15 years of age. Dense stands begin to produce seeds when they are 30 years old. Large quantities of seeds are produced every 2–3 years. Cones are harvested between November and February before they open and release seeds (*Nasiennictwo*... 1995, MURAT 2002). In the natural habitat, seeds fall out of the cone due to the continuous bending and flexing of the scales. In extraction plants, seeds are removed from cones by a combination of mechanical and thermal extraction methods (*Nasiennictwo*... 1995, TYLEK 2004). Mechanical extraction devices dewing seeds, but they also grind and crush cone scales. As the result, the separation of seeds from impurities is more problematic than in thermal extraction systems. The processed material often contains many empty seeds which cannot be separated with the involvement of conventional cleaning machines (pneumatic separators, mesh sieves) (*Nasiennictwo*... 1995, MURAT 2002). Liquid-based cleaning methods, such as PRE-VAC (LESSTANDER, BERGSTEN 1985) and IDS (DEMELASH et al. 2002, 2003, PASQUINI et al. 2008, POULSEN 1995), are more effective in removing impurities from seed lots.

Only seeds of the highest quality should be used for the generative reproduction of trees (JANSON, ZAŁĘSKI 1998). Their germination capacity is determined by a variety of factors, including habitat type, soil class, geographic location, weather conditions during cone and seed development, incidence of diseases and pests that affect cones and seeds, the genetic traits of tree stands and the position of cones within the tree crown (BODYŁ et al. 2007, KLUCZYŃSKI 1992, *Nasiennictwo*... 1995, SKRZYPCZYŃSKA, KOZIOŁ 2001). Seed quality can deteriorate due to improper methods of harvesting, storage and sowing pre-treatment (ANIŚKO et al. 2006, BODYŁ et al. 2007, JANSON, ZAŁĘSKI 1995, *Nasiennictwo*... 1995, TYLEK 2010). The minimum germination capacity of certified reproductive material varies between species. Due to a high number of empty seeds, the reproductive material of the European larch should be characterized by minimum 10% germination capacity (*Nasiennictwo*... 1995, PN-R-65700:1998). According to the above standard, prime quality seeds have germination capacity higher than 41% and minimum germination energy of 31%.

There is a general scarcity of information about correlations between the physical attributes and germination capacity of European larch seeds. The relevant data could be of key significance for designing seed cleaning and sorting processes. At present, the parameters of seed cleaning and separating machines are selected intuitively based on the results of several cleaning trials (SARNOWSKA, WIĘSIK 1998).

The objective of this study was to determine correlations between the basic physical attributes (critical transport velocity, dimensions, the angle of sliding friction, weight, shape factors, cross-sectional area, volume and density) and germination capacity of European larch seeds to eliminate poor-quality seeds from the material and promote even germination.

Materials and Methods

The experimental material comprised three batches of European larch from a seed extraction plant in Ruciane-Nida. The analyzed batches were harvested from the following tree stands:

a) registration number – MP/2/30945/05, municipality – Kowale Oleckie, region of provenance – 202, forest habitat – fresh forest, age – 130 years, year of cone harvest – 2007 (symbol – M1-07),

b) registration number – MP/2/30988/05, municipality – Ruciane Nida, region of provenance – 206, forest habitat – fresh mixed forest, age – unknown, year of cone harvest – 2007 (symbol – M2-07),

c) registration number – MP/2/30988/05, municipality – Ruciane Nida, region of provenance – 206, forest habitat – fresh mixed forest, age – unknown, year of cone harvest – 2008 (symbol – M2-08).

The analyzed material was divided by halving (*Nasiennictwo...* 1995), to obtain samples of slightly above 100 seeds each. The selected method produced samples of size: M1-07 – 119, M2-07 – 124, M2-08 – 122.

The critical transport velocity, basic dimensions (thickness, width and length), the angle of sliding friction and weight of the studied seeds were determined in accordance with the methodology described by KALINIEWICZ et al. (2011, 2012a). The following laboratory devices were used: Petkus K-293 pneumatic classifier, MWM 2325 workshop microscope, an apparatus for measuring seed thickness, an inclined plate with angle control and WAA 100/C/2 laboratory scales.

Donev's shape factors (DONEV et al. 2004) were applied to determine the shape of the studied seeds. The axis of rotation and seed length overlapped, therefore, Donev's shape factors took on the following form:

$$\alpha = \frac{L}{T} \tag{1}$$

$$\beta = \frac{W}{T} \tag{2}$$

It was assumed that the cross-sectional shape of European larch seeds resembled an ellipsoid. Thus, the cross-sectional area of individual seeds was calculated using the below formula:

$$F = \frac{\pi \cdot W \cdot T}{4} \tag{3}$$

Seed volume was calculated from an experimentally derived correlation with the use of a pycnometer (KALINIEWICZ et al. 2012b):

$$V = 0.420 \cdot L \cdot W \cdot T \tag{4}$$

Seed density ρ was calculated from the formula:

$$\rho = \frac{m}{V} \tag{5}$$

To determine germination capacity, the seeds were placed on moistened filter paper in a glass tank covered with a glass pane. The experiment was carried out at the recommended temperature of 20 to 30°C under exposure to natural light. Evaporated water was supplemented daily with a sprinkler, and filter paper was kept moist. Germination progress was evaluated daily between 8 to 9 a.m. Germinated seeds were classified as seeds that produced a sprout with a minimum length of 3/4 of seed length (*Nasiennictwo*... 1995). Observations were continued for 26 days until all seeds had germinated. The germination process was completed when the analyzed seeds ceased to produce new, correctly formed sprouts over a period of five successive days.

Germination time W_k was determined with the use of the below equation:

$$W_k = \frac{T_o - T_n}{T_o} \tag{6}$$

Germination time was the time required by the last germinated seed to produce a healthy sprout plus one day. In this experiment, germination time was 21 days.

Non-germinated seeds were eliminated from the analyzed seed lots to improve germination efficiency on the assumption that live seed loss would not exceed 5%. Germination capacity ε_k was calculated as the number of germinated seeds in a given analytical period in the total number of seeds in the sample.

Separation efficiency of non-germinating seeds ε_w was determined as the number of non-viable seeds separated according to a selected physical attribute in the total number of non-germinating seeds in the sample.

The obtained results were processed statistically using Winstat and Statistica Pl ver. 10 software. The level of significance was $\alpha = 0.05$. The following methods were used:

– analysis of variance with Snedecor's F distribution (single classification), to compare the mean values of the analyzed traits for different batches of European larch seeds. In case of statistically significant differences, homogeneous subsets were determined by Duncan's test (GAWĘCKI, WAGNER 1984, GREŃ 1984);

– correlation analysis, to determine correlations between germination time and the physical attributes of European larch seeds, based on the coefficients of Pearson's linear correlation.

Results and Discussion

The measured traits and the coefficients calculated for the analyzed material are presented in Table 1. The highest values of the coefficient of variation in physical traits were noted for seed weight (from 26.4% to 30.3%). The value of the coefficient of variation for the remaining attributes was reported in the range of around 9.3% to 20.2%, which is consistent with the observations made by other authors (CZERNIK 1983a, TYLEK 1998, 1999, 2004). Critical transport velocity ranged from 4.7 to 8.0 $m \cdot s^{-1}$, with an average of 6.0 $m \cdot s^{-1}$. The above results are somewhat higher than the data reported by TYLEK (1999, 2004) and CZERNIK (1983b), and this discrepancy could be attributed to differences in seed origin. The seeds harvested in the Regions of Mazury and Podlasie are larger and, consequently, heavier, than those from southern parts of Poland. The analyzed seeds had the following dimensions: thickness – 1.41÷1.56 mm, width – 2.60÷2.69 mm and length – 4.39÷4.53 mm, and they were plumper than the material investigated by other authors CZERNIK 1983a, *Nasiennictwo leśnych drzew...* 1995, TYLEK 1998, 2004). The weight of the studied seeds ranged from 2.2 to 12.3 mg.

Table 1

Statistical distribution of the physical attributes of European larch seeds

Batch of seeds	Attribute/indicator	x_{min}	x_{max}	x	S	V_s
M1-07	v	4.675	7.425	5.96^b	0.614	10.29
	T	1.10	1.84	1.45^b	0.135	9.35
	W	1.82	3.27	2.63^a	0.330	12.55
	L	2.86	5.75	4.51^a	0.601	13.35
	γ	21	63	39.6^a	7.988	20.15
	m	2.4	12.3	6.2^b	1.627	26.42
	α	2.228	4.315	3.119^a	0.399	12.78
	β	1.255	2.346	1.817^a	0.206	11.34
	F	1.766	4.465	3.006^b	0.570	18.95
	V	2.702	12.776	7.362^b	2.145	29.14
	ρ	0.510	1.119	0.854^a	0.131	15.32
	W_k	0	0.714	0.279^a	0.239	85.88
M2-07	v	4.675	6.875	5.92^b	0.610	10.30
	T	0.98	1.83	1.41^c	0.163	11.55
	W	1.83	3.38	2.60^a	0.340	13.09
	L	2.81	5.85	4.39^a	0.584	13.31
	γ	28	64	39.1^a	6.351	16.23
	m	2.2	9.8	5.8^b	1.773	30.32
	α	2.153	3.953	3.118^a	0.333	10.68
	β	1.254	2.467	1.855^a	0.211	11.35
	F	1.553	4.513	2.912^b	0.615	21.11
	V	2.389	11.990	6.963b	2.139	30.71
	ρ	0.584	1.129	0.849^a	0.127	14.96
	W_k	0	0.667	0.247^a	0.231	93.42
M2-08	v	4.675	7.975	6.24^a	0.594	9.52
	T	1.20	1.98	1.56^a	0.145	9.29
	W	1.75	3.48	2.69^a	0.356	13.21
	L	3.32	6.17	4.53^a	0.538	11.88
	γ	29	55	38.3^a	5.288	13.81
	m	3.0	11.5	6.8^a	1.832	27.08
	α	2.344	3.757	2.911^b	0.322	11.08
	β	1.151	2.245	1.733^b	0.230	13.27
	F	2.016	5.023	3.315^a	0.616	18.57
	V	3.579	14.632	8.138^a	2.243	27.56
	ρ	0.514	1.142	0.843^a	0.135	15.98
	W_k	0	0.714	0.203^b	0.256	126.08

$^{a, b, c}$ – different letters in the superscript indicate significant differences at a level of 0.05
Source: own calculations

Shape factors α and β were characterized by the smallest variation, and germination time W_k – by the highest variation. Owing to their large size, the cross-sectional area and volume of the analyzed seeds were also somewhat higher than the values reported by CZERNIK (1983a) and TYLEK (1998, 2004).

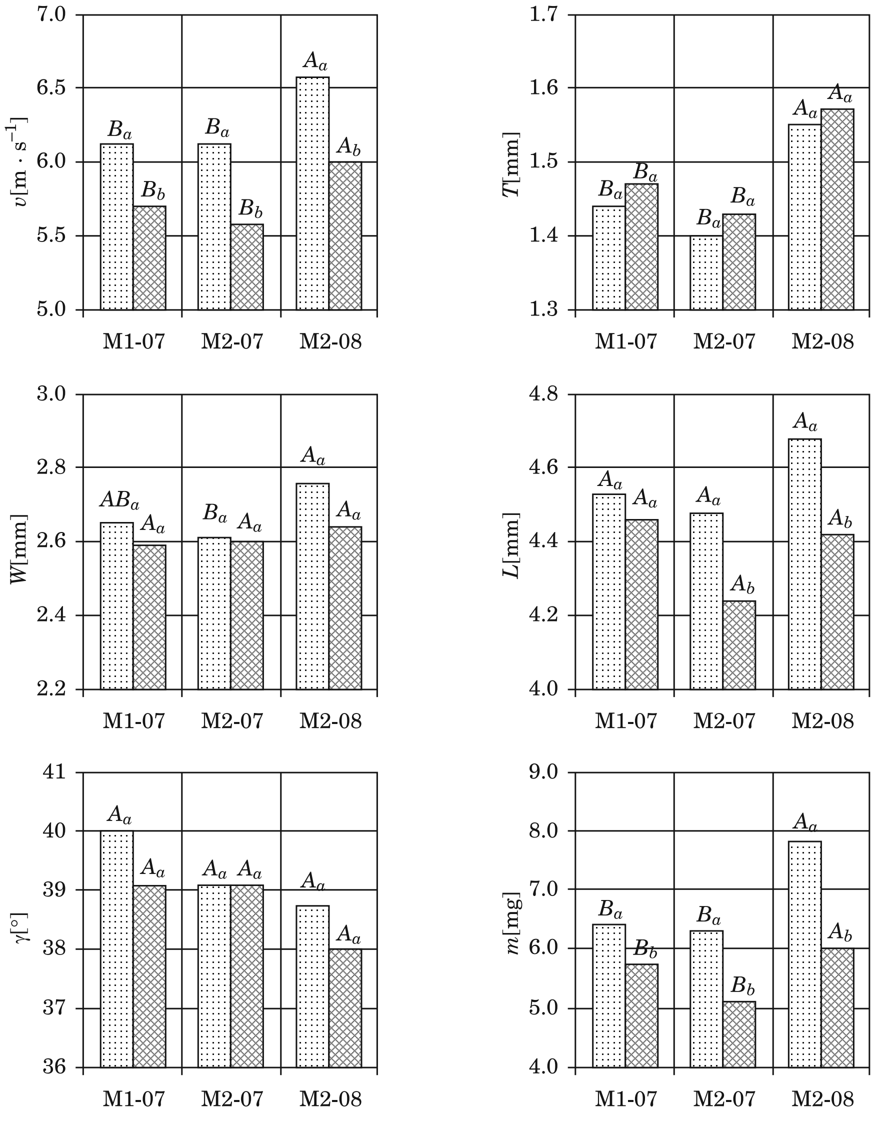
The results of a single classification analysis of variance revealed an absence of significant differences in the width, length, angle of sliding friction and density of European larch seeds. Seed lots harvested in the same year

(M1-07 and M2-07) differed significantly only with regard to seed thickness. Seeds collected from the same tree stand in successive years (M2-07 and M2-08) showed significant variations in critical transport velocity, thickness, weight, shape factors, cross-sectional area, volume and germination time. In general, seeds harvested in 2008 were thicker and heavier than the material obtained in 2007, and the above contributed to an increase in their critical transport velocity.

A comparison of the physical traits of germinated and non-germinated European larch seeds is presented in Figure 1. The analyzed groups significantly differed with regard to critical transport velocity, weight and density. Seeds harvested from the same stand varied in length, and those collected in 2008 had different shape factors. Some of the non-germinated seeds were empty, and their basic parameters, cross-sectional area, volume and springiness values differed from full seeds (TYLEK 2004). No significant differences were observed between the lots of germinated seeds harvested in 2007, but those batches differed from the material collected in 2008 with regard to critical transport velocity, thickness, weight, shape coefficients, cross-sectional area and volume. A comparison of non-germinated seeds did not reveal significant differences in their average width, length, volume or density.

During the experimental period, the following number of seeds produced healthy sprouts: M1-07 – 75, M2-07 – 75 and M2-08 – 51. The germination capacity of the analyzed batches reached 63.0%, 60.5% and 41.8%, respectively, indicating that the studied material falls into the premium quality category. The germination efficiency of seeds harvested from a given stand varied between years. Meteorological conditions during the formation and development of cones significantly affect the quality of harvested seeds (*Nasiennictwo...* 1995). Seeds harvested in various parts of the Regions of Warmia and Podlasie during the same year had similar germination capacity. Although they had been stored for one year less than the remaining batches, the seeds harvested in 2008 were characterized by significantly lower germination capacity.

Due to the noted differences in selected attributes of germinating and non-germinating seeds, non-viable seeds were separated to improve the germinating capacity of the batch. The effects of separating non-germinating seeds according to the lower limit of classification are shown in Table 2. The highest separation efficiency was obtained when critical transport velocity and density were used as the separation traits. Our observations are consistent with the results reported by TYLEK (2004). The use of a vertical air stream and the selection of cleaning parameters which promoted the separation of lightest seeds produced the best results. Germination capacity increased to 72.4% in M1-07, 74% in M2-07 and 56.5% in M2-08 when 17.6%, 22.6% and 30.3% of the



7.0
6.5
6.0
5.5
5.0
v[m · s−1]
Ba
Bb
Ba
Bb
Aa
Ab
1.7
1.6
1.5
1.4
1.3
T[mm]
Ba
Ba
Ba
Ba
Aa
Aa
3.0
2.8
2.6
2.4
2.2
W[mm]
ABa
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4.2
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41
40
39
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γ[°]
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M1-07
M2-07
M2-08

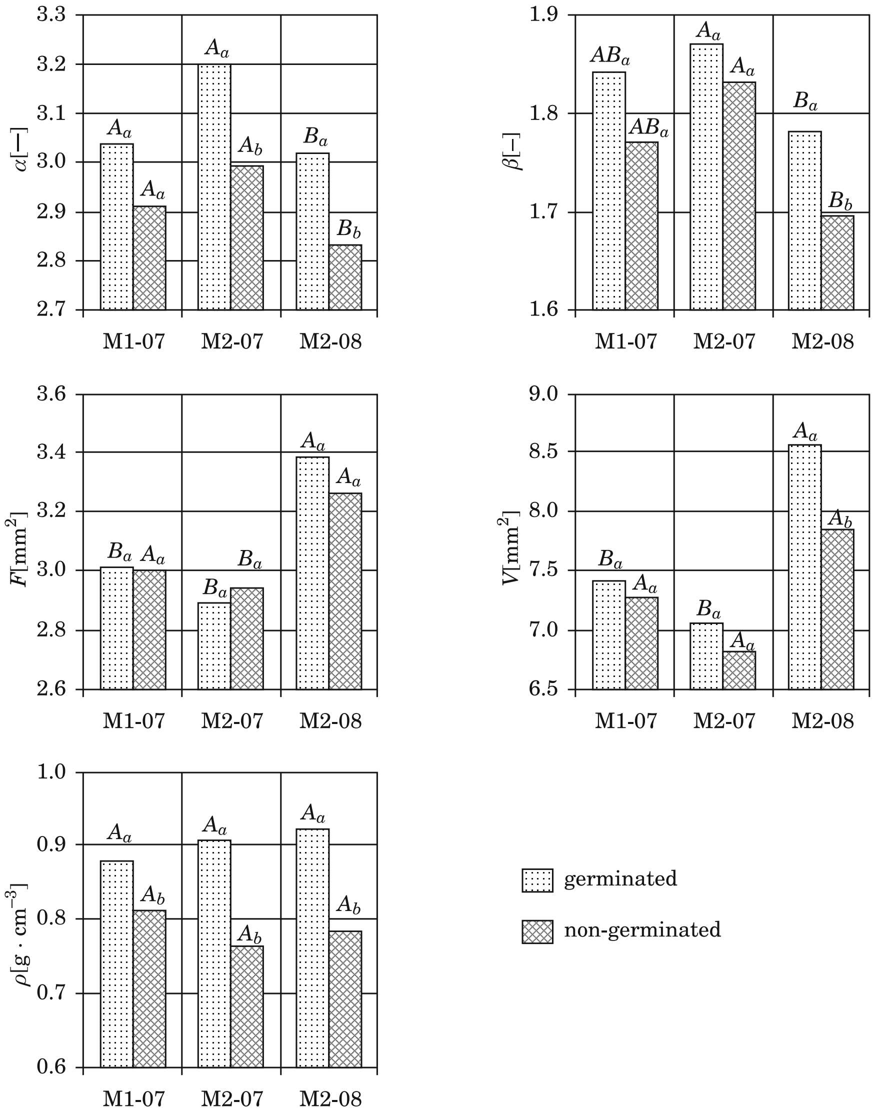

Fig. 1. Significance of differences (at a level of 0.05) between the attributes of European larch seeds: *A*, *B* – different letters indicate significant differences between different seed batches; *a*, *b* – different letters in the superscript indicate significant differences between germinated and non-germinated seeds

Source: own study

Table 2

Separation efficiency ε_w of non-germinating seeds and germination capacity ε_k of European larch seeds according to the adopted limit of classification in the separation process

Batch of seeds	Limit of classification	ε_w [%]	ε_k [%]
M1-07 (ε_k = 63.0%)	v = 5.1 m · s^{-1}	38.6	72.4
	T = 1.65 mm	11.4	64.6
	W = 2.18 mm	18.2	66.4
	L = 3.60 mm	9.1	64.0
	γ = 30°	18.2	66.4
	m = 3.9 mg	11.4	64.5
	ρ = 0.68	22.7	67.6
M2-07 (ε_k = 60.5%)	v = 5.1 m · s^{-1}	49.0	74.0
	T = 1.62 mm	16.3	63.4
	W = 2.12 mm	8.2	61.2
	L = 3.60 mm	8.2	61.2
	γ = 30°	6.1	60.7
	m = 3.8 mg	24.5	65.7
	ρ = 0.73	46.9	73.2
M2-08 (ε_k = 41.8%)	v = 5.6 m · s^{-1}	47.9	56.5
	T = 1.76 mm	11.3	43.2
	W = 2.25 mm	16.9	44.9
	L = 4.03 mm	25.4	47.5
	γ = 31°	8.5	42.5
	M = 5.5 mg	40.8	53.3
	ρ = 0.77	52.1	58.5

Source: own calculations

Table 3

Coefficients of Pearson's linear correlation between germination time and other attributes of European larch seeds from three batches

Variables		Coefficients of correlation calculated for:		
X	Y	M1-07[1]	M2-07[2]	M2-08[3]
W_k	v	0.349	0.427	0.505
	T	-0.106	-0.113	-0.045
	W	0.033	0.002	0.171
	L	0.004	0.153	0.221
	γ	0.102	0.033	0.041
	m	0.167	0.274	0.476
	α	0.050	0.284	0.268
	β	0.107	0.101	0.187
	F	-0.038	-0.067	0.100
	V	-0.020	0.022	0.151
	ρ	0.281	0.507	0.502

Critical value of the correlation coefficient: [1] – 0.180; [2] – 0.176; [3] – 0.178

Source: own calculations

seeds were discarded, respectively. The above process efficiently separates around 40% of non-viable seeds. Density can also be used as a separation trait, but due to the complexity of the process (solution density has to be adjusted precisely to the batch of floated seeds) and the need to dry the seeds, it is not recommended.

An analysis of the linear correlation between germination time and the remaining attributes of European larch seeds (Table 3) indicates that the critical value of the correlation coefficient for all three seed batches was exceeded only for critical transport velocity and density. The above results suggests that in order to produce a more evenly distributed germination pattern, a pneumatic separator, a liquid separator or a pneumatic vibratory table should be used to split the material into fractions.

Table 4 shows the germinating capacity of three potential seed fractions separated by a vertical stream of air to eliminate non-germinating seeds according to the lower limit of classification. According to the presented data, the sorting of seeds based on their critical transport velocity can narrow down sprouting times. The above particularly applies to seeds characterized by the

Table 4

Effect of germination time on the percentage of three fractions of European larch seeds (sorted by critical transport velocity)

Batch of seeds	Range W_k	Percentage of seeds [%]			
		total	division into fractions		
			$v < 6.0$ m · s^{-1}	$v = 6.0 \div 6.5$ m · s^{-1}	$v > 6.5$ m · s^{-1}
M1-07	0.001÷0.100	1.0	1.0	0	0
	0.101÷0.200	3.0	1.0	1.0	1.0
	0.201÷0.300	2.0	1.0	1.0	0
	0.301÷0.400	15.3	5.1	9.2	1.0
	0.401÷0.500	30.8	9.2 (25.8)	14.3 (28.0)	7.3 (54.9)
	0.501÷0.600	8.2	2.1	5.1	1.0
	0.601÷0.700	11.2	4.1	6.1	1.0
	0.701÷0.800	1.0	0	1.0	0
	0*	27.5	12.2 (34.2)	13.3 (26.1)	2.0 (15.0)
M2-07	0.001÷0.100	2.0	1.0	1.0	0
	0.101÷0.200	8.3	2.1	3.1	3.1
	0.201÷0.300	3.1	0	3.1	0
	0.301÷0.400	16.8	6.3	8.3 (18.1)	2.2
	0.401÷0.500	27.2	12.5 (33.3)	5.3	9.4 (56.3)
	0.501÷0.600	8.3	0	7.3	1.0
	0.601÷0.700	8.3	3.1	5.2	0
	0.701÷0.800	0	0	0	0
	0*	26.0	12.5 (33.3)	12.5 (27.3)	1.0 (6.0)
M2-08	0.001÷0.100	1.2	0	0	1.2
	0.101÷0.200	1.2	0	1.2	0
	0.201÷0.300	0	0	0	0
	0.301÷0.400	7.1	3.5 (29.7)	2.4	1.2
	0.401÷0.500	22.4	2.4	8.2 (16.6)	11.8 (30.4)
	0.501÷0.600	13.0	0	2.4	10.6 (27.3)
	0.601÷0.700	7.0	1.2	3.4	2.4
	0.701÷0.800	4.6	0	1.2	3.4
	0*	43.5	4.7 (39.8)	30.6 (61.9)	8.2 (21.1)

* Seeds that did not germinate over the experimental period

Source: own calculations

highest critical transport velocity (at $v > 6.5\ \mathrm{m \cdot s^{-1}}$). The share of seeds from the most populous germination time interval reached 54.9%, 56.3% and 30.4% in each fraction. Non-viable seeds had a significantly smaller share (15.0%, 6.0% and 21.1%, respectively), implying that this material could be used in container nurseries where only prime quality seeds are sown. Similar results were reported in a study of Norway spruce seeds (KALINIEWICZ et al. 2012a).

The germination capacity of three potential seed fractions separated based on density values is presented in Table 5. As before, non-germinating seeds were eliminated according to density classification limits indicated in Table 2. In this case, the germination interval was also narrowed down for the last fraction ($\rho > 0.95\ \mathrm{g \cdot cm^{-3}}$). The share of seeds from the most abundant

Table 5
Effect of germination time on the percentage of three fractions of European larch seeds (sorted by density)

Batch of seeds	Range W_k	Percentage of seeds [%]			
		total	after division into fractions		
			ρ<0.85 g · cm^{-3}	ρ=0.85÷0.95 g · cm^{-3}	ρ>0.95 g · cm^{-3}
M1-07	0.001÷0.100	1.0	1.0	0	0
	0.101÷0.200	2.9	2.9	0	0
	0.201÷0.300	2.0	1.0	0	1.0
	0.301÷0.400	14.1	4.7	3.7	5.7
	0.401÷0.500	28.6	10.5 (23.4)	7.6 (31.9)	10.5 (33.4)
	0.501÷0.600	7.7	2.9	2.9	1.9
	0.601÷0.700	10.4	4.7	2.9	2.8
	0.701÷0.800	1.0	0	0	1.0
	0*	32.3	17.1 (38.2)	6.7 (28.2)	8.5 (27.1)
M2-07	0.001÷0.100	3.1	2.1	1.0	0
	0.101÷0.200	8.3	1.0	2.1	5.2
	0.201÷0.300	3.0	1.0	1.0	1.0
	0.301÷0.400	16.5	3.1	8.2	5.2
	0.401÷0.500	25.7	4.1 (12.1)	10.3 (30.3)	11.3 (35.3)
	0.501÷0.600	8.3	2.1	5.2	1.0
	0.601÷0.700	8.3	3.1	3.1	2.1
	0.701÷0.800	0	0	0	0
	0*	26.8	17.5 (51.5)	3.1 (9.1)	6.2 (19.4)
M2-08	0.001÷0.100	1.2	0	0	1.2
	0.101÷0.200	2.4	1.2	1.2	0
	0.201÷0.300	0	0	0	0
	0.301÷0.400	7.4	2.5	3.7	1.2
	0.401÷0.500	23.2	4.9 (16.7)	7.3 (17.6)	11.0 (37.7)
	0.501÷0.600	12.1	1.2	4.8	6.1
	0.601÷0.700	7.3	1.2	3.7	2.4
	0.701÷0.800	4.9	1.2	3.7	0
	0*	41.5	17.1 (58.4)	17.1 (41.2)	7.3 (25.0)

* Seeds that did not germinate over the experimental period
Source: own calculations

germination time interval was around 35% in a given fraction. The material characterized by the highest density had a smaller share of non-viable seeds than the entire batch, therefore it could be successfully used in container nurseries.

The combination of pre-treatment cleaning based on a selected separation trait (e.g. critical transport velocity) and seed sorting based on another attribute (e.g. density) did not significantly improve the quality of the resulting material, which is why the results of the above analyses are not presented in this paper.

Conclusions

1. The germinating capacity of European larch seeds ranged from 42% to 63% which qualifies the studied material for the prime quality group. Germinating capacity is largely affected by the year of cone harvesting and the prevalent weather conditions during the formation and development of seeds.

2. Germinating seeds and non-viable seeds differed most significantly with regard to their critical transport velocity, weight and density. In order to improve seed quality, pneumatic and hydraulic separators or pneumatic vibratory tables should be used to eliminate the lightest fraction from seed material. Separation efficiency reaches around 40%, and it increases germination capacity to 56-74%.

3. The germination capacity of European larch seeds can be improved and more evenly distributed germination patterns can be obtained by fractioning seeds. This can be achieved with the use of the above cleaning machines. The heaviest seeds (with the highest critical transport velocity and density) should be used for sowing.

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