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The quality and the depth of dormancy of beechnuts in individual stand groups with varying climatic conditions within a single unit of approval

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ABSTRACT: The goal of this study was to analyse the quality and dormancy of beechnuts originating from different harvesting sites within large UA and to determine the homogeneity of seed lots from large-scale areas. Currently, European beech (*Fagus sylvatica* L.) accounts for 7.21% of the forested area of this country. Almost 24,000 ha of beech are registered as units of approval (UA) for harvesting of reproductive material. About 40% of these UA are made up of areas of 10 ha consisting of stands with different micro-sites. Beechnut dormancy and thus the chilling requirements for the rate of germination are affected by provenance and weather conditions (precipitation and temperature) during seed maturation. Beechnuts collected from different harvest sites reached significantly different germination and also showed different degrees of dormancy. Results illustrated that beechnut seed lots collected from large areas (a set of different stands) can show high heterogeneity in germination and dormancy and this can significantly affect the uniformity of pre-sowing treatment and emergence in nurseries.

Keywords: beechnuts; germination; rate of germination; temperature; precipitation; seed collection

Currently, the representation of European beech (*Fagus sylvatica* L.) in the Czech Republic is 7.21% (182,000 ha), which is about a third of its planned optimal representation (ca 18%). Despite the ongoing increase from natural regeneration, it is artificial afforestation that creates the basis for the growing number of beech trees in our forests. During recent years, out of the total annual reforestation (ca 20,000 ha), beech has accounted for 4,000 ha (Anonymous 2014a). This requires approximately about 56 t of beechnuts annually. Harvesting beechnuts for forestry purposes can be undertaken only from approved stands; it is a basic material of the category identified (area of over 24,000 ha) and selected (area of nearly 14,000 ha) (Anonymous 2014b). The quality of seeds (weight, viability and germination percentage) is influenced by several factors, which, apart from their origin and weather conditions, also include the manner of the handling of the nuts (the seeds) during their collection. Both the time and the harvesting method are key factors that have a major impact on the germination of seeds and their capacity to retain their vitality, especially during long-term storage (Procházková, Bezděčková 1999).

The depth of seed dormancy and thereby the requisite length of the pre-sowing treatment of beechnuts are significantly affected both by their provenance and by precipitation and temperature variations during their period of ripening (Gosling 1991; Procházková et al. 2002). Due to the geographical conditions and weather fluctuations in the Czech Republic during recent years, some seed lots of beechnuts are characterised by substantial dormancy variability both within and between the yields. Therefore, the length of the pre-sowing treatment of beechnuts also varies significantly (Procházková et al. 2000, 2002; Hlavová, Procházková 2002; Procházková 2003).

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Table 1. Information about Units of approval (Anonymous 2014b)

Unit of approval (UA)		Stand groups 2A	Stand groups 2B	Total
Number		526	579	1,105
Area (ha)		2,588.16	11,236.84	13,825.00
Average area (ha)		4.92	19.41	12.51
Number (%) of UA	with 20 stand groups	0	18 (3.1%)	18 (1.6%)
	> 100 ha	0	34 (5.9%)	34 (3.1%)
	> 20 ha	19 (3.3%)	239 (41.2%)	258 (23.3%)
	> 10 ha	119 (22.6%)	381 (65.8%)	500 (45.2%)
Stand groups				
Number		526	3,003	3,529
Average area (ha)		4.92	3.74	3.92
Number (%) of stand groups	> 20 ha	19 (3.6%)	70 (2.3%)	89 (2.5%)
	> 10 ha	119 (22.6%)	564 (18.8%)	683 (19.4%)

In addition, especially in large seed lots of beechnuts, the degree of dormancy of those that are harvested from several different stand groups located in the same unit of approval varies considerably, even within the same seed lot (Gugala 2002; Procházková unpublished data). Pre-sowing treatment of these inhomogeneous seed lots is difficult. In the event of an excessively long pre-sowing treatment being necessary for the elimination of dormancy of seeds with a deeper level of seed dormancy, the less vital beechnuts with dormancy that has already expired will die, while in the event of insufficient pre-cooling the germination of the seeds may be delayed.

The harvesting of beechnuts in the Czech Republic is implemented both from selected and identified stand groups. In regard to the sources of the selected reproductive material, the stands of phenotypic class A occupy a smaller area than do the stand groups of phenotypic class B (Table 1). In addition to the essential requirements (i.e. origin, production volume, morphological characters and health status) for classification in the phenotypic class A or B, the stand groups that are approved as a basic material in the category selected shall also meet the following requirements: i.e. in terms of isolation, size, age and development stage, homogeneity and adaptability to the environmental conditions in the region of provenance (Act No. 149/2003 Coll). Gene bases represent complexes of indigenous forest stand groups or are composed of a significant proportion of the indigenous forest populations of an area of this nature that is sufficient to maintain the genetic variability of its population and that are capable of autoreproduction by using appropriate management methods. Approved stand groups of class A and B in the age category over 60 years are usually prevalent in the gene base. The area of one gene base should not generally be less than 100 ha, while it does not usually exceed 1,500 ha (Anonymous 1988).

Beechnuts ripen in September or October, but, depending on the weather conditions, the period for their harvesting may stretch until the end of November. Mature beechnuts are usually collected either from the ground or from the nets into which they are shaken (Suszka 1994). In the Czech Republic, beechnuts are mostly collected from the ground, with the proviso that in large units of approval with a large acreage and a high number of stand groups the beechnuts that are harvested within the unit of approval (hereinafter referred to as the UA) can only constitute one seed lot. There is no legal restriction in regard to the number of stand groups that can be located within a unit of approval. The area of an approved stand group should constitute at least one hectare, while the law does not lay down any upper limit. A stand group of class A is always created by one seed lot per stand group, while for stand groups of class B and C the number of seed lots is not restricted and they can be pooled within one provenance, one forest altitudinal zone or one forest management authority. The sizes of the stands pooled in this manner may be between 100 and 200 ha. Seed collection is governed by Act No. 149/2003 and by its implementing Decree No. 29/2004. In a mast year, on a small area of 0.5 ha with ca 40 trees, it is possible to collect up to 500 kg of beechnuts in nets (Jurásek; personal communication).

The aim of this study is to determine whether there are significant differences between the quality and the depth of dormancy of beechnuts harvested from individual stand groups within the area of a single unit of approval. The results obtained will constitute the basis for proposing measures to improve the homogeneity of beechnut seed lots in regard to their germination and their dormancy.

MATERIAL AND METHODS

Seeds and experimental design in 2011 and 2013. The selection of stand groups and the locations of data loggers in 2011 and 2013. In 2011 three UA were selected in the stand groups of class B (Forest Enterprises Luhačovice, Buchlovice and Svitavy) and each UA comprised three stand groups. In addition, in a stand group of class A (Buchlovice Forest Enterprise) were selected three UA with one stand group per UA (Table 2). At the end of August 2011 (from 25th to 30th), meteo data loggers collecting data on air temperature and humidity at 15-min intervals were located in sites within the selected stand groups in order that the measured points within the UA should be spaced as far apart as possible. Data loggers were placed at a height of 2 m in the stands located on the shaded side of the trees and were covered by a cup to prevent any rainwater.

Nets for capturing the beechnuts were placed under the trees, close to the data loggers. From late September to mid-October, on the area where the data loggers were located, beechnuts were collected from at least 5 trees within a radius of 50–100 m. After they had been collected, the beechnuts were delivered to the Research Station in Kunovice, where they were stored at a temperature of 3°C until testing. In 2012, the beech in the Czech Republic hardly provided any yield, nor was another higher yield recorded until 2013. In that year, the distribution of sensors in the field was carried out between the 27th and the 30th August. The harvesting and the storage of seeds were done in the same manner as in 2011. Pooled samples (LM, BM and SM) were implemented by mixing 3 × 1 kg accumulations of the beech seed lots obtained from the stand groups at the Forest Enterprise Luhačovice, Buchlovice and Svitavy in both years, for which the same parameters were determined as for the other seed lots.

Moisture content, viability and germination determination. Moisture content (fresh weight basis) was determined in two replicates of cut beechnuts (10 g each) dried at 103 ± 2°C for 17 ± 1 h in an oven (ČSN 2006). A tetrazolium test (ČSN 2006) was used for determining the viability of four replicates of 100 seeds each. The number of seeds in a weighed quantity of pure seeds was counted, and the weight per 1,000 seeds was calculated (ČSN 2006). Germination tests were done using a peat-sand substrate (1:1 by volume) (ČSN 2006). Four replicates of 100 seeds each being mixed with a peat-sand substrate (one volume of seed to two volumes of substrate, 28–30% mc) for germination in 17 × 12 cm boxes at 3°C. The boxes were kept closed with translucent lids except when they were opened weekly to check germinants. Beechnuts with visible protruding radicles were considered as germinated and discarded after counting. Germination counts were made weekly from the first week after sowing until when in two consecutive weeks no germinants were observed. Then, all the remaining (ungerminated) seeds were cut and the dead (rotten), empty, insect-infested and 'fresh' seeds were counted. The speed of germination was determined by calculating the mean germination time (MGT) according to the equation (1):

$$MGT = \sum (t_i \times n_i)/(\sum n_i)$$

where:

t_i – number of days from the beginning of the germination test,

n_i – percentage of germinating beechnuts on day t_i (Fernandéz et al. 1997).

Table. 2. Information about the European beech (*Fagus sylvatica*) seed lots used in the experiments

Site	Forest enterprise	Unit of approval	Stand group	Area (ha)	Aspect	Altitude (m a.s.l.)	Actual age in 2011 (years)
L1			411 C 13	13.49	SE	620	137
L2	Luhačovice	CZ-2-2B-BK-3056-38-4-Z-G230	411 A 13	6.79	SE	620	137
L3			408 D 12	7.26	E	545	123
B4		CZ-2-2A-BK-03132-36-3-Z-G152	404 B 14	6.75	SE	400	147
B5	Buchlovice	CZ-2-2A-BK-03131-36-3-Z-G152	206 A 14	12.62	N	400	142
B6		CZ-2-2A-BK-03129-36-3-Z-G152	110 C 13	14.23	E	450	132
B7			308 B 12	14.82	E	420	125
B8	Buchlovice	CZ-2-2B-BK-03171-36-4-Z-G152	312 A 17	2.69	N-NE	380	187
B9			302 A 15	3.29	S	470	148
S10			318 C 11	13.36	E	540	107
S11	Svitavy	CZ-2-2B-BK-03552-31-4-E-G130	319 B 12	4.17	E	540	118
S12			428 B 12	5.7	E	520	113

The day of achieving a defined germination percentage. The beechnut germination was compared in the samples that were collected individually at different sites of the same unit of approval. To better illustrate the differences between the seedlots, the coordinates were transposed in accordance with the germination percentage values achieved. Because the standard evaluation of the germination test is based on counting the germinated seeds once a week, the results were interpolated for each day of the week. According to the following equation (2) the values were determined for 10, 30, 50 and 70% of the germinated seeds.

$$\text{Day} = \text{Dd} + 7(p - d)/(h - d) \qquad (2)$$

where:

Dd – the first day at the beginning of the week-long interval,

h – percentage achieved at the end of the week,

d – percentage achieved at the beginning of the week.

Statistical analyses. Differences between sites were evaluated on the basis of single variables (germination and MGT) using one-way analysis of variance (*F*-test). LSD test was used as a post-hoc pair test. All computations were carried out in the STATISTICA 8 software (SPSS, Tulsa, USA).

The arcsin-transformation was proved due to the normal distribution of original percent data on germination would be possible. Results based on original (non-transformed) data are presented here because results of transformed data were similar.

RESULTS

Overall seed quality in 2011 and in 2013

In 2011, the beechnuts from the Forest Enterprises Luhačovice (sites L1, L2, L3) and Buchlovice (sites B4, B5, B6) had a lower water content after their collection in comparison with the beechnuts from the Svitavy Forest Enterprise (sites S10, S11, S12). The beechnuts from the Buchlovice Forest Enterprise (sites B4–B6 and B7–B8) (Table 3) had both extremely low (B5 11.3%, collected in 2011) and high humidity (B8 28.3%, collected in 2013). In the latter year, their water content was not detected on sites S10 and S11 due to the poor yield and the small quantity of seeds. From comparing the average values of the basic parameters of the seeds (Table 3), we can state that the beechnuts from the yield in 2011 exceeded the average value defined for beech in terms of their weight (234 g, ČSN 2006). The beechnuts that were ripening in the Svitavy stands in 2013 had the lowest average weight. In 2011 the germination percentage of beechnuts was high but they germinated slowly. A different situation occurred during the collections in 2013 when the germination percentage was lower but the beechnuts germinated more rapidly.

The year 2011 was characterized by high temperatures during May-June, in August and September. A high precipitation sum was recorded in July. In the Zlín region, precipitation deficit occurs in September. The year 2013 was different. High air temperatures were recorded during July and August. The July precipita-

Table. 3 Sites and their initial quality after collection 2011 and 2013

Forest enterprise	Site	Moisture content (%)		Weight of 1,000 seeds (g)		Germination (%)		MGT (days)	
		2011	2013	2011	2013	2011	2013	2011	2013
Luhačovice	L1	20.9	25.8	299.2	293.7	**84**	84	**90.62**	**87.00**
	L2	17.4	21.7	279.5	257.0	**91**	84	**91.65**	**83.70**
	L3	17.5	17.3	283.9	256.2	**94**	91	**103.67**	**94.57**
	LM	17.2	17.8	289.6	270.5	91	92	98.00	88.00
Buchlovice	B4	17.7	17.2	246.3	207.4	92	88	**102.25**	88.32
	B5	11.3	15.9	246.9	197.8	92	91	104.62	**91.97**
	B6	15.9	22.3	277.6	256.0	90	72	**105.35**	**83.22**
Buchlovice	B7	21.1	16.9	275.7	234.0	92	80	97.37	**93.10**
	B8	17.8	28.3	268.7	217.9	93	93	97.00	**80.97**
	B9	18.7	19.8	279.6	220.1	91	80	96.22	**83.52**
	BM	14.9	22.7	270.0	229.1	95	80	99.75	87.50
Svitavy	S10	20.4	N	276.5	179.1	94	52	**90.52**	**67.02**
	S11	22.4	N	302.3	157.9	**90**	46	**89.02**	**49.17**
	S12	25.8	22.3	312.6	179.4	**97**	60	**96.75**	**73.47**
	SM	22.6	N	300.0	N	94	N	92.75	N

N – not determined due to lack of seeds, in bold – differences between sites for individual forest enterprises are significant at $P < 0.05$

Table 4. Territorial precipitation and air temperature in the region of Pardubice (Svitavy Forest Enterprise) or Zlín (Forest Enterprises Luhačovice and Buchlovice) in 2011 and 2013

Region	Period		Month 1	2	3	4	5	6	7	8	9	10	11	12	Year
Air temperature															
	1961–1990		–3.1	–1.4	2.2	7.1	12.2	15.3	16.6	16.3	12.7	8.0	2.5	–1.3	7.2
	2011		–1.4	–2.0	3.7	10.4	13.3	17.0	16.5	18.1	14.6	8.0	2.5	1.7	8.5
Pardubice	2013		–2.1	–1.3	–0.8	8.1	12.2	15.9	19.3	18.0	11.7	9.4	4.4	1.5	8.0
	2011	difference	1.7	–0.6	1.5	3.3	1.1	1.7	–0.1	1.8	1.9	0.0	0.0	3.0	1.3
	2013	difference	1.0	0.1	–3.0	1.0	0.0	0.6	2.7	1.7	–1.0	1.4	1.9	2.8	0.8
	1961–1990		–2.5	–0.5	3.3	8.2	13.1	16.1	17.4	17.0	13.4	8.7	3.5	–0.6	8.1
	2011		–1.3	–2.1	3.9	10.1	13.1	17.2	16.8	18.5	15.0	8.0	2.6	1.4	8.6
Zlín	2013		–2.6	–0.9	0.3	8.7	13.0	16.5	19.7	18.6	11.8	10.0	4.9	1.6	8.5
	2011	difference	1.2	–1.6	0.6	1.9	0.0	1.1	–0.6	1.5	1.6	–0.7	–0.9	2.0	0.5
	2013	difference	–0.1	–0.4	–3.0	0.5	–0.1	0.4	2.3	1.6	–1.6	1.3	1.4	2.2	0.4
Sum of precipitation															
	1961–1990		47	40	42	46	77	87	82	84	56	45	52	54	711
	2011		41	11	24	30	62	80	149	54	67	38	0	52	610
Pardubice	2013		55	40	32	22	112	126	37	74	103	40	27	21	690
	2011	difference	87	28	57	65	81	92	182	64	120	84	0	96	86
	2013	difference	117	100	76	48	145	145	45	88	184	89	52	39	97
	1961–1990		47	46	44	56	82	102	89	83	58	50	64	60	786
	2011		38	9	34	60	73	117	135	62	20	37	0	44	630
Zlín	2013		65	73	67	19	101	119	11	87	116	38	52	19	769
	2011	difference	81	20	77	107	89	115	152	75	34	74	0	73	80
	2013	difference	138	159	152	34	123	117	12	105	200	76	81	32	98

tion sum was low. September was wet [Table 4, data on regional temperatures and rainfall according to CHMI (2015)]. See Matějka (2013) for the long-time evaluation of regional parameters in the Czech Republic.

Luhačovice Forest Enterprise (sites L1, L2, L3, Fig. 1)

The highest beechnut germination percentage in both harvests (in 2011 significantly) was found in

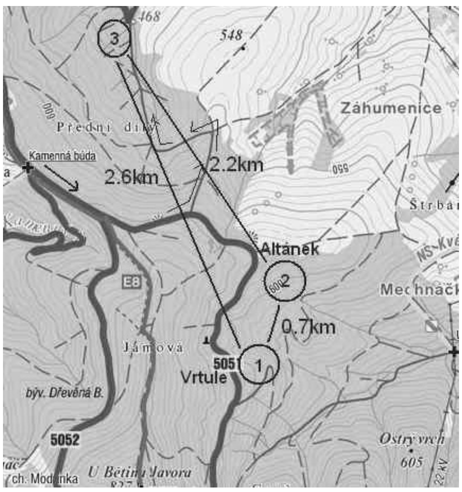

Fig. 1. Luhačovice Forest Enterprise (sites L1–L3)

seeds collected in site L3, which was located almost 3 km away from the other two sites (L1, L2). This site situated at a lower altitude was oriented to the east, and was 14 years younger. The beechnuts from site L3 had deeper dormancy (a significant maximum MGT, Table 3); they germinated more slowly – 10% of the viable beechnuts germinated ca 4–11 days later than the beechnuts from sites L1 and L2 (Fig. 2, Table 5), which are close to each other and iden-

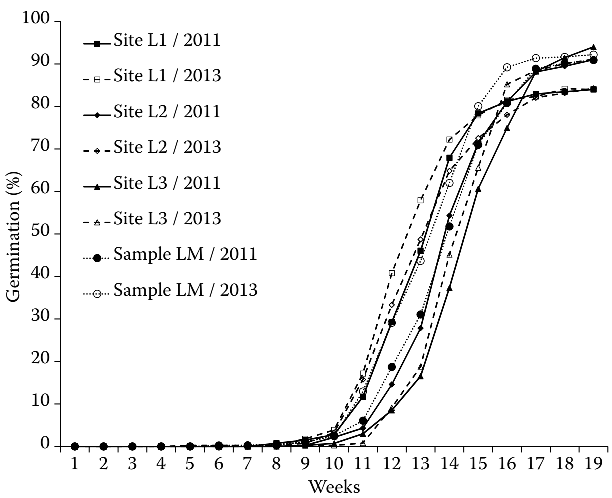

Fig. 2. Germination profiles of beechnuts from sites L1–L3 and LM sample in 2011 and 2013

Table 5. Day to achieve the desired percentage of germination

Forest enterprise	Site	10%*	30%*	50%*	70%*	10–50%**	10–70%**
2011							
Luhačovice	L1	75.8	84.5	92.5	100.2	16.7	24.4
	L2	81.4	92.2	97.9	108.1	16.5	26.7
	L3	85.3	95.6	101.8	109.7	16.5	24.4
	LM	79.2	90.4	97.3	104.6	18.1	25.4
Buchlovice	B4	89.2	98.6	104.2	110.7	15.0	21.5
	B5	89.6	98.7	103.7	109.3	14.1	19.7
	B6	84.0	99.3	104.4	112.0	20.4	28.0
Buchlovice	B7	80.6	89.6	95.7	102.5	15.1	21.9
	B8	81.0	91.0	96.1	102.3	15.1	21.3
	B9	81.9	92.1	97.6	103.5	15.7	21.6
	BM	83.1	92.8	97.1	103.1	14.0	20.0
Svitavy	S10	72.8	82.9	89.7	96.5	16.9	23.7
	S11	73.4	82.5	89.6	97.1	16.2	23.7
	S12	77.8	87.6	94.5	101.0	16.7	23.2
	SM	73.5	84.6	91.3	97.4	17.8	23.9
2013							
Luhačovice	L1	73.2	80.8	87.7	97.0	14.5	23.8
	L2	73.8	82.8	91.4	102.4	17.6	28.6
	L3	84.7	93.9	99.6	106.0	14.9	21.3
	LM	75.1	84.4	93.3	101.1	18.2	26.0
Buchlovice	B4	88.9	98.4	103.6	109.7	14.7	20.8
	B5	89.3	98.9	103.5	109.1	14.2	19.8
	B6	78.7	88.5	98.5	119.0	19.8	40.3
Buchlovice	B7	89.2	95.7	101.8	109.6	12.6	20.4
	B8	72.3	79.1	84.0	90.1	11.7	17.8
	B9	78.7	88.5	96.8	107.3	18.1	28.6
	BM	75.4	87.5	95.8	102.7	20.4	27.3
Svitavy	S10	77.0	90.3	112.0	N	35.0	N
	S11	84.7	93.1	154.0	N	69.3	N
	S12	79.1	90.4	103.2	N	24.1	N

*columns define on which specific day in a sequence the requisite germination percentage of the seeds was reached (10%, 30%, 50% and 70%), **columns express the number of days between the germination of 10% and 50% (70%) of the seeds, N – the requisite percentage was not reached

tical in terms of their age, altitude and aspect. In both harvests, beechnuts from L1 and L2 manifested high germination ability and identical depth of dormancy (Table 3). Ten percent of the beechnuts germinated within 76–81 days (Table 5).

Buchlovice Forest Enterprise (sites B7, B8, B9, Fig. 3)

The beechnuts from the stand groups of one Buchlovice UA (sites B7–B9) were collected from stand groups that are maximally 2 km apart, but that differ in their age, aspect and altitude. In regard to their harvesting in 2011, the beechnuts of all the three sites began germinate at the same rate in the 10th and 11th weeks and achieved a high germination percentage of over 90% (Fig. 4, Table 3). During the harvest in 2013, the beechnuts from site B8 already started to germinate in the 8th week, and 10% of them germinated 6–16 days earlier than those from sites B7 and B9 (Fig. 4, Table 5).

Svitavy Forest Enterprise (sites S10, S11, S12, Fig. 5)

The highest level of germination in both harvests (even significantly in 2011) was recorded in beechnuts from site S12, which was 20 m lower than the other two sites (S10 and S11). The beechnuts from site S12 also germinated significantly slowly than those from sites S10 and S11 (Table 3). Although sites S10 and S11 were located at the same altitude

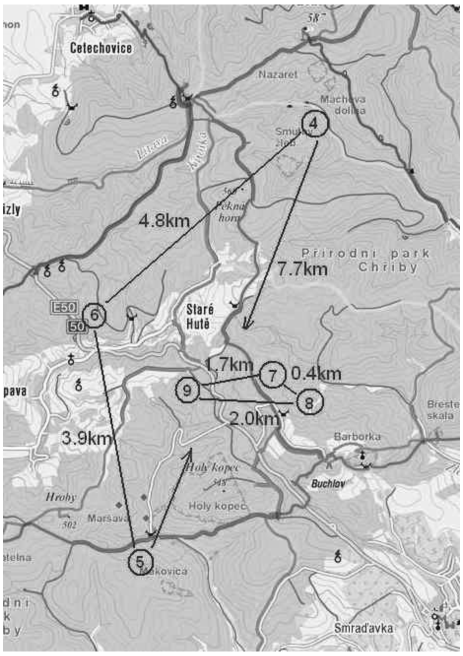

Fig. 3. Buchlovice Forest enterprise (sites B4–B9)

and were separated from each other by less than 2 km, in 2013 a significant difference was recorded in their respective germination rates (Fig. 6). In comparison with the other collection points the harvest of 2013 had the lowest germination percentage (Table 3). In this year the beechnuts at this site contained large quantities of empty and/or insect-infested seeds, which was manifested not only in the low weight of seeds, but also in their maximally 60% level of germination.

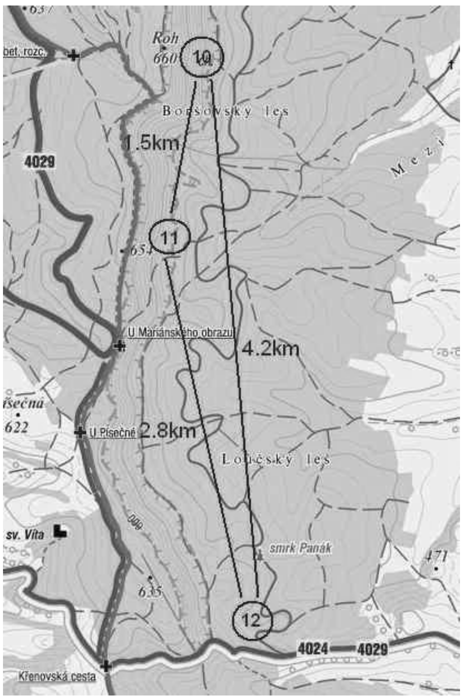

Fig. 5. Svitavy Forest Enterprise (sites S10–S12)

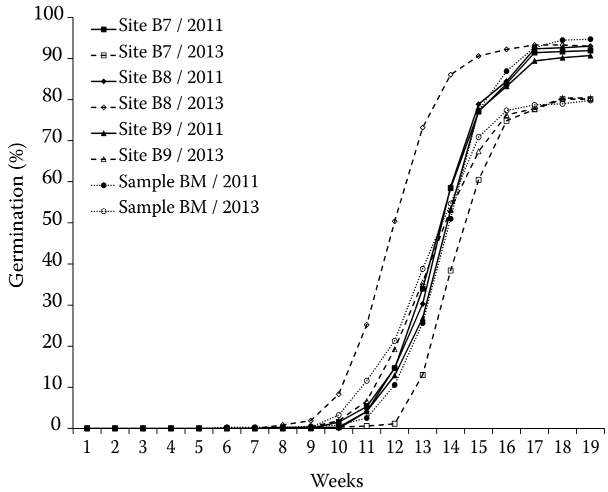

Fig. 4. Germination profiles of beechnuts from sites B7–B9 and BM sample in 2011 and 2013

Buchlovice Forest Enterprise (sites B4, B5, B6, Fig. 3) from three UA within a gene base

On this individual site harvesting was done in three stand groups, and each stand group was classified in the genetic base as part of a single unit of approval. The germination of beechnuts from the individual stand groups (UA) did not differ significantly but, on average, in 2013 the beechnuts germinated for two weeks longer than in 2011. Sites B4 and B5 were located at the same altitude but they differed in their aspect (Table 2). Although they were located almost 8 km apart, the beechnuts from these two sites showed the same depth of seed dormancy. By contrast, site B6 was of younger age and had a higher 50 m difference of altitude. In this section, 10% of the beechnuts germinated 5 to

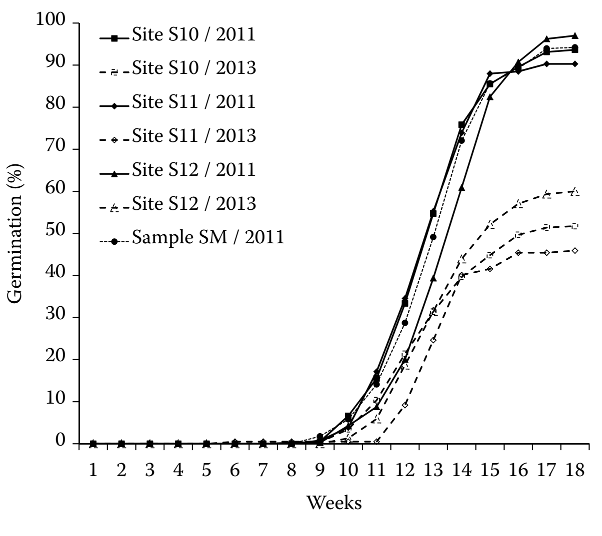

Fig. 6. Germination profiles of beechnuts from sites S10–S12 and SM sample in 2011

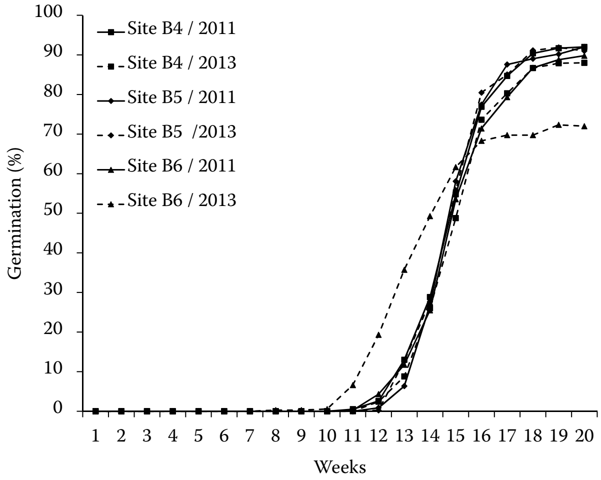

Fig. 7. Germination profiles of beechnuts from sites B4–B6 in 2011 and 2013

11 days earlier than those from sites B4 and B5 (Table 5). In 2013 the beechnuts from this site started to germinate 2–3 weeks earlier, but achieved only a 70% germination rate (Fig. 7). This was due to the greater proportion of dead seeds that was caused by the spread of saprophytic fungi and was identified in the course of the germination test.

Pooled samples LM, BM and SM

In both years the beechnuts from the pooled LM sample achieved a high rate of germination (Fig. 2). In 2011, the germination rate in this sample varied from that of sites L1–L3, however in 2013 the beechnuts in this sample germinated as quickly as did those in site L1 (Table 3). In both years 10% of the beechnuts from LM sample germinated approximately within the same time as did those from sites L1 and L2 (Table 5). In 2011, the germination rate of BM sample exceeded that of sites B7–B9, however the beechnuts in the pooled sample germinated at a slower rate (Table 3). In 2013, the beechnuts from sample LM achieved a germination percentage of 80%, as also did those in sites B7 and B9, while, in terms of their germination rate, however, they differed from the other sites (Fig. 4). During this year the beechnuts from this sample also reached germination rates of 10 to 50% or 10 to 70% 7–11 days later than those from sites B7 and B8 (Table 5). The high level of germination in sample SM was comparable with the level of germination in sites S10–S12 (Table 3). The germination rate of the pooled sample was the same as that of sites S10 and S11 (Fig. 6, Table 5). Due to a lack of seeds at the Forest Svitavy Enterprise no pooled samples were made there in 2013.

DISCUSSION

Beechnuts, when they fall, have 24–30% water content and in extremely dry or humid conditions, the water content may exceed this threshold, or conversely it may not even reach it (Messer 1960). In 2011 beechnuts of some stands in the Forest Enterprises Luhačovice and Buchlovice had lower humidity in comparison with beechnuts from Svitavy Forest Enterprise, which corresponds with the average precipitation in this region (Zlín) during September and October when the beechnuts ripen (Table 4). In those months the precipitation reached only 34 or 74% of the normal values, whereas in the Pardubice Region (where Svitavy Forest Enterprise is situated) it was elevated to 119 and 85% (Table 4). The lowest humidity level was that of the beechnuts from site B5 (Table 3). In the first ten days of October when the beechnuts from sites B4, B5 and B6 were harvested, an average recorded temperature was 12°C, with a maximum of 22–26°C. The recorded air humidity close to the collection points reached 73–83%, with the minimum humidity at a level of 35–39% (this data is not shown). Immediately after they were collected, the beechnuts from site B5 were stored at 3°C, in the same manner as those from the other sites, in order to prevent their additional desiccation. Therefore possible reasons for the low water content of the beechnuts were not identified. The seeds from site B8 (2013) were also partially collected from the ground due to a small quantity of beechnuts falling into nets, which probably explains their higher humidity (Table 3). The weight of the seeds can be influenced by the number of empty seeds. The occurrence and the quantity of empty seeds are associated with the position of trees on the site or with changes in the weather or soil conditions at specific sites in different years (Packham, Hilton 2002). The lowest average absolute weight of beechnuts in 2013 was of those from the Svitavy Forest Enterprise, which was caused by the large number of empty and insect-infested seeds (23–48%). A high percentage of empty seeds often occurs in isolated trees or those that are spaced further apart (Packham, Hilton 2002). Since the collection of beechnuts at the Svitavy Forest Enterprise was carried out in contiguous stand groups, the emptiness of the seeds could possibly have been caused by unfavourable wind conditions at the time of their pollination. The relationship between seed weight, germination and depth of dormancy of the *Fagus orientalis* seeds

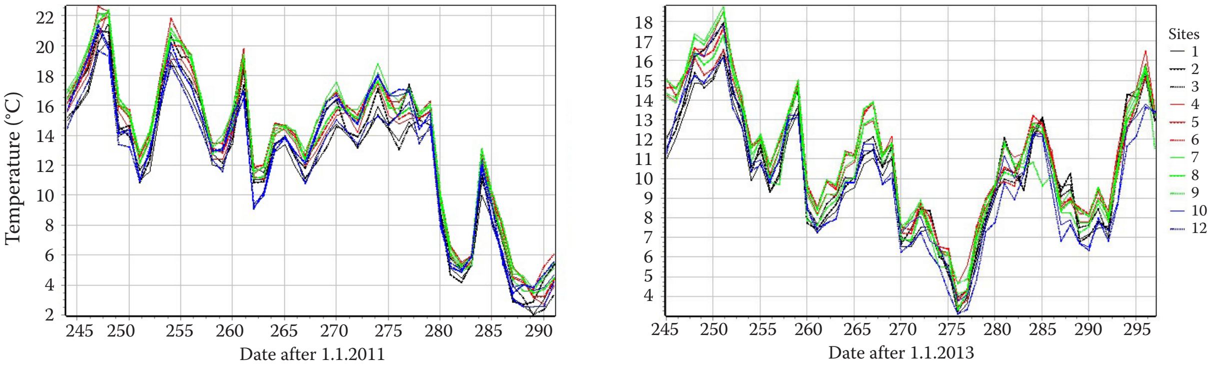

Fig. 8. Average daily temperatures at various sites in the Czech Republic in 2011 and 2013

was investigated by Soltani et al. (2005). They identified not only a higher germination percentage in heavier or moderately heavy beech seeds, but also their accelerated germination rate as compared to that of the lighter seeds. This finding was only partially confirmed in our study. Although the seed lots from 2011 contained heavier beechnuts that had a higher germination percentage, they also had a slower germination rate than those from 2013 (Table 3).

The quality of beechnuts (their viability, germination percentage and seed dormancy expressed as MGT) is conditioned not only by the seed genotype, but also it is significantly influenced by weather conditions in the period of seed development and maturation. If we review the basic climatic characteristics (temperature and precipitation) during the individual harvest years, we can confirm that the viability of beechnuts corresponds with average temperatures and precipitation during September and October when the beechnuts are ripening (Procházková et al. 2002). In 2011 beechnuts achieved a high germination percentage. In that year the territorial temperatures in both regions reached 15°C in September and 8°C in October (Table 4), which is also shown in detail in the progression of the average daily temperatures for all sites (Fig. 8). The air temperatures were high, mostly around 15°C, until the 7th of October (day 280). Then, there was a drop in the temperature by ca 10°C. The total territorial precipitation reached a maximum level of 630 mm, which, together with the higher temperatures in September, caused a higher degree of dormancy of the beechnuts and also their slower germination (Table 3). By contrast, in 2013, the air temperature was decreasing gradually until the 3rd of October (day 276), when it hit its low point and then, in the coming days, the weather became warmer again (Fig. 8). The low temperatures coupled with the high level of territorial precipitation led to the beechnuts being less dormant after they fall and thereby germinating more rapidly (Table 3).

The results obtained from the Luhačovice Forest Enterprise show that beechnuts from different sites (L1–L3) vary significantly, not only in their germination percentage, but also in the depth of their seed dormancy, which, in the event of the creation of a single large seed lot, could significantly affect the success rate of the pre-sowing treatment. Gugala (2002) discussed the quality of beechnuts stored in the seed bank in Kostrzyca. Seed lots from the gene resources that were collected individually were of good quality and during the period of their storage there was only a slight reduction of their vitality. Conversely, the vitality of the beechnuts with a high degree of heterogeneity, based on the pooling of several seed lots, was reduced by more than 30%. The recommendation following from this is to harvest beechnuts separately at individual sites and not to mix them together. This recommendation should apply not only to genetic resources, but also to all beech stand groups.

In 2013 the beechnuts from site B8 of the UA of the Forest Buchlovice Enterprise germinated the most rapidly. This was caused by the high moisture content of the beechnuts at the end of their collection, which created favourable conditions for the gradual elimination of their dormancy during the post-harvest ripening. In comparison with site B8, beechnuts from site B7, which had the lowest moisture content on this site, began to germinate 4 weeks later, and 10% of all viable beechnuts germinated 2.5 weeks later (Table 4). Their water content can also be one of the reasons for not pooling seeds from different sites because such a difference in the seed moisture could lead to uneven post-harvest ripening, which, following the pre-sowing treatment, could be reflected in the uneven emergence rate.

Significant differences in germination percentage and in the depth of seed dormancy were also observed in both years between the beechnuts from different sites at the Svitavy Forest Enterprise, which could lead, if they were pooled and stored over the long-term, to a decline in their viability and germination, thereby confirming the findings of Gugala (2002).

The beechnuts from the Buchlovice Forest Enterprise (sites B4–B6) originated from three UA within the genetic base. Because these were the sources of selected reproductive material of phenotype class A that, in accordance with Act No. 149/2003, may not be pooled, these stand groups served only as a model for the pooling of stand groups from any other type of source. As shown in Fig. 7, seeds from sites B4 and B5 did not differ significantly in germination percentage and seed dormancy. Beechnuts from site B6, however, differed from seeds from B4 and B5 sites as 10% of the viable beechnuts from the latter two collections germinated earlier (in 2013 – due to the higher degree of humidity of the beechnuts). On the other hand, 50% and/or 70% of the viable beechnuts germinated later, which could be due to the higher altitude of the site and/or the later ripening of the beechnuts. The subsequent pooling of the seeds from these sites (the units of approval) into a single larger seed lot might be adversely reflected in regard to the further handling of the seeds.

In both years 2011 and 2013, following the harvest, the pooled LM, BM and SM samples were artificially created. These pooled samples differ from the sites in which the beechnuts were collected separately, not only in their level of germination but also in their depth of dormancy (Figs 2, 4 and 6). The inhomogeneous beechnut samples were created by pooling the beechnuts from several different sites. These beechnuts, if they were stored and subsequently handled, might not provide such favourable results of their germination as did the beechnuts that were collected and stored separately, in accordance with the individual sites.

CONCLUSIONS

It was confirmed that there are significant differences during the germination of beechnuts collected from different stand groups within the same unit of approval, demonstrated by different depths of the seed dormancy of beechnuts. In the case of large volumes of beechnuts that have been collected from a large area of the same UA and also from a larger number of stand groups, this diversity may have a negative impact on the success of the pre-sowing treatment and on the economic aspect of sowing in forest tree nurseries. Seed lots of beechnuts from different beech sites within the same unit of approval may:

– achieve significantly different germination percentages;
– have different degrees of seed dormancy, meaning that they may germinate at different rates;
– have a germination percentage and/or a germination rate that differs from that of the original, separately collected seed lots.
– show that, during the ripening of the beechnuts, temperature and/or precipitation had an effect on germination percentage and dormancy depth during specific years.

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References

Anonymous (1988): Směrnice pro uznávání a zabezpečení zdrojů reprodukčního materiálu lesních dřevin a pro jeho přenos. Brandýs nad Labem, ÚHÚL: 22.

Anonymous (2014a): Zpráva o stavu lesa a lesního hospodářství ČR v roce 2013. Praha, Mininisterstvo zemědělství ČR: 130.

Anonymous (2014b): Informace o nakládání s reprodukčním materiálem lesních dřevin České republiky. Brandýs nad Labem, ÚHÚL: 119.

CHMI (2015): Historická data – meteorologie a klimatologie. Available at http://portal.chmi.cz/portal/dt?portal_lang=cs&menu=JSPTabContainer/P4_Historicka_data/P4_1_Pocasi&last=false (accessed March 03, 2015).

ČSN (2006): ČSN 48 1211 Lesní semenářství: Sběr, kvalita a zkoušky kvality semenného materiálu lesních dřevin. Praha, Český normalizační institut: 60.

Fernandéz H., Doums P., Falleri E., Muller C., Bonnet-Masimbert M. (1997): Endogenous gibberellins and dormancy in beechnuts. In: Ellis R.H. et al (eds): Basic and Applied Aspects of Seed Biology. Dordrecht, Kluwer Academic Publisher: 311–321.

Gosling P.G. (1991): Beechnut storage. A review and practical interpretation of the scientific literature. Forestry, 64: 51–59.

Gugala A. (2002): Changes in quality of beech (*Fagus sylvatica* L.) seeds stored at the Forest Gene Bank Kostrzyca. Dendrobiology, 47: 33–38.

Matějka K. (2013): Vývoj teplot a srážek v ČR od roku 1961. Available at http://www.infodatasys.cz/climate/KlimaCR1961.htm (accessed March 03, 2015).

Messer H. (1960): Die Aufbewahrung und Pflege von Eicheln und Bucheln. Frankfurt am Main, Sauerländer: 44.

Packham J.R., Hilton G.M. (2002): Inter-and intra-site variation in the fruiting of common beech (*Fagus sylvatica* L.) in England over a twenty two year period (1980–2001). Arboricultural Journal, 26: 1–22.

Procházková Z., Bezděčková L. (1999): Comparing viability with germination of stored beechnuts. In: Proceedings Neue Aspekte bei der forstlichen Saatgutlagerung, Teisendorf, May 17–21, 1999: 35.

Procházková Z., Palátová E., Martincová J. (2000): Qualität der Bucheckern aus verschiedenen Ernten und Ihr Einfluss auf Lagerungsfähigkeit und Auflaufen der Samen. In: Tesař V. (ed): Die Baumart Buche im ökologischen Waldbau. XIV. Gemeinsames Waldbau-Kolloquium "Brno-Tharandt" Brno und Křtiny, Brno, 12–14, 2000: 45–50.

Procházková Z., Bezděčková L., Martincová J., Palátová, E. (2002): Quality of beechnuts from different crop years. Dendrobiology, 47: 39–42.

Soltani A., Tigabu M., Odén P.C. (2005): Alleviation of physiological dormancy in oriental beeechnuts with cold stratification at controlled and unrestricted hydration. Seed Science and Technology, 33: 283–292.

Suszka B., Muller C., Bonnet-Masimbert M. (1994): Nasiona lesnych drzew lisciastych: od zbioru do siewu. Poznan, Warszawa, Wydawnictwo naukowe PWN: 299.

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