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Conditions for dormancy breaking and germination of European hophornbeam (*Ostrya carpinifolia* Scop.) seed

Abstract

Chmielarz P., 1990. Conditions for dormancy breaking and germination of European hophornbeam (*Ostrya carpinifolia* Scop.) seed. Arbor. Kórnickie, 36: 147–163.

The experiments were preceded by the segregation of seeds by floatation in water and in 96% ethanol into the following categories: full (sinking in water), half-full (floating in water and sinking in ethanol) and empty (floating in water and ethanol). Most effective for breaking of dormancy of full and half-full seeds was the warm-followed-by-cold stratification with the warm phase at 20°C lasting 4 weeks. After such stratification, germination ran best in a cyclically alternating temperature 3°~20°C (16+8 hours/cycle). The ethanol used for seed segregation was without effect on the germinative capacity, but this was valid only in the most effective conditions of stratification and germination. Of the half-full seeds only about 50% were able to germinate.

Additional keywords: stratification, seed segregation, floatation.

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INTRODUCTION

The genus *Ostrya* Scop. has nine species occurring in North and Central America, in eastern and southwestern Asia and in southern Europe. The European hophornbeam (*Ostrya carpinifolia* Scop.) occurs primarily on the Appenine peninsula and on the Balkans as well as on the Caucasus in Turkey and in the Mediterranean regions of Syria and Lebanon (Jalas, Suominen, 1976; Browicz, 1978; Boratyńska, 1982). It also grows well in Poland, beyond its natural range of distribution, propagating through seeds which mature well in our conditions though the trees fruit rarely (Bugała, 1979). Fruits of this hophornbeam are nutlets about 4–5 mm long. In the nutlets there are endospermless seeds in a state of deep dormancy, containing one, thick and erect embryo (Schopmeyer, Leak, 1974). According to Krüssmann (1964) nutlets of hophornbeam should be collected when not fully mature in the first days of September (in Germany) and immediately sown into the ground or stratified. Fully ripe nutlets, stored in a partially dried state should also be stratified. These observations are confirmed by Bärtels (1982). Panov (1962) recommends for the nutlets collected in Yugoslavia to use a warm-followed-by-cold stratification and determines the critical temperatures for both the thermal phases. In the warm phase a temperature higher than 15°C is needed and the cold phase should have a temperature below 8°C.

Nutlets of the closely related species to the European hophornbeam, namely those of *Ostrya virginiana* (Mill.) K. Koch, occurring in North and Central America require an 8-week warm stratification at a temperature of 20–30°C and then a further 20-week cold stratification at 5°C followed by a germination phase in a cyclically changing temperature of 10°~25°C (Schopmeyer, Leak, 1974).

Referring to these scant informations from the literature, studies were conducted on the cold and warm-followed-by-cold stratification systems for nutlets of European hophornbeam, as well as on the course of germination and on germinability after stratification in such thermal system (Exp. I). In view of the large proportion of empty and half-empty seeds in the lot obtained by us, the method of separating them in water (sinking of full seeds) and in ethanol (sinking half-full seeds and floating empty nutlets) was employed. The efficiency of these seed sorting methods and subsequent germination have been investigated in Experiments II and III.

MATERIALS AND METHODS

Origin of seeds

Nutlets of European hophornbeam used in the studies originate from central Italy, from locality Spello near Assisi (190 m elevation), that is from the western part of the range of occurrence of this species. Nutlets collected in Autumn 1988 were obtained by us on 11th January 1989 from the Società Agricola e Forestale per le Piante di Cellulosa e da Carta, located in Rome.

Handling of nutlets prior to stratification

The nutlets arrived in sealed polythene bags, in which we continued to keep them at −3°C for 35 days till 15th February 1989, i.e. to the day the experiment started.

Initial quality of the seeds

An evaluation of the moisture content and fullness of nutlets was made immediately after opening the bags. The moisture content was determined by drying the nutlets at 105°C for 24 hours (3 × 30 nutlets). The results obtained refer to the fresh weight of the whole nutlets. The moisture content was 15.4%.

For the estimation of seed quality use was made of the cutting test (4 × 50 nutlets). The following results were obtained:

full seeds	29.5%
empty seeds	67.5%
damaged seeds	3.0%
impurities	3.0%

The full seeds could be classified into two categories, full seeds and half-full seeds with incompletely formed embryos.

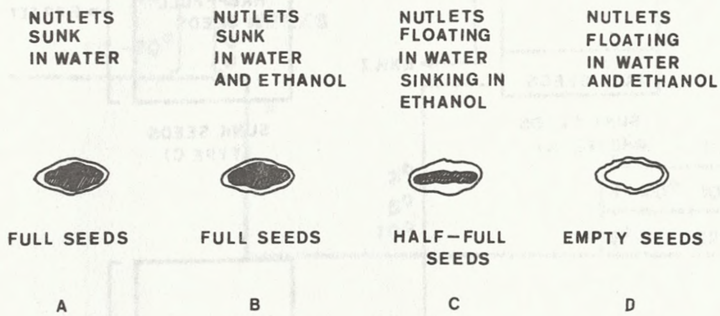

Fig. 1. *Ostrya carpinifolia* Scop. Transverse section of seeds of the various segregation classes

Seeds of type A and B (Fig. 1) differ in that the former were allowed to sink in water only while the latter (type B) sank first in water and then also sank in ethanol. Nutlets of type C contain half-full seeds, which floated in water and sank in ethanol (Fig. 1). After sinking in water or both water and ethanol the nutlets were allowed to air dry. Those which sank in ethanol were not washed in water after the ethanol treatment. Seeds of type D were completely empty and were rejected. Methods and results of seed segregation are presented in Fig. 2. The conditions for nutlets floatation and drying are presented in Table 1. For the studies on the stratification and germination of seeds only seeds of

Table 1

Ostrya carpinifolia Scop. Floatation and drying conditions

	Duration of flotation	Duration of drying	Temperature of drying
Water	5 min	19 h	21–23°C
Ethanol	5 min	1.5 h	21–23°C

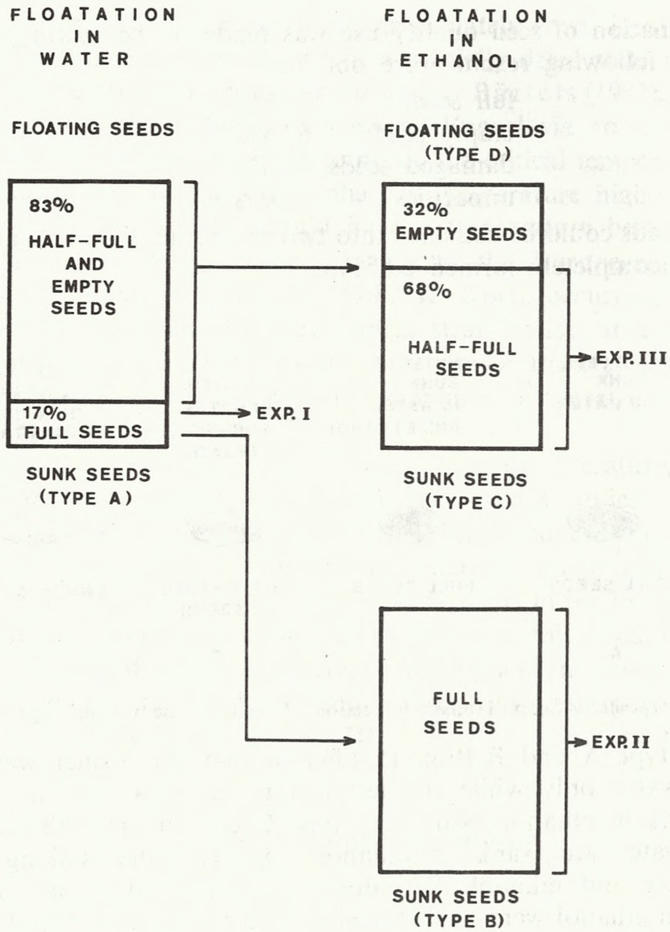

Fig. 2. *Ostrya carpinifolia* Scop. Scheme of seed segregation into fractions of full, half-full and empty seeds. Degree of fullness of seeds was checked by the cutting test

type A were used (exp. I). Seeds of type A and B were used to evaluate the influence of ethanol on germination (exp. II). The utility of half-full seeds of type C has been studied in experiment III, comparing them with those of type B.

Experimental design

Experiment I. Aim: To study the effectiveness of warm-followed-by-cold stratification system compared to exclusively cold stratification (full seeds, type A).

In the experiment use was made of the warm phase with a constant temperature of 20°C or an alternating temperature of 20°~30°C (16+8 h/cycle) lasting for 0, 2, 4, 6 and 8 weeks. The cold phase ran at 3°, 5° or 10°C, basically to the beginning of the germination period (Fig. 3). Germination tests after each stratification were conducted at 3° and 20°C for 10 weeks and at a cyclically alternating temperature of 3°~20°C (16+8 h/cycle) for 12 weeks.

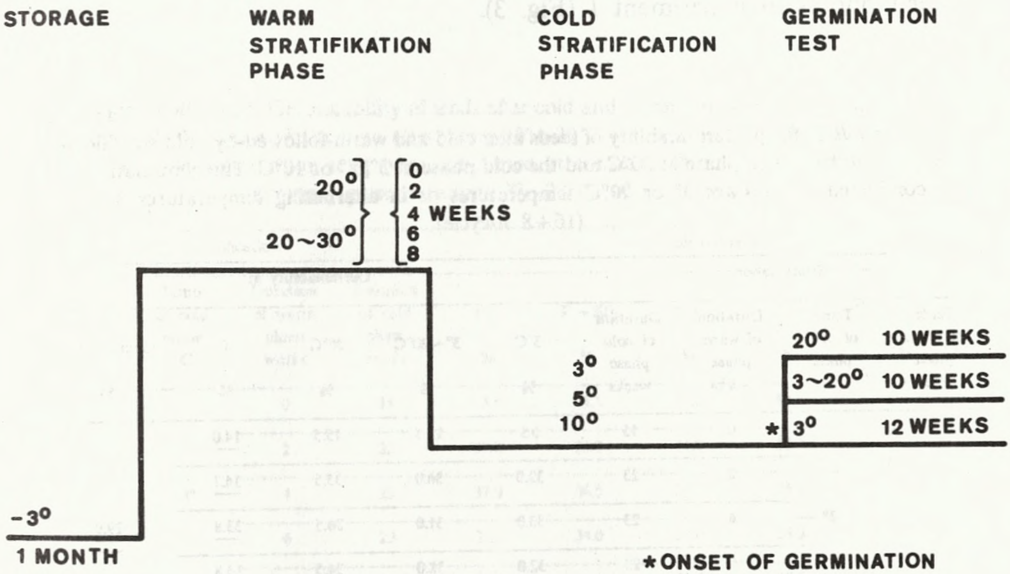

Fig. 3. *Ostrya carpinifolia* Scop. Design of Experiment I

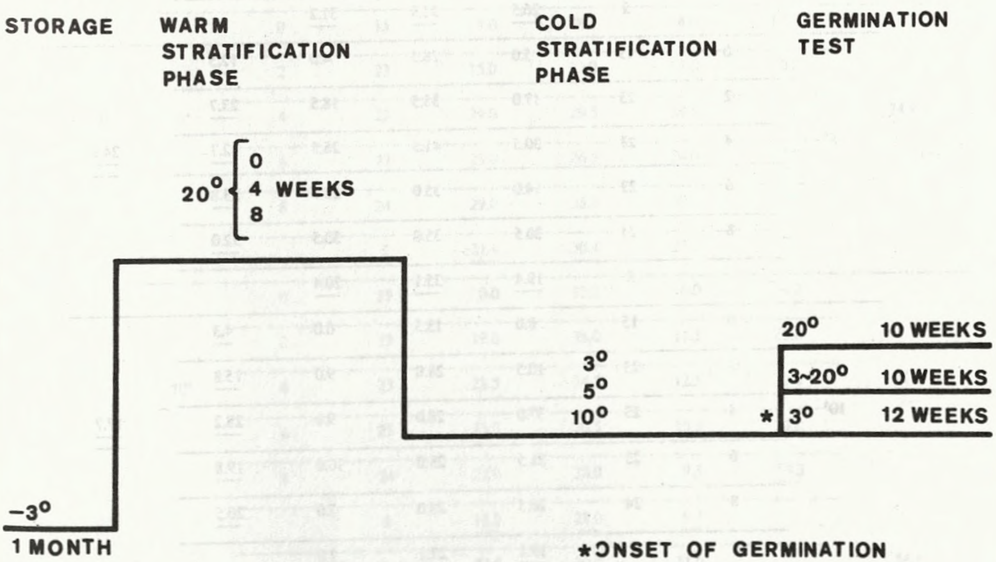

Fig. 4. *Ostrya carpinifolia* Scop. Design of experiments II and III

Experiment II. Aim: To evaluate the effect of ethanol, used for floatation of empty seeds, on the germination of full seeds (type B). Use was made of the cold and warm-followed-by-cold stratification, the warm phase at 20°C lasting 0, 4, or 8 weeks. The cold phase and the germination test were carried out as in experiment I (Fig. 3).

Table 2a

Ostrya carpinifolia Scop. Germinability of seeds after cold and warm-followed-by-cold stratification of nutlets with the warm phase at 20°C and the cold phase at 3°, 5° or 10°C. The germination tests were conducted at constant 3° or 20°C temperatures or in alternating temperatures 3°~20°C (16+8 h/cycle)

Stratification				Germinability at				
Temp. of warm phase °C	Temp. of cold phase °C	Duration of warm phase weeks	Duration of cold phase weeks	3°C %	3°~20°C %	20°C %	$\bar{x}$ %	Overal mean %
		0	15	5.5	21.5	15.5	14.0	
		2	23	33.0	36.0	35.5	34.7	
	3°	4	23	33.0	31.0	36.5	33.8	29.9
		6	23	32.0	38.0	34.5	34.8	
		8	24	29.0	33.0	34.5	32.3	
			$\bar{x}$	26.5	31.9	31.2		
		0	15	5.0	28.5	4.0	12.5	
		2	23	17.0	35.5	18.5	23.7	
	5°	4	23	30.5	41.5	26.5	32.7	24.9
20°		6	23	14.0	35.0	22.5	23.8	
		8	24	30.5	35.0	30.5	32.0	
			$\bar{x}$	19.4	35.1	20.4		
		0	15	0.0	13.5	0.0	4.3	
		2	23	10.5	28.0	9.0	15.8	
	10°	4	23	37.0	28.0	9.0	28.2	17.7
		6	23	21.5	28.0	10.0	19.8	
		8	24	26.5	28.0	7.0	20.5	
			$\bar{x}$	19.1	27.1	7.0		
			Overall mean	21.7	31.4	19.5		24.2

Experiment III. Aim: Evaluation of germinability of half-full seeds (type C).

The stratification and germination tests were run according to the scheme used in experiment II (Fig. 4).

Table 2b

Ostrya carpinifolia Scop. Germinability of seeds after cold and warm-followed-by-cold stratification of nutlets with the warm phase at an alternating 20°~30°C temperature and the cold phase at 3°, 5° or 10°C. The germination tests were conducted at constant 3° or 20°C temperatures or in alternating temperatures 3°~20°C (16+8 h/cycle)

Stratification				Germinability at				
Temp. of warm phase °C	Temp. of cold phase °C	Duration of warm phase weeks	Duration of cold phase weeks	3°C %	3°~20° %	20°C %	$\bar{x}$ %	Overall mean %
		0	15	5.5	21.5	15.0	14.0	
		2	23	37.0	35.0	35.0	35.7	
	3°	4	23	37.0	36.5	34.0	35.8	30.2
		6	23	31.0	34.0	34.0	33.0	
		8	24	29.0	34.0	35.0	32.7	
			$\bar{x}$	27.9	32.2	30.6		
		0	15	5.0	28.5	4.0	12.5	
		2	23	15.0	32.0	13.0	20.0	
20°~30°	5°	4	23	29.0	29.5	29.5	29.3	24.9
		6	23	29.0	26.5	34.0	29.8	
		8	24	29.0	35.5	39.5	33.0	
			$\bar{x}$	21.4	30.4	23.0		
		0	15	0.0	13.0	0.0	4.3	
		2	23	19.0	38.0	11.5	22.8	
	10°	4	23	28.5	34.5	12.5	25.2	18.6
		6	23	23.0	26.5	13.5	21.0	
		8	24	21.0	28.0	9.5	19.5	
			$\bar{x}$	18.3	28.0	9.4		
		Overall mean		22.5	30.2	21.0		24.5

After termination of the germination tests the seeds which did not germinate were in all experiments subjected to the cutting test. In all experiments each variant was replicated four times (4×50 nutlets). Seeds with roots at least 3 mm long were considered as germinated. In these studies seedling emergence was not evaluated, neither in the laboratory nor in the nursery. Results of experiments I and II were subjected to variance analyses and the significance of differences between means has been evaluated by the Duncan test at $\alpha = 0.05$ level.

RESULTS

DORMANCY BREAKING AND SEED GERMINATION (EXP. I)

The results concern full seeds, obtained by sinking nutlets in water (Type A) Tab. 2a i 2b.

No differences were observed in the germinability after using in the warm phase of stratification of the constant 20°C temperature or the alternating 20°C ~ 30°C (Table 2a and 2b). In view of the fact that the general means of germinability were almost identical (24.2% after 20°C and 24.5% after 20° ~ 30°C) no effort was made to evaluate statistical significance of this difference. For the other variables (i.e. for the duration of the warm phase of stratification, the temperature of the cold phase, the temperature of the germination test) a variance analysis was conducted (Table 3) and the Duncan test only for the constant warm phase of stratification at 20°C (Table 2a).

Table 3

Ostrya carpinifolia Scop. Variance analysis of germinability of seeds after warm-followed-by-cold stratification with the warm phase at 20°C lasting 0, 2, 4, 6 and 8 weeks and the cold phase at temperatures 3°, 5° or 10°C. The germination tests were conduced from the onset of germination in constant 3° or 20°C temperatures or in alternating 3° ~ 20° temperature (Exp. I)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Duration of warm stratification phase (A)	4	7 399.85	1 849.96	95.53**
Temp. of the cold phase (B)	2	3 167.86	1 584.93	81.79**
Temp. of germination (C)	2	3 087.08	1 543.54	79.70**
A × B	8	651.15	81.39	4.20**
A × C	8	1 141.71	142.71	7.37**
B × C	4	1 777.21	444.30	22.94**
A × B × C	16	580.24	36.26	1.87*
Error	135	2 614.42	19.37	
Total	179	20 419.52		

** Significant at 0.01 level
* Significant at 0.05 level

Compared with the exclusively cold stratification, the use of the warm phase was highly successful. The highest germinability was obtained when the warm phase lasted 4 weeks. Germinability dropped when the warm phase was extended to 6–8 weeks or shortened below 4 weeks (Fig. 5).

Of the three temperatures of the cold stratification phase tested (3°, 5° and 10°C) the highest germinability was achieved following the lowest temperature

Table 4

Ostrya carpinifolia Scop. Effect of various durations of the warm phase and temperatures of the cold phase, as well as temperatures of the germination test on the germinability of seeds (based on the numerical data presented in Table 2a). Different letters next to the mean values indicate that within the variable the means are significantly different at $\alpha=0.05$ (Exp. I)

Variable	Duration of warm phase of stratification				
	0 weeks	2 weeks	4 weeks	6 weeks	8 weeks
Mean germination %	10.3 c	24.7 d	31.6 a	26.8 c	28.3 b

Variable	Temp. of the cold phase of stratification		
	3°	5°	10°
Mean germination %	29.9 a	24.9 b	17.7 c

Variable	Germination temperature		
	3°	3° ~ 20°	20°
Mean germination %	21.7 b	31.4 a	19.5 c

of 3°C (Table 4, Fig. 5). The cold phase of stratification was usually terminated after radicles appeared. The cold phase, not preceded by the warm phase, lasted 15 weeks. After 2, 4 and 6 weeks of the warm phase of the warm-followed-by-cold stratification the cold phase was terminated after 23 weeks, and after an 8-week warm phase after 24 weeks.

After dormancy breaking the most effective germination temperature was the alternating one 3° ~ 20°C (Fig. 5); the seeds germinating there in the highest percentage and earliest. Less favourable were constant temperatures of 3° and 20°C (Table 4). In Fig. 6 the course of germination is shown after stratification with a 4-week 20°C warm phase.

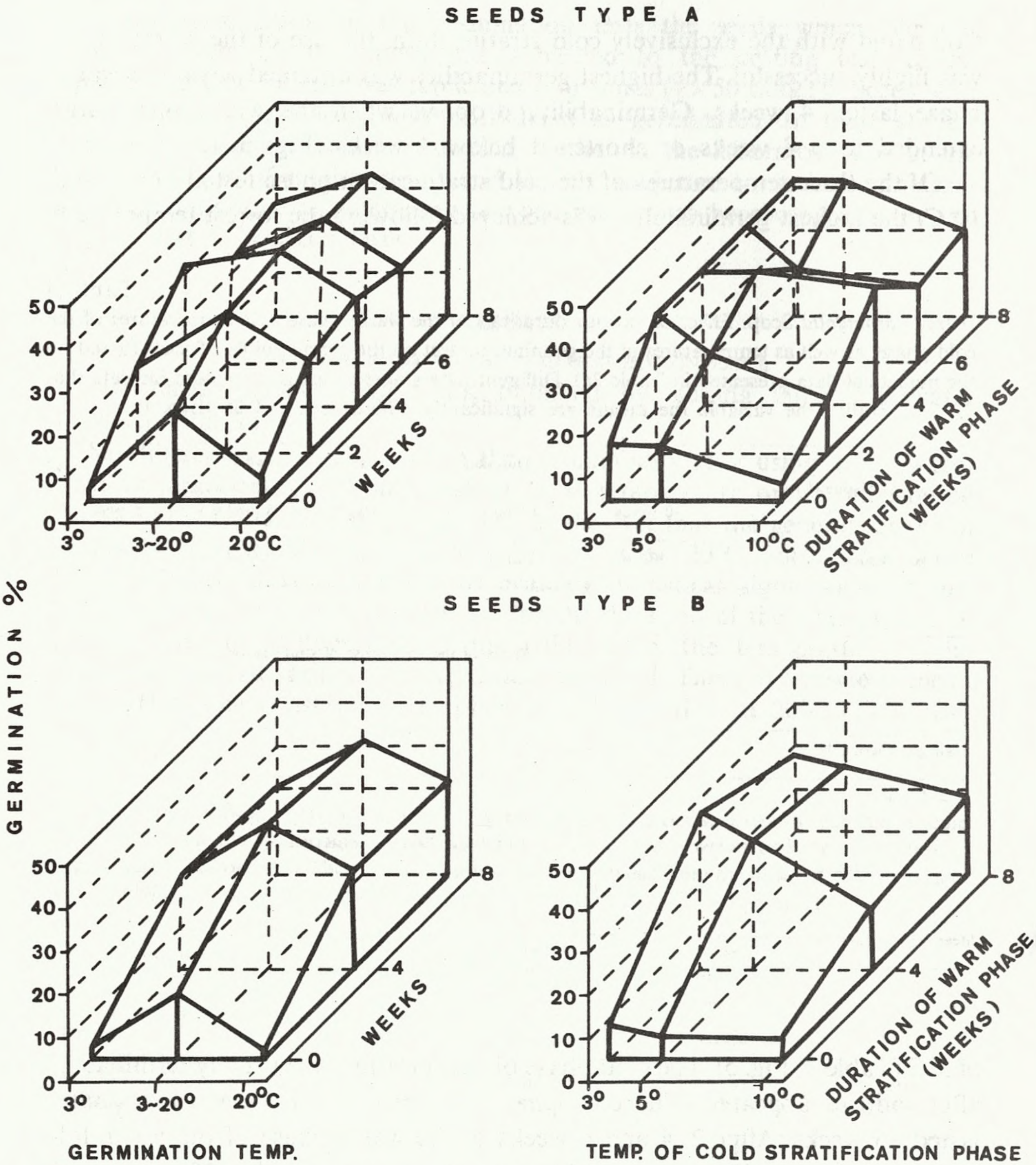

Fig. 5. *Ostrya carpinifolia* Scop. Germinability of seeds of type A (Exp. I) after warm-followed-by-cold stratification of nutlets with the warm phase at 20°C lasting 0, 2, 4, 6, and 8 weeks and the germinability of seeds of type B (Exp. II) with the warm phase at 20°C lasting 0, 4 and 8 weeks. The cold phase of stratification was always run at temperatures 3°, 5° or 10°C. The germination tests were run at constant temperatures of 3° and 20°C and in the alternating temperature 3°~20°C (16+8 h/cycle). Percentage values were referred to viable seeds on the day when germination tests were terminated

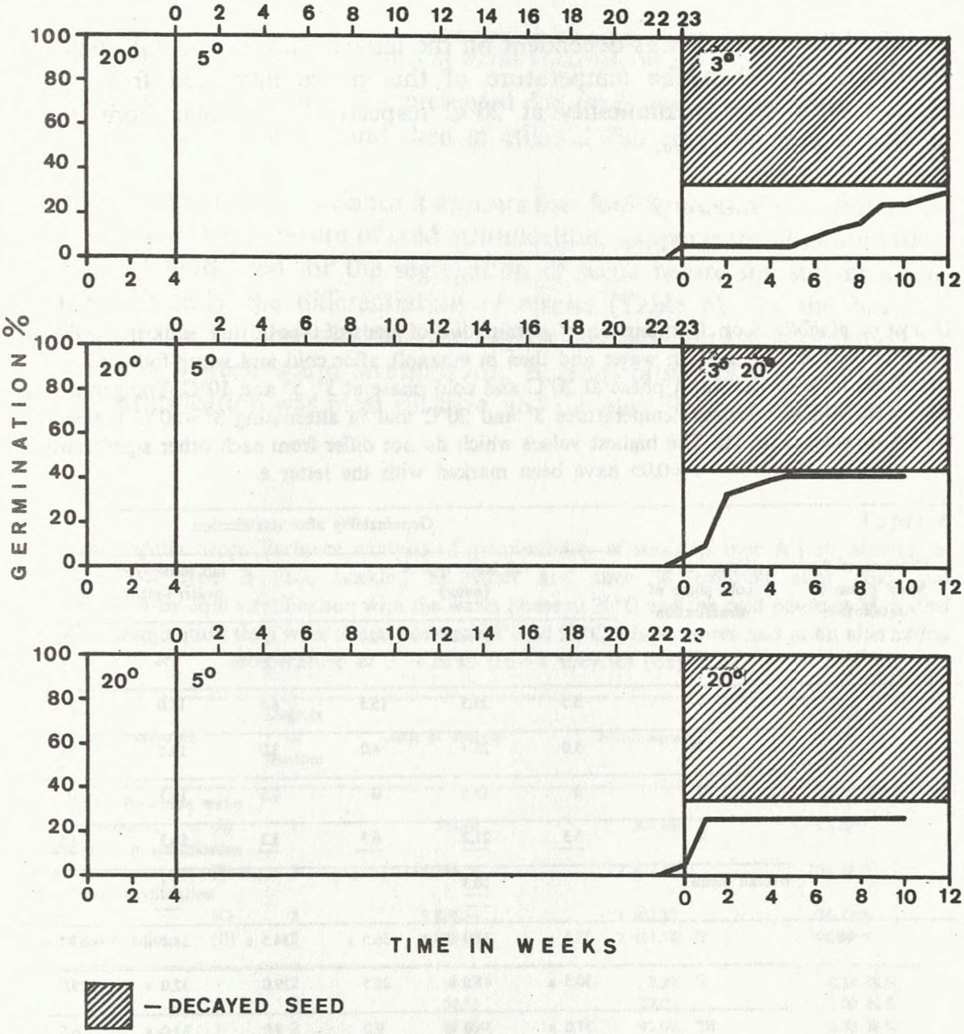

Fig. 6. *Ostrya carpinifolia* Scop. The course of seed germination after warm-followed-by-cold stratification with the warm phase at 20°C and the cold phase at 5°C. Germination tests were conducted in the alternating temperature of 3° ~ 20°C or in constant temperatures of 3° and 20°C. Percentage values were referred to the number of viable seeds on the day of termination of germination tests (full seeds of type A)

Most favourable in the germination test was alternating temperature in which the seeds germinated over 5 weeks, that is faster than in 3°C. In the 3° temperature the germination was extended over several weeks. Seeds germinating at 20°C were at first characterized by a high rate of germination, however the finally attained germinability was lower than at 3°C or at the alternating 3° ~ 20°C. From the data (Table 2a and 2b) it appears that germinability at 20°C was dependent on the temperature in the cold phase of stratification. When the temperature of this phase increased from 3° to 5° and 10°C the germinability at 20°C respectively declined from 31.2% to 20.4% and to 7.0%.

Table 5

Ostrya carpinifolia Scop. Comparison of germination of seeds of type A (full, sank in water) with seeds of type B (full, sank in water and then in ethanol), after cold and warm-followed-by-cold stratification, with the warm phase at 20°C and cold phase at 3°, 5° and 10°C. The germination tests were run at constant temperatures 3° and 20°C and in alternating 3°~20°C temperature (16+8 h/cycle) (Exp. II). The highest values which do not differ from each other significantly at $\alpha=0.05$ have been marked with the letter a

Duration of the warm phase of stratification	Temp. of the cold phase of stratification	Germinability after stratification					
		full seeds type A (water)			full seeds type B (water+ethanol)		
weeks	°C	3° %	3°~20° %	20° %	3° %	3°~20° %	20° %
0	3°	5.5	21.5	15.5	6.5	15.0	3.5
	5°	5.0	28.5	4.0	3.0	14.5	2.0
	10°	0	13.5	0	0.5	19.5	0
	$\bar{x}$	3.5	21.2	6.3	3.3	16.3	1.8
	overall mean		10.3			7.1	
4	3°	33.0 a	31.0 a	36.5 a	34.5 a	38.0 a	37.5 a
	5°	30.5 a	41.5 a	26.5	29.0	32.0 a	29.0
	10°	37.0 a	38.0 a	9.0	8.0	33.0 a	6.5
	$\bar{x}$	33.5	36.8	24.0	23.8	34.3	24.3
	overall mean		31.5			27.5	
8	3°	29.0	33.0 a	34.5 a	20.5	36.5 a	32.0 a
	5°	30.5	35.0 a	30.5 a	25.5	23.5	31.5 a
	10°	26.5	28.0	7.0	16.5	34.0 a	6.0
	$\bar{x}$	28.7	32.0	24.0	20.8	31.3	23.2
	overall mean		28.2			25.1	
			23.3			19.9	

A COMPARISON OF THE GERMINABILITY OF TWO GROUPS OF SEEDS (A AND B) SEGREGATED BY TWO METHODS, IN WATER AND THEN IN WATER FOLLOWED BY ETHANOL (EXP. II)

In Table 5 germinability is presented for seeds segregated in water and successively both in water and then in ethanol (full seeds of type A and B, Fig. 3).

From the analysis of variance it appears that four sources of variation (time of warm phase, temperature of cold stratification, temperature of germination and type of fluid used for the segregation of seeds before the stratification) affect significantly the differentiation of results (Table 6). On the basis of Duncan's test it can be said that the highest germinability was obtained by seeds after a 4-week warm stratification. A temperature of 3°C in the cold phase of stratification was most effective, and the most favourable temperature

Table 6

Ostrya carpinifolia Scop. Variance analysis of germinability of seeds of type A (full, sinking in water) and of type B (full, sanking in water and then in ethanol) after cold and warm-followed-by-cold stratification with the warm phase at 20°C and the cold phase at 3°, 5° and 10°C. The germination tests were run at constant 3° and 20°C temperatures and at an alternating temperature of 3°~20°C (16+8 h/cycle) (Exp. II)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Fluid used for floatation water or water+ethanol (A)	1	303.46	303.46	12.20**
Duration of warm stratification phase (B)	2	14 754.78	7 377.39	296.69**
Temp. of cold stratification phase (C)	2	3 804.64	1 902.32	76.50**
Temp. of germination (D)	2	4 823.08	2 411.54	96.98**
A×B	2	7.07	3.54	0.14 N.S.
A×C	2	54.03	27.02	1.09 N.S.
A×D	2	85.97	42.02	1.73 N.S.
B×C	4	56.37	14.09	0.57 N.S.
B×D	4	1 179.79	294.95	11.86**
C×D	4	2 100.52	525.13	21.12**
A×B×C	4	740.73	185.18	7.45**
A×B×D	4	335.15	83.79	3.37*
A×C×D	4	636.60	159.15	6.40**
B×C×D	8	506.47	63.31	2.55*
A×B×C×D	8	173.28	21.66	0.87 N.S.
Error		4 028.25	24.87	
Total		33 590.20		

** Significant at=0.01
* Significant at=0.05
N.S. not significant

for the germination phase was the alternating temperature of 3°~20°C. The above relationships have been observed in equal measure in seeds of both type A which sank in water and type B which sank first in water and then in ethanol (Table 7).

Table 7

Ostrya carpinifolia Scop. Comparison of the effect of the length of the warm stratification phase, the temperature of the cold phase, temperature of germination and type of fluid used for flotation (seeds type A and B) on the germinability of the seeds based on data presented in Table 5. Different letter following the means within a variable indicate significant differences between the means at $\alpha=0.05$ (Exp. II)

Variable	Duration of warm phase of stratification (seeds of type A and B)		
	0 weeks	4 weeks	8 weeks
Mean germination %	10.3 c	31.6 a	28.2 b

Variable	Temperature of cold phase of stratification (seeds of type A and B)		
	3°	5°	10°
Mean germination %	29.9 a	24.9 b	17.7 c

Variable	Temperature of germination (seeds of type A and B)		
	3°	3°~20°	20°
Mean germination %	21.6 b	28.6 a	19.5 c

Variable	Fluid used for floatation	
	water seeds of type A	water and then ethanol seeds of type B
Mean germination %	23.3 a	19.9 b

It turned out also that ethanol used additionally after the seeds were segregated in water, generally lowers significantly the germinability. This results from a comparison of the means (Table 7) calculated for all seeds of type A and B, and these means are lower for the latter. In some combinations of conditions of the warm stratification and germination phase there was no negative influence of ethanol on the germination of seeds, particularly after warm-followed-by-cold stratification with a 4-week warm phase at 20°C and the cold phase at 3°C. After such a stratification also the germination temperatures of 3°, 3°~20°C and 20°C did not differentiate significantly the germinability of seeds. At the alternating temperature 3°~20°C germinability was highest regardless what the temperature of the cold phase (3°, 5° or 10°C) was. In the optimal thermal stratification and germination conditions described above germinability was equally high for seeds of type A and type B (Figs. 2 and 5), which is indicated by nonsignificance of the difference (Table 5).

Table 8

Ostrya carpinifolia Scop. Comparison of germinability of seeds of type B (full, sank in water and then sank in ethanol) with seeds of type C (half-full, floating in water and sinking in ethanol) after cold or warm-followed-by-cold stratification with the warm phase at 20° and the cold phase at 3°, 5° and 10°C. Germination trials were run at constant 3° or 20°C temperatures or at an alternating 3°~20°C temperature (16+8 h/cycle) (Exp. III)

Duration of warm stratification at 20°C weeks	Temp. of the cold phase of stratification °C	Germinability after stratification					
		full seeds (type B)			half-full seeds (type C)		
		3° %	3°~20° %	20° %	3° %	3°~20° %	20° %
	3°	6.5	15.0	3.5	1.0	10.5	1.0
	5°	3.0	14.5	2.0	1.5	12.5	1.0
0	10°	0.5	19.5	0.0	0.0	12.0	0.0
	$\bar{x}$	3.3	16.3	1.8	0.8	11.5	0.7
	overall mean		7.1			4.4	
	3°	34.5	38.0	37.5	14.5	22.0	20.5
	5°	29.0	32.0	29.0	11.5	19.0	16.0
4	10°	8.0	33.0	6.5	9.0	20.0	5.5
	$\bar{x}$	23.8	34.3	24.3	11.7	20.3	14.0
	overall mean		27.5			15.3	
	3°	20.5	36.5	32.0	15.5	18.5	21.5
	5°	25.5	23.5	31.5	13.0	15.5	16.0
8	10°	16.5	34.0	6.0	10.5	13.5	3.5
	$\bar{x}$	20.8	31.3	23.2	13.0	15.8	13.7
	overall mean		25.1			14.5	
			19.9			11.4	

UTILITY OF HALF-FULL SEEDS (EXP. III)

A comparison of the germination of half-full seeds (Type C) with full seeds (Type B), both of which were first segregated in water and then in ethanol. The aim of experiment III was to check the utility of half-full seeds for sowing. It was shown that the germinability of half-full seeds is about 50% below that of full seeds.

DISCUSSION

Following the suggestion of Panov (1962) about the need to use for seeds of European hophornbeam two stratification phases, a warm one (temperature greater than 15°C) and a cold one (temperature below 8°C) in the present study the conditions were specified more closely as regards needed thermal conditions for these two phases and their durations. Thus an optimal system was obtained which is now recommended: 4 weeks at 20°C, followed by more than 20 weeks at 3°C. It was shown that there exists a relationship between the optimal temperature of the cold phase of stratification and the temperature of the germination phase. It was possible to maintain the highest germinability level using for the cold phase a temperature of 10°C, i.e. higher than the critical one of 8°C proposed by Panov, but on the condition that the germination phase runs at an alternating temperature of 3°$\sim$20°C.

The optimal duration of the warm phase for the stratification of the American hophornbeam (*O. virginiana* (Mill.) K. Koch) is 8 weeks (Schopmeyer, Leak, 1974). On the other hand in the case of the seeds of European hophornbeam we have found that already a 4-week warm phase at 20°C or 20°$\sim$30°C is sufficient to obtain a high germinability provided the cold phase is sufficiently long. Schopmeyer and Leak (1974) claim that the best thermal conditions for the germination of American hophornbeam seeds are provided by an alternating 10°$\sim$25°C system. The seeds of European hophornbeam studied by us germinated in the alternating 3°$\sim$20°C temperature conditions also much better than in constant temperatures of either 3° or 20°.

CONCLUSIONS

1. Dormancy of European hophornbeam seeds has been overcome uniformly and highly successfully by warm-followed-by-cold stratification with a 4-week warm phase at 20°C or alternating 20°$\sim$30°C (16+8 h/cycle) when it was followed by a cold phase at 3°C lasting till the onset of germination, i.e. for about 20–23 weeks.

2. Germinability of seeds after warm-followed-by-cold stratification was highest at an alternating temperature of 3° ~ 20°C or at a constant temperature of 3°C. In the alternating temperature most of the seeds germinated in the first 2–5 weeks while in the constant temperature (at 3°C) over 8–12 weeks. Germinability at a constant temperature of 20°C was distinctly lower.

3. Using water for the segregation of seeds by floatation it is possible to obtain full seeds (those which sink). Wishing to obtain also half-full seeds, which are partially capable of germination it is possible to use after floatation in water a second floatation in ethanol to remove empty seeds. Half-full seeds sink in ethanol. Water and ethanol used for the segregation of seeds do not lower their germinability if during stratification and germination the optimal recommended conditions are used.

LITERATURE

Bärtels A., 1982. Rozmnażanie drzew i krzewów ozdobnych. PWRiL, Warszawa.
Boratyńska K., 1982. Chorologia i rejonizacja leśna brzozowatych (*Betulaceae*). Arbor. Kórnickie, 27: 31–100.
Browicz K., 1978. Chorology of trees and shrubs in south-east Asia. Vol. 1, Kórnik.
Bugała W., 1979. Drzewa i krzewy dla terenów zieleni. PWRiL, Warszawa.
Jalas J., Suominen J., 1976. Atlas Florae Europeae. 3, Helsinki.
Krüssman G., 1964. Die Baumschule. Paul Parey, Berlin–Hamburg.
Panov A., 1962. A review, including the results of tests of the effects of stratification on *Ostrya carpinifolia* seed in two years at Sarajevo. Sumarstvo, 15 (1/2): 23–29.
Schopmeyer C. S., Leak W. B., 1974. *Ostrya virginiana* (Mill.) K. Koch – Eastern hophornbeam. In: C. S. Schopmeyer (ed.). Seeds of Woody Plants in the United States. USDA, Washington, D. C., Agricultural Handbook No. 450: 564–565.

Warunki ustępowania spoczynku i kiełkowania nasion chmielograbu europejskiego (*Ostrya carpinifolia* Scop).

Streszczenie

Przed doświadczeniem dokonano segregacji nasion metodą spławiania. Segregowały się one w wodzie i etanolu 96% na pełne (tonące w wodzie), półpełne (tonące w etanolu) i puste (pływające w wodzie i etanolu). Najskuteczniejszą w przezwyciężaniu spoczynku nasion pełnych i półpełnych okazała się stratyfikacja ciepło-chłodna z fazą ciepłą w 20°C, trwająca 4 tygodnie i fazą chłodną w 3°C przez ponad 20 tygodni. Kiełkowanie przebiega najsprawniej w temperaturze cyklicznie zmiennej 3° ~ 20°C (16 + 8 h/cykl). Stwierdzono też, że użyty do segregacji nasion etanol, w wysoce efektywnych układach cieplnych stratyfikacji i fazy kiełkowania nie obniżał zdolności kiełkowania nasion. Zdolność kiełkowania nasion półpełnych była w porównaniu z nasionami pełnymi o ok. 50% niższa.

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2. Germinability of seeds after warm-followed-by-cold stratification was highest at an alternating temperature of 3°–20°C, at a constant temperature of 3°C. In the alternating temperature most of the seeds germinated in the first 2–5 weeks, while in the constant temperature (at 3°C) over 8–12 weeks. Germinability at a constant temperature of 20°C was distinctly lower.

3. Using water for the segregation of seeds by floatation it is possible to obtain full seeds (those which sink). Wishing to obtain also half-full seeds, which are partially capable of germination it is possible to use after floatation in water a second floatation in ethanol to remove empty seeds. Half-full seeds sink in ethanol. Water and ethanol used for the segregation of seeds do not lower their germinability if during stratification and germination the optimum recommended conditions are used.

LITERATURE

Bartels A., 1982. Rozmnażanie drzew i krzewów ozdobnych. PWRiL, Warszawa.
Boratyńska K., 1982. Chorologia i [illegible] Arboretum Kórnickie, 27: [illegible]
[illegible] K., 1978. Chemistry of tree seeds [illegible] Vol. 1, [illegible]
Bugała W., 1979. Drzewa i krzewy dla terenów zieleni. PWRiL, Warszawa.
Jalas J., Suominen J., 1973. Atlas Florae Europaeae. 2. Helsinki.
Krüssmann G., 1964. Die Baumschule. Paul Parey, Berlin, Hamburg.
[illegible] K., 1982. A review, including the results of tests of the effects of stratification of Ostrya carpinifolia seeds in two years at [illegible] 15 (3): [illegible]
[illegible] K., 1975. [illegible]
Schopmeyer C. S. (ed.). Seeds of woody plants in the United States. U.S.D.A. Agricultural Handbook No. 450: [illegible]

Warunki ustępowania spoczynku i kiełkowania nasion chmielograbu europejskiego (Ostrya carpinifolia Scop.)

Streszczenie

Przed doświadczeniem dokonano segregacji nasion metodą spławiania. Segregowały się one w wodzie i etanolu 96% [illegible] w wodzie [illegible] w wodzie i etanolu). Najskuteczniejszą w przerywaniu spoczynku nasion pełnych i połowicznych okazała się stratyfikacja ciepło-chłodna [illegible] w 20°C [illegible] w 3°C przez ponad 20 tygodni. Kiełkowanie przebiegało [illegible] w temperaturze zmiennej 3°–20°C (16+8 h/dobę). Stwierdzono też, że użyte do segregacji [illegible] stratyfikacji i [illegible] kiełkowania [illegible] 50% [illegible]

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