Seasonal fluctuation in germination of short and long-term stored Norway spruce (*Picea abies* [L.] Karst.) seeds

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ABSTRACT: Routine laboratory testing is done throughout the year to determine the quality of forest seeds. This raises the question of how the results are affected by possible seasonal effects on germination energy and germination capacity of seeds. To answer this question, fluctuations in germination energy (GE) and germination capacity (GC) of Norway spruce (*Picea abies* [L.] Karst.) seed was determined throughout the year. The test seeds had been stored for either a short time (2 months and 1 year) or a long time (12 and 13 years). Seed testing was done according to ISTA rules two times (in the first year T1 and the second year T2) in each month during a year. Ten seed lots from five Norway spruce seed zones in Slovakia were used for each treatment. Obtained data were processed by analysis of covariance (independent factors – T and months, covariate – altitude of seed origin). The monthly germination indicators were compared to annual average (using absolute differences and relative seasonal indexes). The results showed that GE and GC of short-term stored seeds were 59% and 92%, and 35% and 81% for long-term stored seeds. Compared to the annual average, the monthly germination indicators fluctuated very differently: for GE three times more than for GC, for long-term stored seeds 2–3 times more than for short-term stored seeds. For GE, significant deviations were found in six months during a year (in the range 11–23%), for both variants of seed storage. In contrast, for GC values such deviations were confirmed only for short-term stored seeds in February and March, but the differences (–2%) were very small and can be neglected. For use in forestry practice, three methods that eliminate existing seasonal fluctuations are proposed. Seasonal indexes seem promising since they enable converting the observed germination indicators at any one time to a value characterising the entire year average (formula 3).

Keywords: *Picea abies* [L.] Karst.; short-term stored seed; long-term stored seed; germination energy; germination capacity; seasonal fluctuation

Laboratory test of seed germination includes the emergence and development of the seedling to a stage where the aspect of its essential structures indicates whether or not it is able to develop further into a satisfactory plant under favourable conditions in soil (International Rules for Seed Testing 2006). Standardised tests of germination are used during whole year. However, on seeds of some coniferous tree species (Scots pine, Norway spruce, European larch), which were not dormant, considerable fluctuation of the values of laboratory germination capacity and germination energy during a year was observed by several authors (Schmidt 1930; Baldwin 1935; Mamonov et al. 1986; Barnett, Mamonov 1989). This phenomenon was called seasonal periodicity or biorhythm of seeds (Barnett, Mamonov 1989).

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While some authors (Repina 1974; Smurova 1969) confirmed seasonal periodicity of germination capacity; others are of opposite opinion based on their own studies (Rostovcev et al. 1975). In addition, the opinions concerning the occurence of seasonal periodicity of fresh seed and stored seed are not unanimous. A group of authors (Mamonov et al. 1986) deduced a conclusion from their own works that in the assessment of the quality of fresh seed, the fact of the occurrence of endogenous biorhythm need not be taken into consideration. However, in the assessment of the quality of the seed stored for a long period, it is necessary to carry out analyses during the period of increased physiological activity of seeds, otherwise the results of the quality tests may be inconclusive. Schmidt (1930), on the contrary, states that the fresher is the available seed the greater is its sensitivity to favourable periods of the year. Procházková (2002) in her experiments with 2-years stored seed of Norway spruce found a significant decrease of germination energy during the summer months (differences in comparison to other months were about 5–15% by chilled seeds and 20–30% by non-chilled seeds), but the germination capacity fluctuated during a year only randomly.

This issue is of great importance mainly in qualitative analyses of seeds. With regard to the given phenomenon of seed biorhythm, germination testing during whole year may be quite questionable.

Accredited ISTA Laboratory in Liptovský Hrádok carries out testing of the seed of coniferous tree species, mainly from autumn until late spring. In the time of the greatest crop, when the seed is under processing until the spring, testing of fresh seed lots is carried out also in summer. The aim of this study is to test the fluctuation in germination energy and germination capacity of the seed of Norway spruce *(Picea abies* [L.] Karst.) during a year and to compare the results separately for the seed stored for a short-term and for a long-term period.

MATERIALS AND METHODS

In the experiment, 10 short-term (2 months and 1 year) stored seed lots of Norway spruce and 10 seed lots of the same tree species stored for a long period (12 and 13 years) were used. The seed originated from five seed zones in Slovakia and from altitudes ranging between 500 and 1,500 m a.s.l. The short-term as well as long-term stored seed was put into airtight closed tins at temperature 3°C prior to storing. Its water content ranged from 9.4% to 10%. From each lot, random samples of 4 × 100 seeds were chosen and stored wrapped in 2-layer food-industry foil at temperature of 3°C. The experiment lasted 2 years. During this time, germination tests were carried out with the samples. They started on the 12th day of each month; they were performed at alternating temperatures (30/20°C–8/16 hours), in accordance with ISTA Rules (2006). After 21 days all seeds were cut and classified as dead, fresh and empty seeds. The results were the values of germination energy (GE) and germination capacity (GC) in individual months (M = 1, 2, 3 … 12), in total 10 for short-term (S) and long-term stored seed (L) and for testing in the first (T1) and in the second (T2) year of the experiment. In total, 10 × 2 × 2 × 12 = 480 samples of seed were processed. An example of one data series for germination capacity (GC), short-term stored seed (S) and the first year of testing (T1) is given in Fig. 1. This figure shows that individual seed lots have distinct germination capacity, which is kept at a relatively same level during the year, while in some months (February, December) systematic negative deviations from the annual trend are observed for the majority of seed lots.

The obtained dataset was processed and evaluated by mathematical-statistical methods (Statistica 6.0; Meloun, Militký 1994; Šmelko 1998). There were calculated basic statistical characteristics of both studied parameters (GE, GC) for each experimental variant (S, L, T1, T2): their mean values, variability and shape of distribution. The preliminary analyses

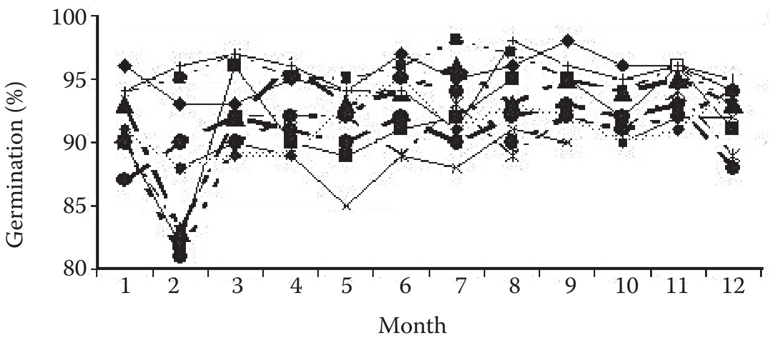

Fig. 1. Example of 10 time series of the germination capacity of fresh seed (S) in the first year of testing (T1)

Table 1. Statistical characteristics of GE and GC of analysed samples of short-term stored seed (S) and long-term stored seed (L) in the first year (T1) and the second year of testing (T2)

Variant	N	Germination energy (GE %)					Germination capacity (GC %)				
		$\bar{Y}$	s_y	s_y%	A	E	$\bar{Y}$	s_y	s_y%	A	E
S, T1	120	62.8	16.2	25.8	–0.48	–0.70	92.4	3.2	3.5	–0.75	1.06
S, T2	120	56.2	16.6	29.5	–0.44	–0.22	92.4	3.0	3.2	–0.74	1.09
S, T1 + 2	240	59.5	17.3	29.1	–0.40	–0.46	92.4	3.1	3.3	–0.77	1.02
L, T1	120	36.4	20.7	56.9	0.07	–1.09	81.9	7.1	8.7	–0.59	–0.28
L, T2	120	33.5	19.3	57.6	0.41	–0.73	79.3	9.4	11.8	–0.62	–0.36
L, T1 + 2	240	34.6	20.1	58.1	0.24	–0.97	80.6	8.5	10.5	–0.66	–0.33

N – number of samples, $\bar{Y}$ – average, s_y – standard deviation, s_y% – variation coefficient, A – skewness, E – kurtosis

showed unambiguous differences between short-term and long-term stored seed (different averages, variances and distribution of GE and GC values – see Table 1). Therefore, the evaluation of the experiment was carried out separately for these two seed lots categories (S, L), which significantly improved distribution normality and variance homogeneity of values GE and GC. The effect of testing-times T (1 and 2), months M (1, 2 ... 12) and seed origin (expressed by altitude of seed collection A = 500–1,500 m) on GE and GC was tested by two-way analysis of covariance ANCOVA with interaction. Independent factors were T and M, covariate A and interaction T × M. Monthly fluctuation of germination parameters during the year was evaluated in each experimental variant (S, L, T1, T2) by multiple Tuckey test of differences among all monthly averages $\bar{Y}_m$ and by comparing individual monthly averages $\bar{Y}_m$ with the annual average $\bar{Y}_{year}$. Average $\bar{Y}_m$ was considered to be biased (from statistical and practical point of view) if the following condition was met:

$$|\bar{Y}_m - \bar{Y}_{year}| > t_{0.025(k-1)} \frac{S_R}{\sqrt{k}} \qquad (1)$$

i.e. if its absolute difference $|\bar{Y}_m - \bar{Y}_{year}|$ exceeded 95% confidence interval of all possible differences provided the null hypothesis, that in the basic population compared averages are equal ($\mu_m - \mu_{year}$), is valid. In formula (1), $t_{0.025(k-1)}$ stands for the quantile of Student's t-distribution, S_R is the residual standard deviation taken from ANCOVA results, and k is the number of tested seed lots in a particular experimental variant. Monthly averages of GE and GC were expressed in absolute values (in %) and also by means of seasonal indexes (Šmelko 1998), which standardise their course and eliminate the differences in the level of GE and GC between the examined seed lots. Seasonal index SI_m was defined by

$$SI_m = \frac{\bar{Y}_m}{\bar{Y}_{year}} \qquad (2)$$

where:

$\bar{Y}_m$ – mean value of GE or GC in the given month (m),

$\bar{Y}_{year}$ – annual average value of GE or GC.

This solution has the practical advantage: if the seasonal fluctuation of monthly values is confirmed, SI_m enables to convert each value of Y_m obtained in

Table 2. Results of ANCOVA for germination energy (GE) and germination capacity (GC), short-time stored seeds (S) and long-time stored seeds (L). Independent factors: 1 – testing (T1, T2), 2 – months (1,2 ... 12), covariate: altitude

Experimental variants	N	Homogenity of variances P	Effects of				
			Testing F (P)	Months F (P)	Interaction T × M F (P)	S_R (%)	r_{GA}
GE, S	240	0.016	24.99 (< 0.001)	7.55 (< 0.001)	8.35 (< 0.001)	12.9	0.21
GE, L	240	0.534	3.09 (0.080)	5.83 (< 0.001)	4.81 (< 0.001)	16.9	0.18
GC, S	240	0.877	0.00 (1.00)	2.78 (0.002)	4.16 (< 0.001)	2.7	0.25
GC, L	240	0.761	3.61 (0.059)	0.68 (0.75)	0.54 (0.87)	8.5	0.13

N – number of seed samples, F – test, P – significance level, S_R – residual standard deviation, r_{GA} – coefficient of correlation between germination indicator (GE, GC) and altitude of seed origin the laboratory seed tests quality in any month into the probable annual average according to the following formula

$$Y_{\text{average}} = \frac{Y_m}{SI_m} \qquad (3)$$

RESULTS

Germination energy

Germination energy is an indicator of the speed of seed germination; it is expressed as a relative number of germinated seeds (in %) during the first 7 days of germination test. The most important data characterising germination energy on the basis of our experiments are presented in Tables 1, 2, 3 and illustrated in Figs. 2 and 3. Resulting knowledge is as follows:

The seed stored for a short period (2 months or 1 year) has an average GE from both testing times T1 and T2 on the level of 59.1% with standard deviation of ± 17.3% and variation coefficient of 29.3%. The shape of values distribution indicates (according to coefficients A and E) a slight right-side skewness and lower kurtosis. Difference between the testing T1 and T2 is 8.1%. It is interesting that it is statistically significant, what was probably caused by a longer storage of the same seed-lots by one year. This fact was not reflected in the variability. Within the same year, GE in individual months ranged from 32% to 72%. Important finding is that monthly mean values of GE are significantly different from annual average almost in 3–6 months during a year: smaller by 11–23% in January, February, March, July, October and December, greater by 11–21% in April, June and September. However, this is not a general tendency in all T1 and T2 variants. The values of seasonal index correspond to the above findings. They fluctuate between 0.62 and 1.38, what means that maximum monthly GE deviations are very large, relatively ± 38% from the annual average value.

The seed stored for a long period (12 or 13 years) has a lower average GE (only 34.6%) but the absolute as well as relative variability of this parameter are substantially greater (variation coefficient is almost 58%) when compared with short-term stored seed. The differences between the testing T1 and T2 (2.2%) are only of random character (Table 2). In fact, the course of GE time series is similar to the course of the short-term stored seed, but they are systematically shifted to lower values (what can be observed

Table 3. Monthly values of germination energy (GE %) and tests of their differences from the annual average

Month	1	2	3	4	5	6	7	8	9	10	11	12	Average
Short-term stored seed (S), testing T1, *k* = 10													
GE %	60.9	**51.7**	**84.0**	66.5	66.5	71.0	**45.7**	66.5	71.4	59.2	66.5	**47.3**	63.1
d(Av)	–2.2	**–11.4**	**20.9**	3.4	3.4	7.9	**–17.4**	3.4	8.3	–3.9	3.4	**–15.8**	
Test	=	–	+	=	=	=	–	=	=	=	=	–	
SI(m)	0.965	**0.819**	**1.331**	1.054	1.054	1.125	**0.724**	1.054	1.131	0.938	1.054	**0.750**	1.000
Short-term stored seed (S), testing T2, *k* = 10													
GE %	**37.4**	56.2	**31.9**	**66.5**	57.6	**70.4**	51.1	58.2	**73.3**	**44.0**	56.0	57.0	55.0
d(Av)	**–17.6**	1.2	**–23.1**	**11.5**	2.7	**15.4**	–3.9	3.2	**18.3**	**–11.0**	1.0	2.0	
Test	–	=	–	+	=	+	=	=	+	–	=	=	
SI(m)	**0.706**	1.060	**0.602**	**1.255**	1.087	**1.328**	0.964	1.098	**1.383**	**0.830**	1.057	1.076	1.000
Long-term stored seed (L), testing T1 + T2, *k* = 20													
GE %	32.1	**17.8**	36.5	33.1	36.2	**51.0**	37.4	41.2	**45.7**	28.6	27.3	28.3	34.6
d(Av)	–2.5	**–16.8**	1.9	–1.5	1.6	**16.4**	2.8	6.6	**11.1**	–6.0	–7.3	–6.3	
Test	=	+	=	=	=	+	=	=	+	=	=	=	
SI(m)	0.928	**0.514**	1.055	0.957	1.046	**1.474**	1.081	1.191	**1.321**	0.827	0.789	0.818	1.000

GE % – average values of quality testing (T) of *k* seed lots, d(Av) – mean difference between monthly GE values and annual average, test – evaluation of differences d(Av) according to formula (1), = random difference, +, – significant difference plus or minus, SI(m) – seasonal index GE in the month (m = 1, 2 ... 12), values in bold type indicate statistical significance of differences at level $P < 0.05$

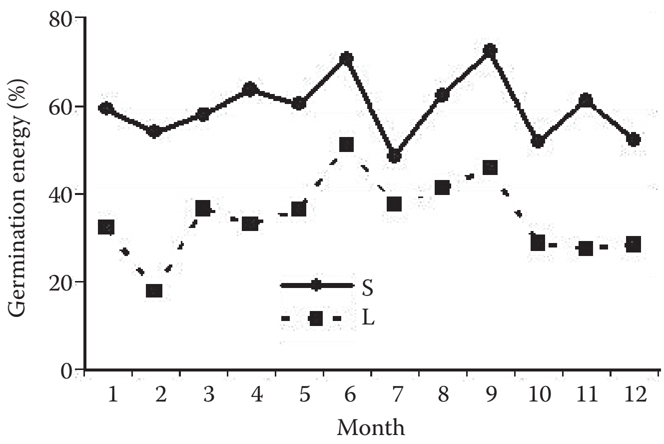

Fig. 2. Average values of germination energy (GE %) of fresh seed (S) and the seed stored for long period (L)

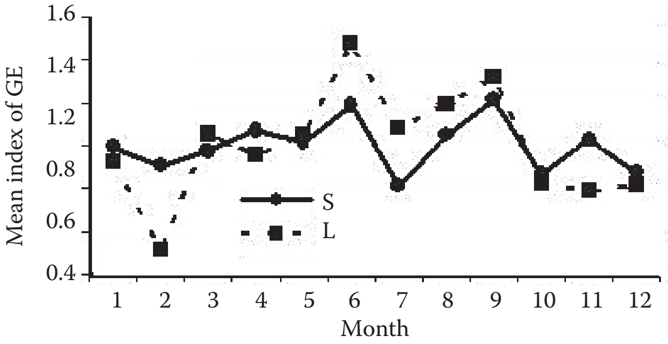

Fig. 3. Average seasonal indexes (SI_t) of germination energy of fresh seed (S) and the seed stored for long period (L)

well in Fig. 2). However, the differences in individual months in absolute and relative values are slightly greater. Seasonal indices reach the values of 0.51 to 1.47. It means that for the long-term stored seed the seasonal character of GE in individual months is relatively about 2–3 times higher than for the short-time stored seed. In general, from October until February the values of GE are lower, and from March until September higher than the annual average.

Germination capacity

Germination capacity is a quantitative characteristic of the whole process of germination giving relative number of germinated seeds after 21 days of germination testing. Data on this characteristic obtained from 40 experimental series were methodically processed similarly to germination energy. The results are summarised in Tables 1, 2 and 4 and illustrated in Figs. 4 and 5. They confirm the following facts:

Short-term stored seed has relatively high germination capacity (more than 92% on average) with a surprisingly low variability (only about 3%). Distribution of individual values is, in fact, normal, slightly right-skewed, kurtosed, and piked (values A are negative and E is about 1.0). Full correspondence was found between germination capacity in the first and second year of testing T1 and T2 (Table 4). Statistically significant differences between indivi-

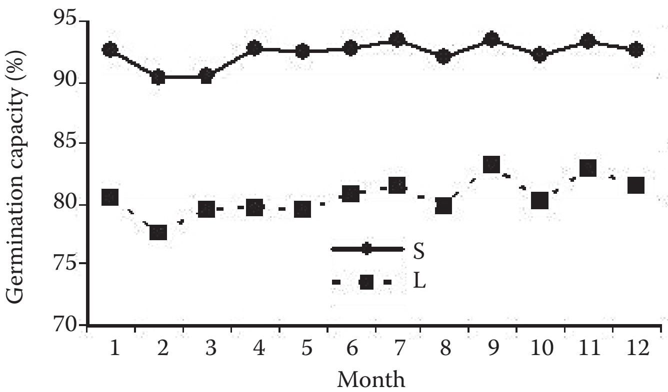

Fig. 4. Average values of germination capacity (GC %) of fresh seed (S) and the seed stored for long period (L)

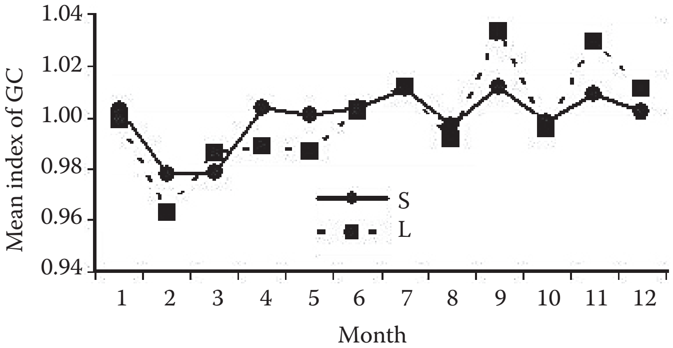

Fig. 5. Average indexes of germination capacity (SI_t) of fresh seed (S) and the seed stored for long period (L)

dual months and the annual average were found less frequently than in the case of germination energy (Table 4). They occurred only in two months, namely in February and March the values GC were smaller by 2% than the average, which can be neglected from practical point of view. Corresponding seasonal indexes were equal to 0.978.

With ***long-term stored seed***, the situation is very similar. The only difference is that GC has generally lower values (by about 12%) and its variability is 2–3 times greater than for short-term stored seed. Very important is the fact that the effect of testing T1, T2 and months and their interaction on GC of long-stored seed was not significant, monthly means differ from the annual average only randomly (Tables 2 and 4). This was also manifested in the seasonal fluctuation: monthly GC values range from ± 0.3% to ± 4%, and seasonal indexes from 0.95 up to 1.03. It is interesting that the effect of altitude of seed origin has not become evident in any of the experimental variants, and the relation of GE and GC with this characteristic was loose, since the correlation coefficients reached the values around 0.20.

DISCUSSION

Our findings correspond very well with the knowledge and opinions of most authors cited in the introduction. The correspondence is not only in the confirmation of the existence of seasonal periodicity of germination demonstrated by Smurova (1969), Repina (1974), Barnett and Mamonov (1989), Procházková (2002), but also in the fact that the course of the process of germination is different for short-term and long-term stored seed (Mamonov et al. 1986). Nevertheless, there exist differences, in which months the seasonal fluctuation has become evident. However, we do not consider their opinion that this fact must be regarded only for the seed stored for a long period, to be fully justified. Our knowledge showed that seasonal fluctuation of germination should be considered in laboratory testing

Table 4. Monthly values of germination capacity (GC %) and tests of their differences from the annual average

Month	1	2	3	4	5	6	7	8	9	10	11	12	Average
Short-term stored seed (S), testing T1 + T2, *k* = 20													
GC %	92.6	**90.4**	**90.4**	92.7	92.4	92.7	93.4	92.1	93.5	92.2	93.2	92.6	92.4
d(Av)	0.2	**–2.0**	**–2.0**	0.3	0.0	0.3	1.0	–0.3	1.1	–0.2	0.8	0.2	
Test	=	–	–	=	=	=	=	=	=	=	=	=	
SI(m)	1.002	**0.978**	**0.978**	1.003	1.000	1.003	1.011	0.997	1.012	0.998	1.009	1.002	1.000
Long-term stored seed (L), testing T1 + T2, *k* = 20													
GC %	80.5	77.6	79.5	79.7	79.6	80.9	81.6	79.9	83.2	80.2	82.9	81.6	80.6
d(Av)	–1.4	–3.0	–1.1	–0.9	–1.0	0.3	1.0	–0.7	2.6	–0.4	2.3	1.0	
Test	=	=	=	=	=	=	=	=	=	=	=	=	
SI(m)	0.999	0.962	0.986	0.989	0.987	1.004	1.012	0.991	1.032	0.995	1.028	1.012	1.000

GC % – average values of quality testing (T) of *k* seed lots, d(Av) – mean difference between monthly GC values and annual average, test – evaluation of differences d(Av) according to formula (1), = random difference, +, – significant difference plus or minus, SI(m) – seasonal index GE in the month (m = 1, 2 ... 12), values in bold type indicate statistical significance of differences at level $P < 0.05$

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of the quality of each forest seed, although the seasonal character is actually twice as much pronounced for long-term stored seed than for fresh seed. We are not associated with the recommendation that the germination testing should be carried out during the period of maximum physiological activity of the seed, because such an approach can overestimate seed quality. We rather consider important to carry out the tests in such a way that information on germination energy and germination capacity, which is typical (most probable) for the seed throughout the whole year, can be obtained. Annual average should be considered to be this typical value, and it can be determined at any time of test performance by means of seasonal indexes according to formula (3).

Although the results of our experiment as well as the knowledge of other authors about the seasonal fluctuation of tree species seed germination during the year are sufficiently justified by trials and statistic tests, they can not be generalised. In many cases, various quite distinct findings exist, e.g. maximum differences of GE and GC have been observed in different months, and the differences also differ in their magnitude. These inconsistencies are due to various reasons, of which some have already been explained by a number of authors. According to experience of Seed laboratory in Liptovský Hrádok, seed crop in the crop year can be taken as another factor, since it was observed that seed from a smaller crop has a tendency towards a faster decrease in its germination parameters than seed from full mast. Owing to the mentioned reasons, it is not possible to derive a unique relation and to develop a biometrical model that would describe the variation of seed germination parameters of individual tree species throughout the year. Nevertheless, the practice of seed quality testing urgently needs a technique that on the base of right performed trial allows a more objective estimation of a typical value characterising annual germination of a particular seed lot.

The following alternatives represent possible solutions:

– To apply our method proposed above to convert the assessed GE and GC in a given month into a probable annual average using formula (3). Provisionally, the simulated values of indexes SI_m determined in local conditions should be used, while progressively these values should be refined using subsequent experiments. We suggest to derive the general model from data at an international level. Its development should be based upon the differences of monthly values from the annual average, or even better upon the relative indexes SI_m, since there exists a close correlation between Y_m and $\bar{Y}_{year}$ values (in our experiment correlation coefficient of this relation ranged from 0.60 to 0.96).

– To make no correction, and to ignore seasonal systematic differences of GE and GC values, and hence to assume that detected Y_m is equal to $\bar{Y}_{year}$. However, this simplification significantly reduces the precision of seed quality testing, since following the law of error propagation the error of estimation $\bar{Y}_{year}$ is calculated in this case as follows (Šmelko 2007)

$$E(\bar{Y}_{year}) = \sqrt{E(Y_m)^2 + B^2} \tag{4}$$

The first element $E(Y_m)$ is the error of determining the germination parameter (GE, GC) for a tested seed lot from the sample of N seeds, and can

– either be taken from the manual SITA, or calculated using the formula derived for the error of relative proportion of a qualitative characteristic $p = Y_m$ (Šmelko 1998)

$$E(Y_m) = 2\sqrt{\frac{Y_m(100 - Y_m)}{N}} \tag{5}$$

The second element B represents an assumed (simulated) seasonal deviation of a monthly value of parameter Y_m from the annual average.

For two examples from our experiment, in which GE and GC of short-term stored seed was determined, we get:

a) Table 3: GE determined in February, sample $N = 4 \times 100 = 400$ seeds, $Y_2 = 51.7\%$, deviation $B = -11.4\%$, then

$E(Y_2) = \pm\ 5.0\%$ and $E(\bar{Y}_{year}) = \pm\ 12.4\%$

b) Table 4: GC determined in February, $N = 400$ seeds, $Y_2 = 90.4\%$, deviation $B = -2.0\%$, then

$E(Y_2) = \pm\ 2.9\%$ and $E(\bar{Y}_{year}) = \pm\ 3.5\%$.

In the first case, the increase of error is really large and cannot be ignored. In contrast, in the second case the error increase is tolerable and allows us to conclude, that deviation B can be ignored if its magnitude does not exceed 3%, or 5% at maximum.

– Another possibility is to test seed quality only in the months, when it can be assumed that $Y_m = \bar{Y}_{year}$.

CONCLUSIONS

The assessment of relatively extensive experiment with the Norway spruce seed has brought new knowledge important for the theory and practice of testing the quality of forest seed. On the basis of 480 samples, each with 400 seeds, the following facts were confirmed with 95% confidence:

– Seasonal periodicity of germination during a year really exists and was manifested differently in the seed stored for a short (2 month or 1 year) and for a long period (12 or 13 years). It was more markant for germination energy than for germination capacity.
– Germination energy showed statistically significant differences in comparison with annual average almost in 3–6 months during one year. Seasonal fluctuations were 2–3 times higher for long-time stored seeds than for short-time stored seeds. They reached almost 11–23%.
– On the contrary, germination capacity had significant seasonal fluctuations only for short-time stored seeds, solely in two months (February and March) and this difference –2% is very small and can be neglected. For long-term stored seeds no significant fluctuations were revealed.
– These findings correspond quite well with the findings obtained for spruce seed in the Czech Republic by Procházková (2002) with the exception that our experiments found significant seasonal fluctuation of germination energy in more months (not only in July and August).
– For practical laboratory testing of seed material quality it is desirable to eliminate existing seasonal fluctuation of tree species seed germination and to determine such a final value, which would represent the annual germination energy and germination capacity of the examined seed lot. Three possible solutions are presented in Section Discussion. Promising is the utilisation of relative seasonal indexes (formula 2), which enable simple conversion of germination indicators observed at any one time to a value characterising the annual average using formula (3).

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Sezónne kolísanie klíčenia krátkodobo a dlhodobo skladovaného semena smreka obyčajného (*Picea abies* [L.] Karst.) počas roka

ABSTRAKT: Laboratórne testovanie kvality lesného osiva podľa International Rules for Seed Testing sa vykonáva počas celého roka. Pritom vzniká otázka, ako zistené hodnoty reprezentujú skutočné parametre klíčenia skúšaného oddielu semena. V práci sa na vlastnom experimentálnom materiáli skúma kolísanie energie klíčenia a klíčivosti semena smreka obyčajného (*Picea abies* [L.] Karst.) v priebehu roka, a to osobitne pri semene skladovanom krátkodobo (2 mesiace, resp. 1 rok) a dlhodobo (12, resp. 13 rokov). K dispozícii bolo pre každý pokusný variant použitých 10 vzoriek semena z piatich semenárskych oblastí smreka na Slovensku, testovanie sa opakovalo dvakrát (prvý rok T1 a druhý rok T2) každý mesiac. Získané údaje mesačných hodnôt energie klíčenia (GE) a klíčivosti (GC) boli zhodnotené analýzou kovariancie ANCOVA (nezávislé faktory boli T a mesiace, kovarianta – nadmorská výška pôvodu semena). Mesačné indikátory klíčivosti boli porovnané s ich celoročným priemerom pomocou absolútnych odchýlok i relatívnych sezónnych indexov (vzorce 1, 2). Štatistické analýzy potvrdili, že GE aj GC bola pri krátkodobo uskladnenom semene 59 % a 92 % a pri dlhodobo uskladnenom semene 35 % a 81 %. Mesačné hodnoty voči celoročnému priemeru kolísali veľmi rozdielne: pri GE trikrát viac ako pri GC, pri dlhodobo skladovanom semene dvakrát až trikrát viac ako pri krátkodobo skladovanom semene, signifikantné boli pri GE až v šiestich mesiacoch počas roka (v rozpätí od 11 % do 23 %) pri oboch variantoch skladovania, naopak pri GC boli signifikantné iba pri krátkodobo uskladnenom semene vo februári a marci, avšak boli malé (–2 %) a môžu sa zanedbať. Pre praktické potreby sa navrhujú tri konkrétne spôsoby eliminácie existujúceho sezónneho kolísania klíčivosti. Za perspektívne sa považuje použitie modelových hodnôt sezónnych indexov, ktoré umožňujú jednoduchý prepočet parametra klíčivosti zisteného v hociktorom mesiaci na hodnotu charakterizujúcu celoročný priemer (podľa vzťahu 3).

Kľúčové slová: *Picea abies* [L.] Karst.; semeno krátkodobo skladované; semeno dlhodobo skladované; energia klíčenia; klíčivosť; sezónne kolísanie

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