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Seedling emergence of beech (*Fagus silvatica* L.) seed pretreated by chilling without any medium at controlled hydration levels

INTRODUCTION

In our earlier work (Suszka, 1975, Suszka and Zięta, 1976, 1977) we have found that beech seeds can be prepared for germination by a treatment replacing stratification and avoiding some of its inconveniences. This treatment consists in rehydrating beechnuts at low temperature (3°C) by gradual imbibition to 28% (fresh weight basis) when dried before, and to chill them at this temperature. The chilling period can be estimated with the help of a simultaneous or earlier conducted control stratification of a small seed lot (4×50 seeds) until 10% of the stratified seed are already germinating i.e. until they have growing radicles longer than 3 mm *. During chilling the minute losses of water have to be replaced at weekly intervals by adding water to the seeds to their initial weight fixed after imbibition, and by thorough mixing. It was found that the 28% water content level was too low to permit germination even when the duration of the chilling period was extended much over the estimated period. On the other hand it was thought that it was high enough to permit the after-ripening processes to run at the low temperature in a normal way i.e. as in fully imbibed seeds.

All this was correct when the seed material was used immediately after collection or after longer dry storage at temperatures in the range from −3° to −10°C. It was also confirmed in laboratory germination tests at different constant temperatures, where seeds placed after chilling in stratification conditions started to germinate immediately, the germination period being extended to 4 - 6 weeks only. The chilled seeds when immediately sown in the nursery not later than May 3rd grew into seedlings in 49 - 57% (Suszka and Zięta, 1977).

The paper presented here is the result of experimental work performed in 1977. It was aranged to study the thermal and hydration conditions of chilling and the after-chilling treatments, adaptable for beech seed material collected in normal forest mass work.

* 10% g. r. = 10% germination rule.

MATERIAL AND METHODS

A series of 4 experiments was started in the season of 1976/1977 to come to a better understanding of the external conditions for the after--ripening of beech seeds when chilled without any medium, and for their subsequent germination and seedling emergence.

Experiment 1 (Laboratory file no. 309, 1977)

Aim of the experiment: to find the minimal hydration level of beech--nuts, sufficient for a successful after-ripening.

Seed material: Freshly collected beechnuts from 4 trees growing close together in the Kórnik Arboretum. They were collected successively from the ground in the period of October 1 - 13th 1976, always as early after seed fall as possible. After cleaning seed viability tested with the help of the indigocarmine staining method (water solution 1:2000, 20°C, 2 hours) was 97.5%, and the water content estimated by weighing before and after drying for 24 hours at 105°C was 31.6%.

Drying of beechnuts: Drying was performed at 15°C in a strong air current according to Vlase (1969). In the first experimental variant (A) non--dried seed material was used, in the next variants (B-L) it was dried down gradually to 11.0% of water content. The rate of drying and the water content of beechnuts used for all experimental variants are shown in Table 1.

Table 1

Course of drying of beechnuts (*Fagus silvatica* L.), started on October 15th, 1976 immediately after termination of collection from the ground (Experiment 1)

Experimental variant	Termination of drying		Water content of beechnuts		
	date	hour	postulated %	obtained %	diff. %
A	October 15	9⁰⁰	32.0	31.6	−0.4
B		11³⁰	30.0	29.6	−0.4
C		15⁰⁰	28.0	27.7	−0.3
D		21⁰⁰	26.0	25.8	−0.2
E		23⁰⁰	24.0	24.1	+0.1
F	October 16	0³⁰	22.0	21.5	−0.5
G		3⁰⁰	20.0	19.9	−0.1
H		5⁰⁰	18.0	17.9	−0.1
I		12⁰⁰	16.0	16.8	+0.8
J		22⁰⁰	14.0	13.8	−0.2
K	October 17	3⁰⁰	12.0	12.3	+0.3
L		9³⁰	10.0	11.0	+1.0

Water content of the freshly collected seed material was estimated by the drying method and basing on dry weight the fresh weight of beechnuts (always of the same number) was calculated for the postulated hydration levels (Tab. 1). At each weight level a part of the dried seed material was taken away, its water content was estimated to find the really obtained water content level. The method used was accurate, the difference between the postulated and the obtained hydration levels only in 3 variants out of 12 was above ± 0.4%.

Treatments after drying: When dried to the postulated water contents beechnuts were treated always in the same way i. e. they were:

— stratified at 3°C in a sand/peat (1:1, vol.) medium for 18 weeks,

— chilled at 3°C without any medium for 12 weeks at the obtained water content level and afterwards they were again stratified at 3°C and 20°C separately for 20 weeks in a sand/peat medium.

The duration of the chilling period (12 weeks) was estimated with the help of an auxiliary stratification at 3°C of freshly collected beechnuts and the period which passed till 10% of seeds germinated (the 10% germination rule) was the wanted duration of chilling necessary for seed after-ripening, according to Suszka and Zięta (1976). Seeds with the radicle 3 mm long or longer were recognized as germinated.

The initial water content was maintained during the whole 12-weeks chilling period. At weekly time intervals beechnuts of each chilled seed lot were weighed and any evaporated water was replaced by adding water to the original weight of the lot followed by a thorough mixing of the beechnuts. Chilling was performed in plastic boxes covered with a perforated lid.

After each stratification at 3°C and 20°C all non-germinated seeds were tested for their viability with the help of the cutting test.

All stratification variants were replicated 4 times with 50 beechnuts in each replication. The stratified seed lots were mixed and aerated at 2-week (at 3°C) or 1 week (at 20°C) intervals and the germinating seeds and the decaying ones were counted and discarded.

Experiment 2 (Laboratory file no. 309, 1977)

Aim of the experiment: To study the effect of chilling beechnuts without any medium twice, both chilling periods being interrupted by drying and low-temperature storage.

Seed material: The same beechnuts were used as for experiment 1 at the same starting time i. e. on October 15th, 1977.

Treatments: Beechnuts when dried down to 28% of water content were placed at 3°C for chilling and the initial hydration level was maintained by weekly repeated weighing and adding of water, followed by mixing of the wetted material.

Duration of the necessary chilling (12 weeks) was estimated as in experiment 1 (10% germination rule).

After chilling the beechnuts were dried at 15°C in an air current to 10% of water content (January 10-12th, 1977). Their weight corresponding to this hydration level was estimated as in experiment 1, basing on the dry weight of a given number of beechnuts. The dried beechnuts were stored over 4 weeks at −3°C in polystyrene containers and on February 8th they were defrosted at 1 - 3°C and in the next 8 days they were rehydrated gradually to 28% of water content by daily repeated sprinkling and mixing until the earlier calculated weight was reached, corresponding to the wanted 28% level. The rehydrated beechnuts were again chilled at 3°C for the next 12 weeks as before drying, and the water content level was maintained as described above. On May 11th after termination of chilling the beechnuts were mixed with the sand/peat medium and they were stratified separately at 3°C and 20°C for the next 8 weeks. During stratification seeds were checked at weekly time intervals and the germinating and decaying seeds were counted and discarded.

Both stratification variants were performed in 4 replications with 50 beechnuts in each.

Experiment 3 (Laboratory file nos. 237, 242 and 243, 1977)

Aim of the experiment: To compare germination at different temperatures and seedling emergence at 20°C after chilling at 3°C without any medium.

Seed material: Beechnuts collected in 1973 in the Forest District Gromnik, voivodship Tarnów, at an elevation of 300 - 400 m in 3 different stands: Bistuszowa (lab. file no. 237), Trzemesna I (lab. file no. 242) and Trzemesna II (lab. file no. 243). After collection they were dried to 10.1 - 10.3% of water content and were stored over 4 winters at −3°C in tightly closed polystyrene containers. On February 28th 1977 these beechnuts were defrosted at −1°C followed by 3°C, and immediately their viability and water content were estimated (as in experiment 1):

Bistuszowa	viability	86.7%	water	content	7.9%,
Trzemesna I	„	78.0%	„	„	8.4%,
Trzemesna II	„	92.5%	„	„	8.3%.

To test their real germinative capacity and to estimate the duration of chilling periods necessary for after-ripening each seed lot was tested at 3°C by stratification and separately on moist filter paper.

The germinability levels during stratification and on filter paper were as follows respectively:

Bistuszowa	84.5% and 86.5%,
Trzemesna I	88.5% and 74.0%,
Trzemesna II	92.5% and 88.5%.

In both tests seeds started to germinate in the 6th week, the whole germination period being extended for the next 10 weeks. Chilling for 8.5 weeks was chosen according to the 10% germination rule.

T r e a t m e n t s: The defrosted beechnuts were rehydrated at 3°C to 28% of water content by sprinkling and mixing repeated twice every day, which made possible the rehydration in 4 days. Chilling was performed at 3°C for the estimated period. The water losses were replaced at weekly intervals as in experiment 1.

After chilling beechnuts of each provenance were separately stratified at 3°, 5°, 10°, 15° and 20°C in a sand/peat medium, where germination and the eventual seed decay were observed at weekly time intervals, both types of seeds being counted and discarded.

Another part of the same seed material was sown simultaneously with the start of stratification. Sowings were performed in plastic boxes 1 cm deep in the same sand/peat medium. The holes pressed into the medium with the help of templates were after sowing filled with sand. Each box (20 × 20 cm) contained 2 replicates with 50 seeds in each. Each sowing variant (4 × 50 seeds) was sown in 2 boxes. After sowing the boxes were covered with transparent lids with 4 holes in the corners for aeration and afterwards they were placed in an air-conditioned chamber at 20°C. During this time moisture losses were replaced at weekly time intervals. One part of the sowing variants was held at this temperature for 12 weeks i. e. till the seedling emergence tests were terminated. Another part was placed at 3°C for 8 weeks only to be transferred afterwards to 20°C for the next 2 weeks. Seedling emergence was observed at 20°C only at weekly intervals, at the same temperature but after transfer from 3°C two times each week (3 + 4 days). The emerged seedlings were left till the end of the test but they were counted during each observation, the decaying seedlings being counted and removed. Moisture of the medium was maintained by sprinkling with tap water when needed. Only seedlings with both cotyledons free above the medium level were recognized as emerged.

Simultaneously with laboratory sowings beechnuts were sown in the nursery in a randomized block design with 5 replications. Each experimental variant was represented once in each replication by 50 beechnuts sown in a drill drawn transversely to the seedbed 120 cm broad. The drills were 20 cm apart and 3 cm deep.

The sown seeds were covered with soil. After sowing the seedbeds were shaded and when needed they were watered through rotating sprinklers. The shading material was removed in midsummer. On the sowing day i. e. immediately after termination of chilling no signs of germination were observed. After sowing seedling emergence was observed at weekly time intervals. The seedlings were counted but they were left till the end of the field emergence test in late autumn.

Experiment 4 (Laboratory file no. 309, 1977)

Aim of the experiment: To find if beech seed germination and seedling emergence can be improved by a prolongation of the chilling period, by increase of the hydration level during chilling and after chilling by sowing in various thermal conditions.

Seed material: Beechnuts, the same as used for experiment 1 were collected on October 15th 1976 in Kórnik. After drying at 15°C in an air current to 11.0% of water content they were stored sealed at −3°C over 4 months. After defrosting the beechnuts the experiment was started on February 8th 1977.

Treatments: The seed material was divided into 3 main seed lots which were rehydrated at 3°C by repeated sprinkling with water and mixing. Water was added only once daily and the rate of rehydration was slow. The hydration levels planned and reached during rehydration are shown in Table 2.

Table 2

Rehydration of beech (*Fagus silvatica* L.) seeds to 3 different water content levels performed at 3°C (Experiment 4)

Termination of rehydration date	Water content of beechnuts postulated %	obtained %	diff. %
February 15th 1977	25.0	25.2	+0.2
February 18th 1977	28.0	27.8	−0.2
February 25th 1977	31.0	31.3	+0.3

Table 3

Design of experiment 4 on beech (*Fagus silvatica* L.) seeds, stored before in dried condition over 4 months at −3°C

	Hydration level of beechnuts		
	25%	28%	31%
Duration of chilling at 3°C in weeks	10	10	10
	12	12	12
	14	14	14

The duration of the chilling period was estimated by the 10% germination rule (Suszka, 1976) during a control stratification to be 12 weeks, and besides this period (x) two other chilling periods were fixed for all 3 hydration levels: one 2 weeks shorter i.e. 10 weeks ($x-2=10$ weeks) and the other 2 weeks longer i.e. 14 weeks ($x+2=14$ weeks). The experiment was performed according to the design shown in Table 3.

Beechnuts from each of the 9 main combinations of water content level and duration of the chilling period were sown in plastic boxes as in experiment 3 and the following 3 variants were applied for observations of germination and seedling emergence:

20°C for 10 weeks,
3°C for 10 weeks, afterwards transfer to 20°C,
3° and 20°C in an alternating daily cycle (16+8 hours).

In this way an experiment of 27 variants was constructed. In all variants 4 replicates were sown with 50 beechnuts in each, but in the case of seeds held at 3°C before transfer to 20°C seeds from 2 replicates (one from each of the 2 boxes) were taken out and used for estimation of germination, which at this low temperature was limited to the growth of radicles only. The other 2 replicates of each variant were left till the end of the seedling emergence test at 20°C. For this reason the analysis of variance was performed for all other variants also on 2 replicates only, but the differences beteen replicates and beteen means calculated for 2 and 4 replicates were very small.

After each chilling period beechnuts from all combinations of hydration level× ×chilling period were also sown in the nursery in a randomized block design with 5 replicates with 50 beechnuts in each. Sowing and all other work in the nursery was performed in this vegetation season as described already for experiment 3.

The results were expressed in percentage of seedlings emerged in the laboratory and nursery sowings in each replication of each variant and the mean seedling emergence levels were calculated. The values on the replication level were used for an analysis of variance at the 5.0% and 1.0% risk of error. For comparisons between means the Newman-Keuls test was used.

RESULTS

EXPERIMENT 1

The course of germination in the individual experimental variants is demonstrated in Fig. 1. Other data are collected in Table 4.

Table 4

Germination of beech (*Fagus silvatica* L.) seeds during stratification at 3°C performed after drying to various hydration levels and after drying to the same levels followed by 12 weeks of chilling without any medium at 3°C and a stratification at 3° or 20°C (Experiment 1)

Variant	Water content of beechnuts after drying %	Seed stratified at 3°C immediately after drying		Seed stratified at 3°C after drying followed by chilling at 3°C		Seed stratified at 20°C after drying followed by chilling at 3°C	
		germinative capacity %	start and termination of germination weeks	germinative capacity %	start and termination of germination weeks	germinative capacity %	start and termination of germination weeks
A	31.6	80.5	10 - 20	—	—	—	—
B	29.6	94.0	10 - 18	95.0	1 - 6	31.0	0 - 3
C	27.7	93.5	10 - 18	94.5	7 - 16	4.5	6 - 7
D	25.8	94.5	10 - 18	93.5	6 - 17	3.5	6 - 8
E	24.1	97.0	10 - 18	96.5	8 - 16	2.0	7 - 9
F	21.5	97.0	10 - 18	93.5	9 - 18	1.5	6 - 7
G	19.9	89.0	10 - 18	94.0	10 - 17	0.5	7 - 8
H	17.9	93.5	10 - 18	94.5	11 - 17	2.5	6 - 7
I	16.8	97.5	10 - 16	98.5	11 - 16	1.5	7 - 8
J	13.8	94.0	10 - 16	92.0	10 - 17	3.0	6 - 7
K	12.3	95.0	10 - 16	96.0	10 - 18	2.0	7 - 8
L	11.0	98.0	10 - 16	94.5	9 - 15	4.0	6 - 7

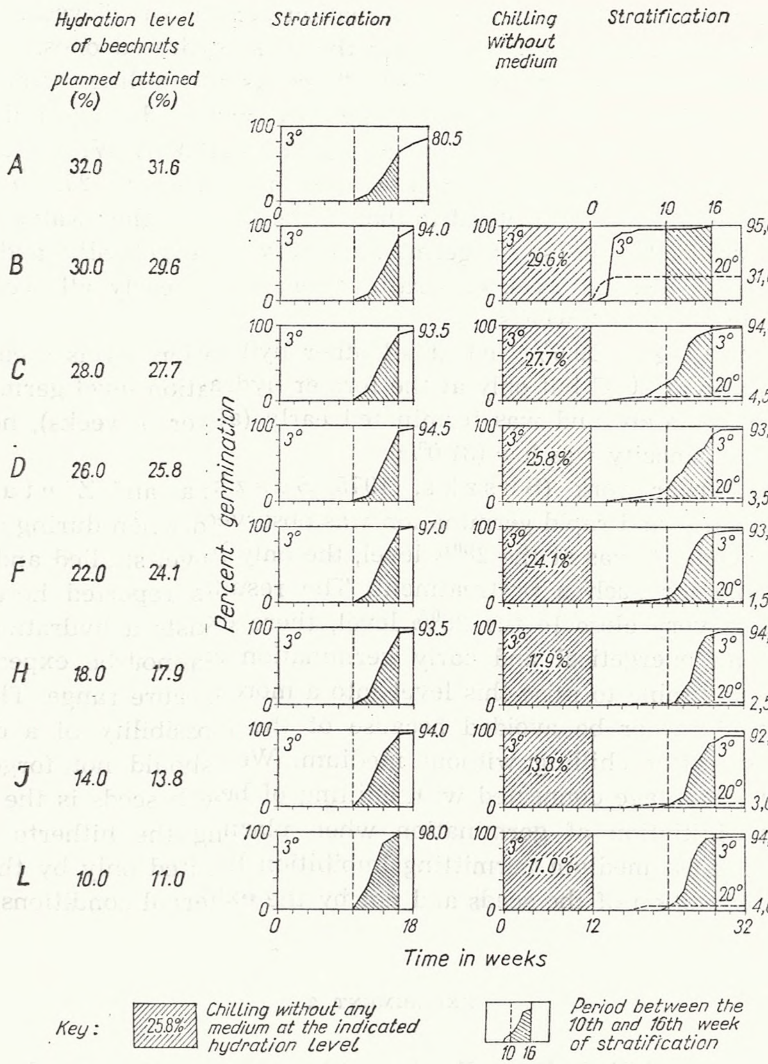


Fig. 1. Experiment 1. Course of germination during stratification at 3°C of beech (*Fagus silvatica* L.) seed dried after collection to different hydration levels. Stratification was started immediately after drying or after a 12-weeks period of chilling at 3°C without any medium and at the succesively decreasing hydration levels. In the latter case seeds were also stratified at 20°C

From these data we can conclude that partial drying never reduced the germinability of seeds because even in the range 19.6 - 11.0% of water content it never fell below 93.5%. Only at the highest hydration level (31.6%) 80.5% of seed germinated. Stratification at 3°C started immediately after drying to the postulated hydration levels. The lower were these levels the more energetic was the course of germination. Start of germination never occured in these conditions earlier than after

10 weeks and the extent of the germination period was 6 weeks for the driest beechnuts, and 8 - 10 weeks for the most hydrated ones.

Beechnuts stratified at 3°C after 12 weeks of chilling without any medium germinated with a similar delay only, when during chilling the water content was at levels in the range 11.0 - 19.9%. With increasing hydration level germination started earlier but even at 27.7% it was still severely delayed. In contrast to that at the next higher water content level i.e. at 29.6% the seeds germinated very energetically and early, starting in the second week of stratification, and nearly all seeds germinating in the next 2 weeks.

After chilling at 29.6% and at all other hydration levels seeds were stratified also at 20°C but only at the former hydration level germination started immediately and was terminated early (after 3 weeks), however germinative capacity was low (31.0%).

In the earlier work (Suszka, 1975, Suszka and Zięta, 1976, 1977) this early and rapid germination was observed when during chilling the water content was at the 28% level, the only level studied and found as advisable for such a pretreatment. The results reported here show clearly that very close to the 28% level, there exists a hydration level at which an energetical and early germination cannot be expected. It would be advisable to raise this level into a more secure range. The 28% level should rather be avoided because of the possibility of a delayed germination after chilling without medium. We should not forget that the great advantage connected with chilling of beech seeds is the nearly immediate initiation of germination when placing the hitherto chilled seeds in a moist medium permitting imbibition limited only by the physiological condition of the seeds and not by the external conditions.

EXPERIMENT 2

Beech seeds chilled after collection without any medium at a hydration level of 28% for a period estimated with the help of the 10% germination rule (12 weeks) and afterwards dried rapidly to 10.1% of water content, and stored sealed over 4 weeks at −3°C, and rehydrated to 28% and chilled again for the same period as before and finally stratified at 3°C — germinate during this last treatment very energetically (in 3 weeks) and in a high percent (85.5%). Seeds stratified after the same succesion of treatments at 20°C instead of 3°C germinated even more rapidly (in 2 weeks) but in a somewhat lower percent (62.5%). The germination curves illustrating these statements are presented in Fig. 2, the other data in Table 5.

When comparing the germination curves after the double chilling treatments with that after the single chilling presented in Fig. 1 (variant

Table 5

Laboratory germination and seedling emergence in the nursery of beech (*Fagus silvatica* L.) seeds stratified after two chilling periods of 12 weeks each, interrupted by drying and a sealed low-temperature storage (Experiment 2)

Results obtained after second chilling at 3°C					
Onset of stratification	sowing in the nursery	germinative capacity depending on temperature of stratification		start and termination of germination or seedling emergence	seedling emergence
		temperature	germinative capacity		
date	date	°C	%	weeks	%
May 11th, 1977		3°C	85.5	0 - 3	
May 11th, 1977		20°C	62.5	0 - 2	
	May 11th, 1977			4.5 - 6	10.4

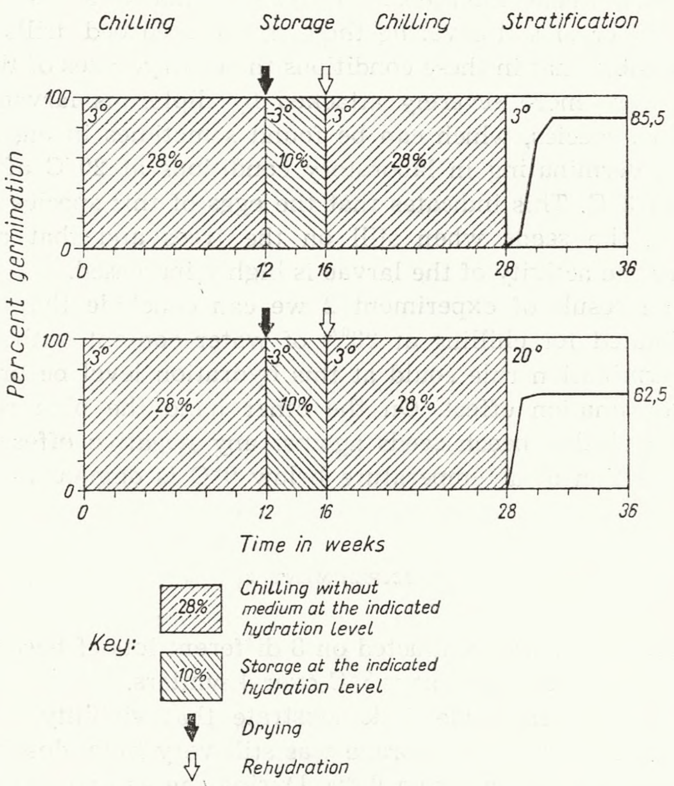


Fig. 2. Experiment 2. Course of germination during stratification of beech (*Fagus silvatica* L.) seed chilled after collection for 12 weeks at 3°C at the 28% hydration level without any medium. Afterwards beechnuts were dried to 10% of water content and stored in a sealed container at −3°C over 4 weeks. After storage they were rehydrated again to the 28% level and they were chilled at 3°C for the next 12 weeks. After a second chilling stratification in a sand/peat medium was started at 3° and 20°C

B) for the same seed material, an additive effect can be observed: the twice chilled seeds germinate earlier and at a slightly lower percentage at 3°C but in a much higher (62.5% instead of 31.0%) one at 20°C. All this suggests that at the 28% hydration level during chilling at 3°C the duration of this treatment could and should be longer than that estimated with the help of the 10% germination rule. A prolongation of this period could increase the percent of fully after-ripened seeds, because only these seeds are capable of a rapid germination at a higher temperature (here 20°C).

The twice chilled seed when sown on May 11th in the nursery produced after this late sowing date only 10.4% of seedlings. It is possible that the changing soil temperature was at that time i.e. in May and June no longer suitable for an energetic germination and seedling emergence, or that the seeds were already weakened by the total of 24 weeks of chilling, which made emergence of the germinated seeds through the 3 cm thick layer of soil covering them in the seed-bed drills impossible. It is also possible that in these conditions the embryo axes of the germinating seeds were more severely attacked by dipterous larvae of an unknown for us species, which can be found sometimes in big numbers in beech seeds germinating in laboratory conditions at 20°C after chilling, but never at 3°C. This indicates that the eggs of this species are already deposited in the seeds when still on the trees and that at a higher temperature the activity of the larvae is highly increased.

From the result of experiment 2 we can conclude that the chilling period estimated for chilling at 28% of water content with the help of the 10% germination rule could at this hydration level be prolonged for a better germination effect. On the other hand the high resistance of imbibed and chilled beech seeds against any negative effects of partial drying and action of a temperature below 0°C is demonstrated.

EXPERIMENT 3

This experiment was conducted on 3 different lots of beechnuts stored at a low water content level at −3°C over 4 winters.

Data presented in Table 6 demonstrate that viability tested immediately after termination of storage was still very high, despite the long-term storage and not far from 90%. During the subsequent rehydration to 28% and chilling at 3°C lasting 8.5 weeks a decrease of viability was observed of about 10 - 18%, depending on the seed lot. A similar decrease of germinability was observed after chilling during stratification tests at 3°C and a special test on moist filter paper and at the same temperature. It should be pointed out, that the extensions of the germination periods were shortened after chilling to 40 - 60% of those found for seeds tested

Table 6

Viability and germinability of 3 seed lots of *Fagus silvatica* L. used in experiment 3 after storage at −3°C over 4 winters followed by subsequent rehydration to 28% and chilling at 3°C lasting 8.5 weeks

	No. of seed lot	Seed viability %	Germinative capacity: on moist filter paper at 3°C %	Germinative capacity: during stratification at 3°C %	Start and termination of germination weeks
After storage at −3°C	237	86.7	86.5	84.5	6 - 16
	242	78.0	74.0	88.5	6 - 16
	243	92.5	88.5	92.0	6 - 16
After subsequent chilling at 3°C	237	not tested	not tested	59.0	0 - 4
	242	67.5	66.0	60.7	0 - 4
	243	70.5	not tested	78.7	0 - 6

Table 7

Germinability and extension of germination period of *Fagus silvatica* L. seeds used in experiment 3 after dry storage at −3°C over 4 winters, during stratification at various temperatures following rehydration and chilling at 3°C, the latter lasting 8.5 weeks

Temperature of stratification following chilling at 3°C °C	Germinative capacity			Mean germinative capacity %	Start and termination of germination		
	seed lot 237 %	seed lot 242 %	seed lot 243 %		seed lot 237 weeks	seed lot 242 weeks	seed lot 243 weeks
3°	59.0	60.7	78.7	66.1	0 - 4	0 - 6	0 - 6
5°	67.0	60.0	69.3	65.4	0 - 4	0 - 6	0 - 6
10°	62.0	58.7	67.3	62.7	0 - 2	0 - 2	0 - 2
15°	69.5	58.0	64.0	63.8	0 - 2	0 - 2	0 - 2
20°	38.0	41.3	48.7	42.7	0 - 4	0 - 3	0 - 3

immediately after storage i.e. to 4 - 6 weeks and germination started in the first week at 3°C.

When the already chilled beechnuts were stratified at different temperatures (Tab. 7) germinability was very similar in the range 3° - 15°C (mean values: 62.7 - 66.1%) but the obtained level was about 20% lower than that found immediately after storage and without any chilling. At 20°C germinability of the chilled seeds was much lower (mean: 42.7%). The positive effect of chilling is expressed by a radical shortening of the extension of the germination period (to 2 weeks at 10 - 15°C) and its immediate start after the onset of stratification at any of the temperatures applied. At the lower temperatures the germination period was more extended because of the temperature-restricted rate of radicle growth.

Nothing can be said about the ability of seeds germinating in the above mentioned temperatures to grow into seedlings when sown. During the stratification tests all germinating seeds are discarded at regular time intervals and they are not allowed to form seedlings. For this reason other experimental variants were included in which beechnuts chilled in

Table 8

Results of laboratory seedling emergence tests on *Fagus silvatica* L. seeds used for experiment 3. The sown seeds were held for 8 weeks at 3°C and afterwards at 20°C for 2 weeks or at 20°C since the sowing time. Before sowing beechnuts were stored dry at −3°C over 4 winters followed by rehydration at 3°C to 28% and chilling for 8.5 weeks at this temperature

No. of seed lot	Duration of both phases of seedling emergence test		Germination (radicles) during cold phase of the test	Seedling emergence during warm phase of the test		Sound non-germinated seeds	Empty, decayed and insect attacked seeds
	3°C	20°C		seedlings	start and termination of seedling emergence		
	weeks	weeks	%	%	days	%	%
237	8	2	51.0	65.0	0 - 3	1.0	34.0
242	8	2	59.0	74.0	0 - 7	3.0	21.0
243	8	2	65.0	63.0	0 - 3	1.0	36.0
237	–	–	–	–	–	–	–
242	–	12	–	41.0	0 - 42	0.5	58.5
243	–	12	–	44.0	0 - 35	2.0	53.0

Table 9

Final results of laboratory and nursery seedling emergence tests of *Fagus silvatica* L. seeds, sown in experiment 3 after dry storage at −3°C over 4 winters followed by rehydration and chilling without any medium at 3°C and at a 28% hydration level lasting 8.5 weeks

No. of seed lot	Laboratory seedling emergence test			Nursery sowings
	germination (radicles) after 8 weeks at 3°C	seedlings after 8 weeks at 3°C and transfer to 20°C	seedlings after sowing at 20°C only	seedlings
	%	%	%	%
237	51.0	65.0	–	7.6
242	59.0	74.0	41.0	7.8
243	65.0	63.0	44.0	10.0
Mean	58.3	67.3	42.5*	8.5

* Mean for 2 seed lots only.

the same way as above were not stratified but sown in laboratory conditions. Some boxes with the sown seeds were transferred from 3° to 20°C after a period similar to that of chilling. The results of these tests are shown in Fig. 3 and in Table 8. Simultaneously with these tests in controlled thermal conditions the chilled beechnuts were sown in the nursery. The results of the laboratory and field tests are collected in Table 9.

From these data and from the course of the germination curves in Fig. 3 it is evident that seeds sown at 20°C immediately after chilling grow into seedlings in a relatively low percent. It lasts about 35-days until seedling emergence is definitively finished. A major part of the non-emerged seedlings are killed by dipterous larvae atacking the embryo axes and very active at this relatively high temperature.

The same seeds when held after sowing at first for additional 8 weeks at 3°C, thus prolonging the duration of the period of low-temperature action on the imbibed seeds, and afterwards transferred to 20°C emerge in an extremely short period of time i.e. in 3 - 7 days in 63 - 74% (mean value 67.3%). When being still at 3°C the radicles are already 5 - 7 cm long and at the higher temperature only the hypo- and epicotyls grow rapidly.

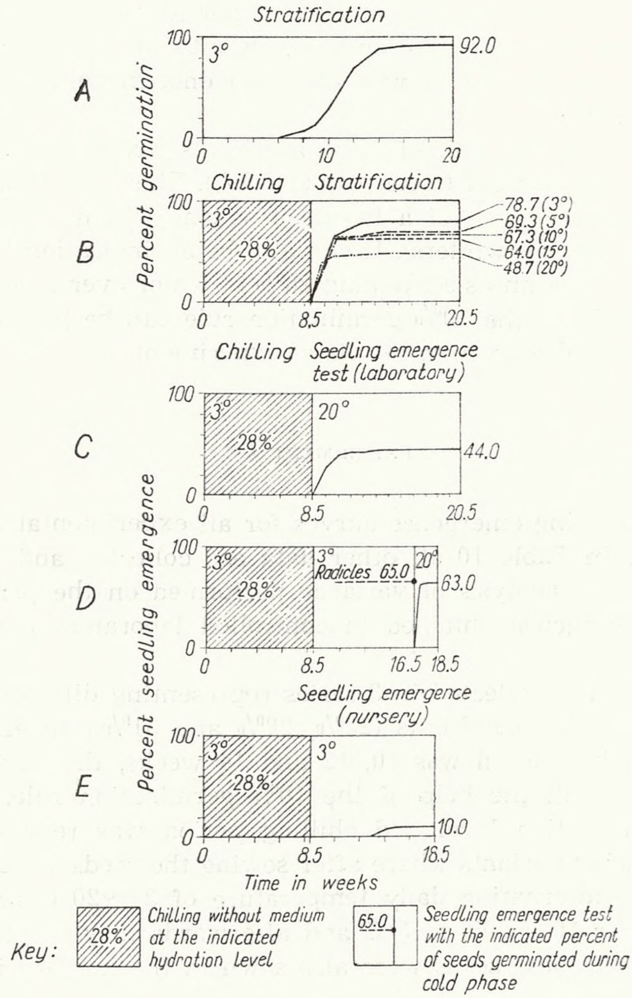


Fig. 3. Experiment 3. Course of germination during stratification and seedling emergence after laboratory and nursery sowings of beech (*Fagus silvatica* L., provenance Bistuszowa II) seed. Beechnuts were stored at 7.9 - 8.4% hydration level at −3°C over 4 winters. Stratification started immediately after termination of storage (A). Stratification at various temperatures (3° - 20°C) started after storage, rehydration to 28% and chilling without any medium at 3°C lasting 8.5 weeks (B). Seedling emergence from seed sown after chilling as above in laboratory conditions 1 cm deep at 20°C (C) or held after chilling and sowing at first for 8 weeks at 3°C and afterwards at 20°C (D). Seedling emergence in the nursery when beechnuts were sown immediately after chilling (E)

This seed behaviour is shown in Fig. 3 (D). It should be pointed out that the extraordinarily energetic seedling emergence was obtained by a combination of two periods at 3°C: the first at a hydration level restricted to 28% during chilling and the second after sowing in a wet medium allowing a full imbibition of the sown seeds, both periods lasting for nearly the same time i.e. for 8.5 and 8 weeks. In this way the seeds were held at the low temperature for a period twice as long as that indicated by the 10% germination rule. Despite the reduction of germinability caused by chilling it was still high enough being close to 70% (mean value 67.3%).

In the nursery the chilled only beechnuts grew into seedlings to a surprisingly low percent (mean value: 8.5%). This low seedling percent could be the consequence of a too deep sowing (3 cm) for seed stored relatively long (over 4 winters). It can also be an indication that in some cases chilling of beechnuts containing 28% of water over a period estimated with the help of the 10% germination rule can be insufficient. This is the general conclusion from results of experiment 3.

EXPERIMENT 4

In Fig. 4 seedling emergence curves for all experimental variants are demonstrated. In Table 10 all other data are collected and in Table 11 the results of the analysis of variance performed on the percent values of seedling emergence obtained in controlled laboratory conditions are presented.

All variants are collected in 3 series representing different hydration levels of the chilled beechnuts (25%, 28% and 31%). In each of these series the chilling period was 10, 12 and 14 weeks, the 12-week period was estimated with the help of the 10% germination rule. Each combination of hydration level and chilling period was represented by 3 laboratory sowing variants where after sowing the seeds were either held at 20°C, at an alternating daily temperature of 3°~20°C or they were held at first for 10 weeks at 3°C and afterwards they were transferred to 20°C. Besides these seeds were also sown in the nursery immediately after chilling.

We know already that the chilling period should be estimated separately for each seed lot, here the standard chilling time was fixed as 12 weeks. When we symbolize this period as x we can symbolize the 10--weeks and the 14-weeks periods as $x-2$ weeks or $x+2$ weeks. This would make comparable results of this experiment with results of similar experiments performed on other seed lots and in different years or on the same seed lots stored over various numbers of winters.

All variables in the experiment i.e. hydration levels, chilling periods

Table 10

Results of laboratory and nursery seedling emergence tests on *Fagus silvatica* L. seeds stored dry at −3°C over one winter and afterwards rehydrated to 25%, 28% and 31% and chilled for 10, 12 and 14 weeks (Experiment 4)

Conditions applied for seeds sown after chilling	Data concerning: germination, seedling %, start and termination of seedling emergence, sowing date	Water content of beechnuts during chilling at 3°C								
		25% chilling period			28% chilling period			31% chilling period		
		10 weeks	12 weeks	14 weeks	10 weeks	12 weeks	14 weeks	10 weeks	12 weeks	14 weeks
20°C	seedling %	1.5	1.5	4.0	63.0	67.0	84.0	42.5	61.0	80.0
	start and termination, days	7 - 21	7 - 21	7 - 14	0 - 14	0 - 14	7 - 14	10 - 42	0 - 32	7 - 21
3°~20°C	seedling %	4.5	12.5	13.0	90.5	88.5	91.5	95.5	87.5	95.0
	start and termination, days	21 - 42	28 - 35	21 - 49	14 - 32	14 - 35	14 - 28	14 - 42	14 - 28	14 - 35
3°C, 10 weeks + 20°C, 2 weeks	germination % (after 10 weeks at 3°C)	70.0	64.0	70.0	89.0	90.0	91.0	91.0	83.0	92.0
	seedling %	84.0	84.0	70.0	84.0	86.0	85.0	93.0	89.0	95.0
	start and termination, days	0 - 14	0 - 10	0 - 14	0 - 4	0 - 3	0 - 4	0 - 7	0 - 7	0 - 3
Nursery	seedling %*	2.8	4.4	8.8	54.8	9.2**	56.0	46.4	49.2	50.6
	date of sowing (1977)	April 16th	May 12th	May 25th	April 30th	May 14th	May 28th	May 6th	May 20th	June 3rd

* Included are seedlings lost during the first vegetation period.
** Accidental result, cause unknown.

Table 11

Analysis of variance calculated for percentage values of seedling emergence in laboratory conditions of experiment 4, after the Arcsin percentage transformation

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	*F*
Variables	26	32,482.01	1,249.31	44.76**
Hydration levels (H)	2	17,259.11	8,629.56	309.19**
Chilling periods (C)	2	159.37	97.68	3.50*
Treatments (T)	2	8,135.21	4,067.60	145.74**
H×C	4	275.20	68.80	2.46**
H×T	4	5,747.93	1,436.98	51.49**
C×T	4	383.47	95.87	3.43*
H×C×T	8	485.72	60.72	2.18 NS
Replications	1	3.47	3.47	0.12 NS
Error	26	725.62	27.91	
Total	53	33,211.10		

NS Not significant
* Significant at 5.0% level.
** Significant at 1.0% level.

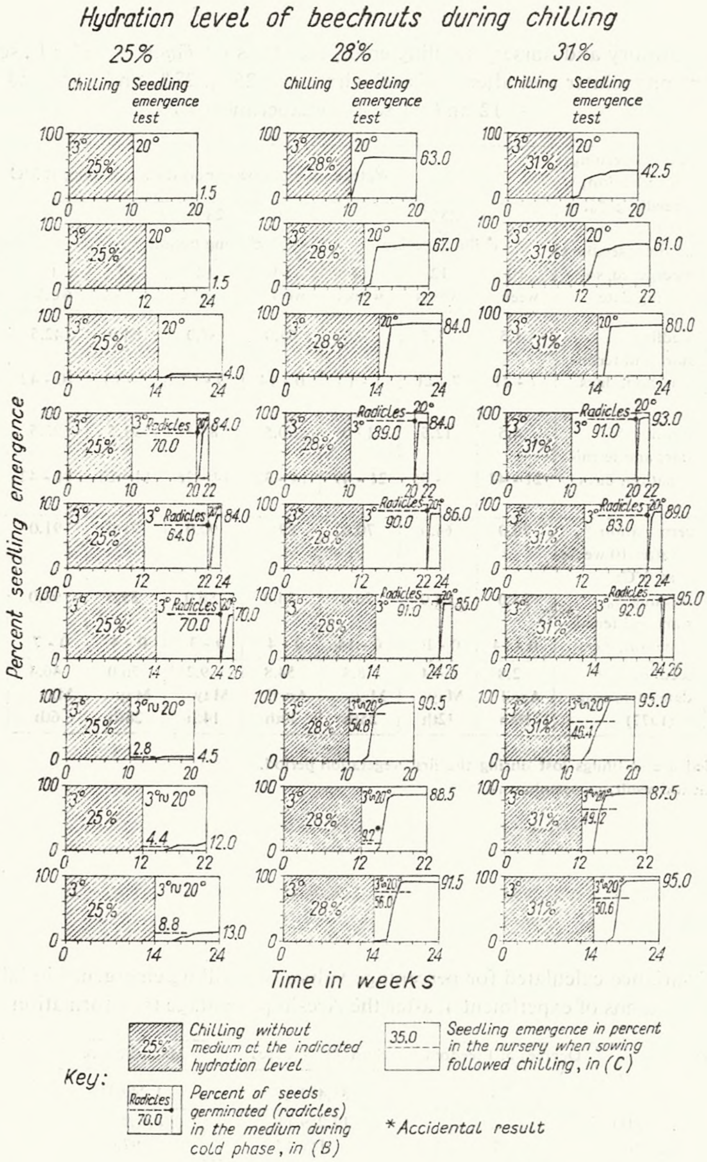


Fig. 4. Experiment 4. Course of seedling emergence of beech (*Fagus silvatica* L.) seed stored after collection and drying to the 11.0% hydration level over one winter at −3°C. After storage beechnuts were rehydrated and chilled at 25%, 28% and 31% hydration levels for 10, 12 and 14 weeks. Afterwards they were sown in laboratory conditions 1 cm deep and the sowing boxes were placed at 20°C (A), or at first for 10 weeks at 3°C and afterwards at 20°C (B), or at an alternating temperature 3∼20°C (C). Seedling emergence obtained in the nursery when beechnuts were sown immediately after chilling is indicated in (C)

Table 12

Final results of seedling emergence tests on *Fagus silvatica* L. seed used in experiment 4, sown in laboratory conditions after storage over one winter at −3°C, followed by rehydration to different hydration levels and chilling at 3°C for 10, 12 and 14 weeks without any medium. The 12 weeks chilling period was estimated with the help of the 10% germination rule. The reason for small differences with data in Table 11 is that for the needs of the statistical analysis all data in Table 12 are based on 2 replicates. Small letters indicate germinative capacity values not differing at the 5% significance level

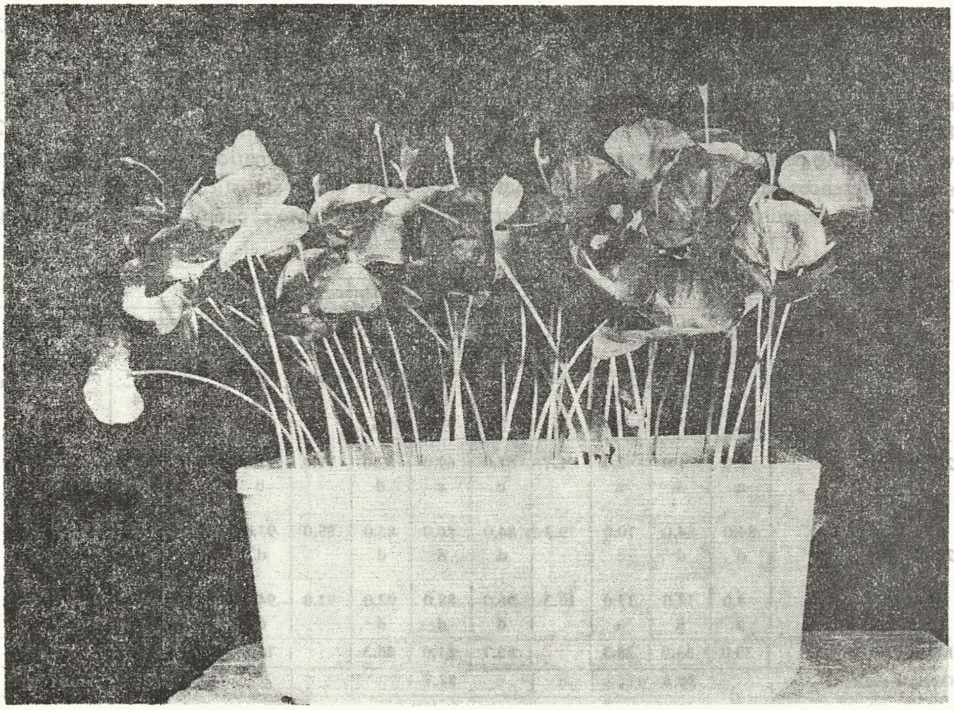
Conditions applied for seeds sown after chilling	Seedling emergence in %												Overall mean
	25% of water content				28% of water content				31% of water content				
	duration of chilling period in weeks			mean	duration of chilling period in weeks			mean	duration of chilling period in weeks			mean	
	10 %	12 %	14 %	%	10 %	12 %	14 %	%	10 %	12 %	14 %	%	%
20°C	2.0 a	1.0 a	2.0 a	1.7	62.0 c	69.0 c	82.0 d	71.0	41.0 b	63.0 c	82.0 d	62.0	44.9
3°C 10 weeks 20°C+2 weeks	84.0 d	84.0 d	70.0 c	79.3	84.0 d	86.0 d	85.0 d	85.0	93.0 d	89.0 d	95.0 d	92.3	85.5
3°~20°C	4.0 a	14.0 a	13.0 a	10.3	96.0 d	88.0 d	92.0 d	92.0	94.0 d	85.0 d	96.0 d	91.7	66.1
Mean	30.0	33.0	28.3		80.7	81.0	86.3		76.0	79.0	96.0		
Overall mean	30.4				82.7				82.0				

and the thermal treatments after chilling were found as significant sources of variation at the 5.0% level, the first and the last of them also on the 1.0% level. This is supported by data in Table 12, where the overall mean for seedling emergence obtained for the 25% hydration level differs sharply from those for both the higher hydration levels. Similarily the mean for treatments is generally very high for the two-step thermal treatment (3°C 10 weeks, afterwards 20°C), in contrast to the much lower means for the 20°C and the alternating 3°~20°C treatments. Within each hydration level the different chilling periods does not differentiate seedling emergence with the exception of the 31% level where the higher mean for the 14-weeks period differs from those for both the shorter periods.

A comparison of all individual percentage values for seedling emergence, performed with the help of the Newman-Keuls test at the 5.0% level of significance, divides them into 4 clearly separated groups of experimental variants (a, b, c and d in Tab. 12).

It was hoped to find whether the chilling pretreatment can be combined with constant high temperature or with an alternating or a two--steps one after sowing, assuring high percentage of emerged seeedlings. The best case would be such a combination of hydration levels and chilling period which would result in the highest possible seedling emergence in all thermal conditions including the nursery sowings.

It was found that after chilling at the 25% hydration level very low



Phot. K. Jakusz

Fig. 5. Seedling emergence of beech (*Fagus silvatica* L.) seed sown in laboratory conditions after dry-cold storage over one winter. The seeds were chilled at a 31% hydration level for 14 weeks at 3°C and afterwards they were sown and the boxes were held for the first 10 weeks at 3°C. In that time seeds germinated under the surface of the sowing medium. Seedlings emerged immediately after transfer of the boxes to 20°C

percentage of seeds grew into seedlings in the constant high temperature (20°C) and in the alternating one (3°~20°C). When the sown seeds were held at 3°C for 10 weeks a subsequent increase of temperature to 20° resulted in a high-percent and relatively energetic seedling emergence. This treatment assured for both higher hydration levels a high-percent and extremely energetical seedling emergence with the best results when chilling was performed at the 31% hydration level. In such thermal conditions seedlings emerged in the first 3 - 7 days in not less than 84.0% (Fig. 5). When temperature after sowing was alternating but without any preceding cold treatment similar effects were obtained when hydration level during chilling was 28% or 31% but seedling emergence started after 14 days and was terminated 14 - 28 days later.

In this way only 2 combinations of hydration level and chilling period could be found assuring a very effective seedling emergence during all 3 laboratory thermal treatments applied, but also in the nursery in the changing and alternating thermal conditions of the soil: 28% and 31%

of water content during chilling extended by 2 weeks, compared with the chilling period estimated with the help of the 10% germination rule alone, i.e. in this case after 14 weeks of chilling.

It should be pointed out that satisfactory seedling emergence in the nursery (50% or more) was obtained for both higher hydration levels (28% and 31%) irrespective of the duration of the chilling period in the range $(x-2)$ to $(x+2)$ weeks. This effect was not dependent on sowing time which was earliest on April 30th and latest on June 3rd, the longer chilled beechnuts being always sown latest.

Basing on the results of experiment 4 we can conclude that beech seeds become resistant against the negative action of moderately high (20°C) constant temperature when during chilling at 3°C the hydration level is 28% as in our earlier work or it is increased to 31%, but the chilling period is 2 weeks longer than that estimated with the help of the 10% germination rule during a control stratification at 3°C. In these conditions the best effects can be also expected concerning seedling emergence at alternating temperature and at the higher constant one (20°C), when the latter is preceded by a period of low-temperature (3°C) action on the already fully imbibed seeds.

DISCUSSION OF RESULTS

For some years already many efforts are devoted in the Institute of Dendrology in Kórnik (Suszka, 1975, Suszka and Zięta, 1976, 1977) to develop a new method of beechnuts pretreatment which would make an energetical and high-percent seed germination and seedling emergence possible. This should be obtained after Spring sowings in outdoor seedbeds or in the nursery. The new method should be suitable not only for freshly collected beechnuts stored over one winter but also for those stored at controlled water content and temperature conditions over 2, 3, 4 and even more winters (Suszka, 1966, 1974; Bonnet-Masimbert and Muller, 1975). The other requirements of such a pretreatment are:

— the whole pretreatment should be performed in controlled conditions to assure its repeatability and to provide a proper course of the after-ripening processes,
— the method should be suitable for seed lots of different provenances, and differing in the still unsatisfied low-temperature requirements for after-ripening,
— difference between seed viability before and after treatment, germinative capacity and ability of seedlings to emerge should be as low as possible,
— the pretreated beechnuts should germinate after sowing and grow into

seedlings in the highest possible percent, irrespective of the initial low, high or alternating soil temperature,

— when to avoid damage caused by late frosts late sowings are used the already relatively high soil temperature should not harm in any way germinability and seedling emergence,

— after treatment beechnuts should be ungerminated and superficially dry to make machine sowing possible.

The method elaborated so far consists of chilling beechnuts at 3°C without any medium and at a carefully maintained 28% (fresh weight basis) hydration level. When needed, especially in the case of beechnuts stored before chilling at a low water content (usually 9 - 10%), they should be rehydrated at 3°C to 28% which needs about 4 - 5 days, when beechnuts are sprinkled twice a day with sufficient amount of water and throughly mixed, this permits all water to be quickly imbibed.

The 28% hydration level corresponds to the water content of beechnuts freshly collected in not too wet Autumns just after falling off the trees. In a series of chilling treatments of different duration (Suszka, 1975) it was found, that chilling can be extended much over the time needed during normal moist stratification at 3°C in a sand/peat medium for the start of germination. At the 28% of water content seeds studied in 1975 did not germinate even when chilling was extended to 126 days, though during normal stratification germination was already nearly finished. After transfer to moist-warm (20°C) conditions germination was started the earlier and the more energetically, the closer the transfer was to the day when during normal moist-cold stratification in the sand/peat medium 10% of this highly viable seed material germinated. This period (10% g.p. — 10% germination period) can differ greatly for various lots of beech seeds and has to be estimated separately for each of them.

The proper duration of the chilling period at the 28% hydration level was subject to a special study (Suszka and Zięta, 1976) and it was found that shortening or extending the chilling period estimated as above reduces thereafter germinative capacity of beech seeds in stratification conditions at 20°C. At 3° only a 3-weeks extension excerts similar negative effects.

When these studies were continued (Suszka and Zięta, 1976) it was found that the chilling method works well in the case of beechnuts stored over 3 winters and that after chilling the rate of germination and germinability depended on temperature, being highest at 3°C and lowest at 20°C (extremes of the studied temperature range). In the nursery sowing of beechnuts immediately after chilling resulted in that year in a 49 - 57% seedling emergence.

The studies reported in this paper have shown that there exists some risk of failure when fixing rigidly to 28% the hydration level during chilling, whose duration was estimated according to the 10% g.r. In the experiment 1 it was found that very close to the 28% value there lies a critical level of water content, below which after chilling germination does not start at low temperature immediately but is seriously delayed. In the same conditions but at a stratification temperature of 20°C instead of 3°C it is reduced to an unsignificant percent. It would therefore be reasonable to chill beechnuts at a somewhat higher hydration level. Simultaneously the chilling period should be extended to avoid an untimely germination.

Results of experiment 2 demonstrate the fact that germination is improved when at the 28% hydration level to the chilling period (10% g.r.) another one is added, though both chillings are separated by drying of beechnuts and a short-term storage at low temperature. This improvement was very distinct when stratification temperature after chilling was increased to 20°C. This is an indication that duration of the chilling period estimated by the 10% g.r. can be insufficient at the hydration level mentioned above.

In experiment 3 it was shown that after chilling (hydration level 28%, duration 10% g.r.) germinability (declining during stratification with temperature increasing from 3° to 20°C) can be radically improved as well as the seedling emergence when after chilling beechnuts are sown in a moist medium and are held at 3°C for a period as long as that of chilling. In that time seeds germinate (radicles only) under the surface of the sowing medium but after the temperature is increased to 20°C seedling emergence runs in 7 - 10 days. The same seed material when sown after chilling but without any additional cold treatment in the nursery (May 3rd) grew into seedlings only in 7.6 - 10.0%. This could indicate that chilling period sufficient for a satisfactory germination of radicles at 3°C is insufficient for an energetic and high-percent germination and seedling emergence in the already rather high though alternating soil temperature in May. On the other hand it should be taken into account that the depth of the sowing drills applied in our work in the nursery (3 cm) can be too big. T y s h k e v i c h (1977) reports that Autumn sowings of beechnuts should be covered in Autumn 3 - 4 cm high but in Spring only 2 cm. It is possible that seeb used in this experiment after 4 winters of low-temperature storage was already weakened. Though germinating and emerging well in laboratory sowings where they were covered with 1 cm of sand, they were no more able to pierce through the nearly 3 cm cover of sandy loam in the outdoor seedbeds.

In experiment 4 in laboratory and nursery conditions an energetic and high-percent seedling emergence (82 - 96% and 48.2 - 56.0% respectively) was obtained for seeds stored over one winter, when hydration level of beechnuts was either 28% or 31%. In the nursery the emergence level indicated above was obtained even when the chilling period preceding sowing was 2 weeks shorter than that estimated (10% g.r.) for this seed material, and when the sowing date was early (end of April or early May). However, the results in the nursery were not worse even when duration of chilling was extended 2 weeks over the 10% g.p. but this could be tested only when sowing date was relatively late (end of May, early June).

Such results were obtained in the thermal and soil moisture conditions of the nursery in Kórnik in 1977. In another year or in other weather conditions the result could be different. For this reason much more important are results obtained in experiment 4 in controlled laboratory conditions, where beechnuts chilled for $(x-2)$ weeks, x weeks and $(x+2)$ weeks (x being the 10% g.p.) were sown and held in some variants at 3°C for 10 weeks before the temperature was increased to 20°C. At the lower temperature most seeds germinated under the surface of the sowing medium and the mean length of radicles approached 7 - 8 cm. After transfer to 20°C seedlings emerged in 84 - 95% in 3 - 7 days when the hydration level during chilling was 28% or 31% and its duration was from $(x-2)$ to $(x+2)$ weeks i.e. 10 - 14 weeks. In the other series of variants of experiment 4 beechnuts were sown immediately after chilling in constant high (20°C) or alternating temperature (3°$\sim$20°C). Here satisfactory seedling emergence was obtained also after chilling at both the higher hydration levels (28% and 31%) and after all variants of chilling duration for the alternating thermal conditions. When the after-sowing temperature was 20°C only $(x+2)$ weeks of chilling assured a satisfying result. This means that the only combinations assuring extremely good seedling emergence are 28% or 31% of water content of beechnuts during chilling lasting $(x+2)$ weeks.

We can suggest that an additional cold-moist treatment of beech seeds, after-ripening at first at 3°C during chilling without medium over a period lasting $(x+2)$ weeks, would be beneficial assuring a rapid seedling emergence in the nursery even when after sowing the thermal conditions of the nursery soil at the sowing depth would be very different (warm, cold at first for a longer period or alternating).

The aim of further studies should be to find the proper conditions for the additional cold treatment and to see if it could not be replaced by sowing the already chilled beechnuts in early Spring, when the soil is still cool and will remain so for some weeks.

Acknowledgement

I would like to express my thanks to Mrs. A. Kluczyńska for her highly effective technical assistance in the experimental part of this work.

SUMMARY

It was found that the rules for the new presowing treatment elaborated earlier (Suszka and Zięta, 1977) in the Institute of Dendrology in Kórnik for beech (*Fagus silvatica* L.) seed should be corrected. It would be advisable to increase the water content of beechnuts during rehydration at 3°C following storage at a reduced water content, and during the sebsequent chilling without any medium at the same temperature to 31% instead of the earlier recommended 28%. This would eliminate the risk of insufficient after-ripening of seeds. Beneficial is also an extension of the chilling period to $x+2$ weeks, where x is the duration in weeks of the period needed during a normal control stratification in a sand/peat medium at 3°C until 10% of seeds germinate. The x value can differ in various seed lots and has to be estimated separately for each of them. It was also found that even if these requirements were fulfilled the seeds need after chilling an additional period at 3°C but with an unrestricted access of water from the medium, to be fully after-ripened. Duration of the additional cold-moist treatment tested in this study was $x-2$ or x weeks and in that time a big part of the seeds germinated under the surface of the sowing medium and the length of radicles reached 7 - 8 cm. The low temperature repressed efectively elongation of hypocotyls thus hindering seedling emergence. When temperature was increased to 20°C seedlings emerged more than 90% in 3 days. The aim of further experimental work will be to find the proper duration of the additional cold period. It is probably much shorter than applied in this work. It seems also that in nursery conditions this additional treatment could be replaced by sowing the already chilled beechnuts when soil temperature at the sowing depth is still low in Spring and will remain so for some weeks.

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BOLESŁAW SUSZKA

Wschody nasion buka zwyczajnego (Fagus silvatica L.) przysposobionych do kiełkowania przez chłodzenie bez podłoża przy kontrolowanym poziomie uwodnienia

Streszczenie

Stwierdzono, że zasady nowej metody przedsiewnego traktowania nasion buka zwyczajnego (*Fagus silvatica* L.) opracowanej w Instytucie Dendrologii PAN w Kórniku (Suszka i Zięta, 1977) powinny ulec pewnej korekcie. Wskazane jest więc podwyższenie zawartości wody w bukwi do 31%, zamiast zalecanych wcześniej 28%, podczas koniecznego po przechowaniu w stanie podsuszonym ponownego jej uwadniania oraz podczas następującego po tym chłodzenia bez jakiegokolwiek podłoża w 3°C. Pozwala to na eliminację ryzyka niepełnego ustąpienia spoczynku. Korzystne jest również przedłużenie okresu chłodzenia do $x+2$ tygodni, gdzie x jest mierzonym w tygodniach okresem koniecznym podczas normalnej kontrolnej stratyfikacji orzeszków buka w 3°C w torfowo-piaskowym podłożu do ukazania się łącznie 10% nasion kiełkujących. Okres ten musi być ustalany oddzielnie dla każdej jednolitej partii nasion buka. Stwierdzono również, że nawet w przypadku spełnienia tych warunków nasiona wymagają po chłodzeniu dodatkowego okresu czasu w 3°C przy nieograniczonym już dostępie wody, aby spoczynek mógł całkowicie ustąpić we wszystkich żywotnych nasionach danej partii bukwi. W pracy uwzględniono okresy dodatkowego oddziaływania chłodu rzędu $x-2$ lub x (odpowiednio 8 lub 10) tygodni, w którym to czasie większość nasion skiełkowała pod powierzchnią podłoża wysiewnego, a długość korzeni dochodziła do 7 - 8 cm. Niska temperatura powstrzymywała jednakże skutecznie wydłużanie się hypokotyli, a w efekcie i wschody. Po podwyższeniu temperatury do 20°C nasiona wschodziły w ponad 90% w ciągu 3 dni. Celem dalszych badań będzie ustalenie koniecznego czasu trwania dodatkowego okresu chłodnego. Wiele przemawia za tym, że będzie to okres znacznie krótszy od zastosowanego w tej pracy. Wydaje się również, że w warunkach szkółkarskich ten dodatkowy zabieg będzie mógł być zastąpiony przez wysiew uprzednio chłodzonej bukwi wczesną wiosną, gdy temperatura gleby jest na głębokości wysiewu ciągle jeszcze niska i pozostanie taka jeszcze przez pewien okres czasu.

БОЛЕСЛАВ СУШКА

Всхожесть семян бука лесного (Fagus silvatica L.) подготовленных к прорастанию путем охлаждения без субстрата при контролируемом уровне влажности

Резюме

Найдено, что некоторые положения нового метода предпосевной обработки семян бука лесного (*Fagus silvatica* L.), разработанные в Институте Дендрологии ПАН в Курнике (Suszka, Zięta 1977), должны подвергнуться некоторой корректировке.

После периода хранения семян бука в подсушенном состоянии целесообразным является увеличение содержания воды в семенах до 31% вместо рекомендуемых ранее 28%, а затем охлаждение без какого-либо субстрата до 3°C. Это позволяет исключить риск неполного выхода семян из состояния покоя. Положительно сказывается и удлинение периода охлаждения до $x+2$ недели, где x — это выраженный в неделях период нормальной контрольной стратификации орешков бука при 3°C на торфяно-песчаном субстрате до появления 10% прорастающих семян. Этот период необходимо установить отдельно для каждой однородной партии семян бука. Констатировано также, что даже в случае соблюдения этих условий семена требуют после охлаждения дополнительного содержания при 3°C, при неограниченном уже доступе воды, чтобы все жизнеспособные семена данной партии могли полностью выйти из состояния покоя. В работе были взяты во внимание периоды дополнительного воздействия низкой температуры порядка $x-2$ или x (соответственно 8 или 10) недель, в течение которых большинство семян проросло под поверхностью посевного субстрата, а длина корней достигла 7 - 8 см. Однако низкая температура тормозила действенным образом удлинение гипокотилей, а в следствии этого и появление всходов. После повышения температуры до 20°C семена всходили в более чем 90% в течение 3 дней. Целью дальнейших исследований будет определение продолжительности времени дополнительного холодного периода. Это будет по всей вероятности период, значительно более короткий по продолжительности по сравнению с примененным в этой работе. Возможно, что в питомниках эту дополнительную процедуру можно будет заменить посевом предварительно охлажденных семян в почву, температура которой на глубине посева незначительна и сохранится такой в течение какого-то периода времени.