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Breaking of seed dormancy, germination and seedling emergence of the common hawthorn (*Crataegus monogyna* Jacq.)

Abstract: The most advantageous time for collecting fruits of the common hawthorn (*Crataegus monogyna* Jacq.) falls on October, when they are fully ripe. The stones extracted from the fruits must be dried at room temperature to the moisture content of about 10%. The dormancy of the common hawthorn seeds can be overcome by their stratification in a moist medium in one of the three thermal regimes:

– 25°/3°C (16 weeks at 25°C followed by 15–18 weeks at 3°C, i.e. to the time when the first seedlings start to appear)
– 20~30°/3°C (16 weeks at 20~30°C (16+8 hrs/day) followed by 15–18 weeks at 3°C, i.e. to the time when first seedlings start to appear)
– 20~30°/3°C (16 weeks at 20~30°C (24+24 hrs) followed by 15–18 weeks at 3°C, i.e. to the time when first seedlings start to appear)

Having been stratified, the seeds germinate vigorously (in 3–5 weeks) and at a high percentage at temperatures of 3~10°, 3~15°, 3~20° and 3~25°C, (16+8 hrs/day) and the seedlings emerge at 3~20°C (16+8 hrs/day) in 4–6 weeks. Storage for one year at –3°C in the case of the seeds dried after harvest to the moisture content of 10% does not reduce their germination capacity. Stones scarification in concentrated sulphuric acid for 120 minutes followed by stratification at 3°C has an adverse effect on seed emergence at the temperature 3~20°C (16+8 hrs/day). It is recommended that stratified seeds should be sown into the still cool soil at the end of March or the beginning of April, as the increased temperature induces the secondary dormancy in seeds.

Additional key word: *Crataegus monogyna*, dormancy, stratification, scarification, germination, seeding emergence

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Introduction

Seeds of numerous trees and shrubs require specific environmental conditions to initiate germination. The cardinal ones include appropriate temperature, air access and humidity. As far as common hawthorn is concerned, its deep dormant seeds, are often observed to remain dormant in the ground for 2 or even 3 years (Tyszkiewicz 1949).

Common hawthorn (*Crataegus monogyna* Jacq.) occurs all over Poland. It usually grows into a big, thorny shrub or a small tree up to 8 m high. Fruits are spherical or egg-shaped, 7–10 mm long, usually containing 1 or 2 stones, each with two furrows. The mass of 1000 seeds equals 55 g and the number of seeds in 100 g is 1800 (Hrynkiewicz-Sudnik and others 1987). It is a very variable species. It forms hybrids with *C. laevigata* (syn. *C. oxyacantha* L.).

The use of hawthorns in tree areas is manifold. They make not only excellent hedges, but also unformed tree-alleys, especially along roads, as well as in rural and farmland landscape. They also grow in forests,

where they provide valuable biocoenotic admixture, and create convenient breeding grounds for many bird species (Bugała 1991). Common hawthorn valluable as grafting-stock for the full-blossomed is hawthorn varieties, quince and shadbush (Bärtels 1982).

The species *Crataegus monogyna* has considerable ornamental qualities. It flowers very abundantly in May. It is also a valuable therapeutic plant. The flowers are used to produce medicines affecting heart and nerves and lowering blood pressure.

The seeds of hawthorns belong to the orthodox category, because they can be dried up to the low moisture content (8–10%) without loss of their viability.

Literature review

Both in Polish and world literature there are few studies concerning the ways of pretreating the seeds of the common hawthorn to germination. This is probably due to the long time lapse between sowing and seedling emergence.

Attempts have been made at shortening the resting time of seeds by sowing them after very early collection at the beginning of August or by exposing the stones to acids, but even then seedlings emergence occurred only in the second spring (Tyszkiewicz 1949).

According to Bärtels (1982) dormancy disappears during stratification at 3–5°C after 180 days, but only some seeds germinate the next spring, the other remain quiescent in the soil for another year or two.

Nyholm (1975) recommends stratifying seeds for 5 months at 25°C and then for the next 5 months at 5°C.

Warm-followed-by-cold stratification at 20–25°C for 4–8 weeks, and later at 1–5°C for 12–16 weeks is also recommended by Gordon and Rowe (1982). Soaking of stones in water for 24 hours at room temperature has also been attempted, followed by 12-month stratification at 1–10°C, after which the seeds were sown in autumn (Anonim 1987).

The use of warm-cold stratification, first at 25°C for 3 months, then the cold one at 3°C for 9 months, and next 35 days at 20°C in sand is recommended by ISTA (International Seed Testing Association 1999).

Some authors advocate treating stones with concentrated sulphuric acid for 2 hours, and then subjecting them to cold stratification (Buszewicz and Holmes 1955). Treatment with concentrated sulphuric acid and then sowing is recommended by St.-John (1983).

The aim of the research

The research initiated in 1999 in the Department of Seed Biology of the Institute of Dendrology, Polish Academy of Sciences in Kórnik, comprised the following issues:

– effect of time of the harvest and of the seed moisture level after collection upon breaking of dormancy
– effect of conditions for stratification of seeds
– effect of chemical scarification of stones.

Moreover, after breaking the dormancy, the optimal temperature range for germination and seedling emergence as well as emergence of seedling sown in the nursery after stratification have been examined.

Methods

The experiments were conducted in the season of 1999/2000 and in the next season 2000/2001. In the year 1999/2000 the aim of the experiments was to study overcoming of seed dormancy in varians thermal conditions.

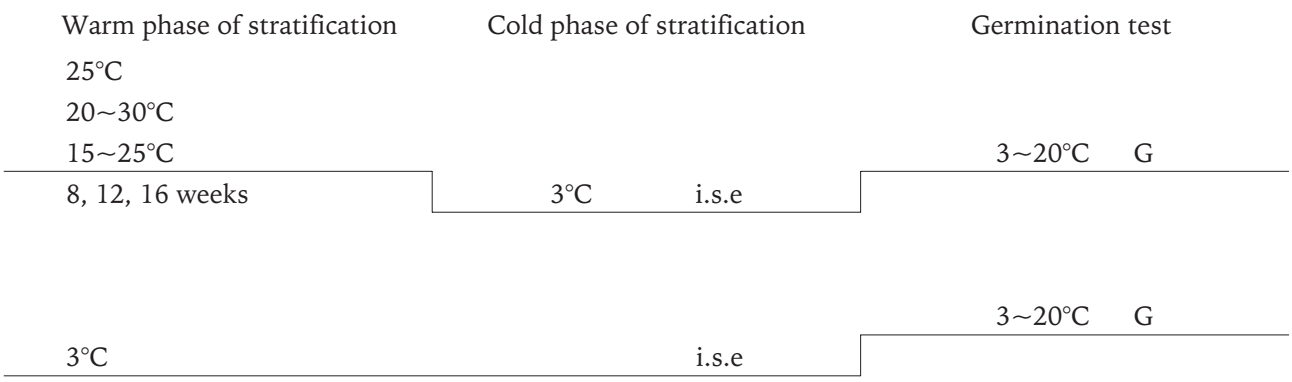
The fruits originated from three different shrubs in the area of greater Poland (Wielkopolska) (Kórnik, Poznań, Lednogóra, Table 1) at three terms (in mid-August, at the end of August/beginning of September, October when fruits were fully ripe). After extracting the seeds from fruits their viability was examined (by the cutting test) the moisture content was determined, using the drying method (105°C for 24 hours), and then the seeds were, in three replications of 50 seeds each, subjected to the following treatments:

– cold stratification at 3°C in the stratification medium (sand and peat, volume ratio 1:1);
– warm-followed-by-cold stratification first at 25°C, with the warm phase lasting of 8, 12 and 16 weeks followed by the cold phase at 3°C until first seedlings appear,
– warm-followed by-cold stratification with the warm phase at cyclically alternating temperature 15~25°C (16+8hrs/day) for 8, 12 and 16 weeks followed by cold phase at 3°C until first seedlings appear,
– warm-followed by-cold stratification with the warm phase at cyclically alternating 20~30°C (16+8 hrs/day) for 8, 12 and 16 weeks followed by cold phase at 3°C until first seedlings appear.

After stratification, the seeds were subject to germination tests in the same medium as was used for stratification at 3~20°C (16+8 hrs/day) for 10 weeks. The above mentioned treatments comprised seeds both not dried and dried after collecton (Fig. 1, Table 2).

Seeds collectad in the year 2000 (Table 3) were dried to the moisture content of 8,7–10,1% and stored for one year at –3°C (Fig. 2).

Seed germination and emergence capacities were examined after warm-cold stratification at 25°/3°, 15~25°/3° and 20~30°/3°C (16+8 hrs/day), the



i.s.e. – initiation of germination

Fig. 1. *Crataegus monogyna* Jacq. Designs of the experiments 1339, 1340, 1341 from the year 1999

Table 1. *Crataegus monogyna* Jacq. Characteristics of seeds collected in 1999. Experiments no. 1339, 1340, 1341

Seed lot no.	Origin	Harvest time (date)			Moisture content of fresh stones (%)			Moisture content of dried stones (%)	Viability of fresh seeds (cutting test)			Viability of dried seeds (cutting test)
		I	II	III	I	II	III	III	I	II	III	III
1339	Poznań, os. Bohaterów II wojny św., single shrub in the row of other shrubs	16.08.1999	30.08.1999	11.10.1999	32.6	27.7	28.1	11.6	68.7	87.5	67.8	88.7
1340	Vicinity of Kórnik, a path in the field in the direction of Celestynowo	18.08.1999	1.09.1999	13.10. 1999	31.3	25.7	23.0	9.4	77.5	77.5	64.3	64.3
1341	Dziekanowice, the vicinity of Lednogóra, single shrub	19.08.1999	2.09.1999	6.10.1999	34.2	31.7	25.1	9.8	86.2	82.5	69.0	90.0

warm phase lasting 16 and 20 weeks. After stratification, the seeds were subjected to germination and emergency tests at 3~20°C (16+8 hrs/day), and they were also sown in the nursery (Fig. 2).

In one experimental variant stones were after storage subjected to scarification in the concentrated sulphuric acid for 45 and 120 minutes (lot 1339) and 120 minutes (lot 1340) followed by to stratification at 3°C, until the first seedlings appear.

In the year 2000 three seedlots were collected from the same shrubs as in 1999 (Table 8). After extracting the seeds from stones and drying them to the moisture content of 13,8–14,5%, they were stratified (Fig. 3) in the following conditions:

Table 2. *Crataegus monogyna* Jacq. Characteristic of seeds collected in 1999, stored until the year 2000. Experiment 1339, 1340, 1341

Seed lot no.	Place of harvest	Date of pick-up	Moisture of dried seeds	Seed storage at –3°C		Seed moisture after storage	Seed viability (cutting test)
				dates	months	content %	%
1339	Poznań	11.10.1999	11.6	22.10.99–5.09.00	11	10.1	82.0
1340	vicinity of Kórnik	13.10.1999	9.4	23.10.99–6.09.00	11	8.7	80.0
1341	Dziekanowice	6.10.1999	9.8	20.10.99–7.09.00	11	8.8	78.0

Table 3. *Crataegus monogyna* Jacq. Seeds characteristics of seeds collected in 2000. Experiments 1455, 1456, 1457

Seedlot no.	Origin	Harvest	Drying		Moisture content after drying	Seed viability (cutting test)
		date	date	days	%	%
1455	Dziekanowice	28.09.2000	29.09.–9.10.2000	10	13.8	80.0
1456	Poznań	3.10.2000	3.10.–9.10.2000	6	13.8	85.0
1457	Kórnik	10.10.2000	10.10.–19.10.2000	9	14.5	80.0

Table 4. *Crataegus monogyna* Jacq. Non-stored freshly collected seeds. Germination and emergence capacities of seeds dried and not dried after cold stratification at 3°C and warm-followed-by cold stratification at 25°/3°, 15~25°/3°, 20~30°/3°C with the warm phase lasting 8, 12, 16 weeks. Germination tests were carried out at 3~20°C (16+8 hrs/day). Results related to full seeds only. Experiment 1339, 1340, 1341.

Seed lot no.	Seeds not dried after harvest						Seeds dried after harvest					
	Warm phase		Cold phase		Germination capacity at 3~20°C		Warm phase		Cold phase		Germination capacity at 3~20°C	
	°C	weeks	°C	weeks	%	mean %	°C	weeks	°C	weeks	%	mean %
1339	–	–	3°	18	17		–	–	3°	17	9,3	
	25°	8	3°	18	51	**51**	25°	8	3°	17	22	**45**
		12		14	45			12		16	33	
		16		15	55			16		15	81	
	20~30°	8	3°	18	54	**60**	20~30°	8	3°	15	91	**91**
		12		16	57			12		13	91	
		16		15	70			16		14	93	
	15~25°	8	3°	18	35	**44**	15~25°	8	3°	15	90	**93**
		12		16	48			12		13	93	
		16		15	49			16		14	96	
1440	–	–	3°	32	28		–	–	3°	36	19	
	25°	8	3°	17	82	**86**	25°	8	3°	16	85	**87**
		12		16	89			12		15	87	
		16		16	88			16		15	88	
	20~30°	8	3°	17	89	**90**	20~30°	8	3°	16	85	**90**
		12		17	86			12		15	89	
		16		16	95			16		15	96	
	15~25°	8	3°	17	59	**72**	15~25°	8	3°	15	72	**84**
		12		17	79			12		16	93	
		16		16	79			16		15	86	
1441	–	–	3°	36	50		–	–	3°	34	40	
	25°	8	3°	17	90	**87**	25°	8	3°		96	**97**
		12		18	83			12		17	96	
		16		18	89			16			98	
	20~30°	8	3°	18	88	**90**	20~30°	8	3°		92	**95**
		12		18	91			12		17	96	
		16		18	91			16			99	
	15~25°	8	3°	18	53	**67**	15~25°	8	3°		81	**95**
		12		18	71			12		17	94	
		16		18	77			16			96	

Warm phase of stratification	Cold phase of stratification		Germination test G Seedling emergence test S	
			3~20°C	S
25°C			3~20°C	G
20~30°C			3°C	G
16, 20 weeks	3°C	i.s.g.	nursery	NI
			3~20°C	S
			3~20°C	S
H_2SO_4			3~15°C	S
45 min., 120 min.	3°C	i.s.g.	3°C	G

i.s.g. – initiation of seed germination

Fig. 2. *Crataegus monogyna* Jacq. Designs of the experiments 1339, 1340, 1341. Seeds collected in 1999 were stored at –3°C for 11 months

– warm-cold stratification in the medium 25°/3°C (16 weeks at 25°C, next for 15–18 weeks at 3°C, i.e. until the first seedlings appear),
– warm-cold stratification in the medium 20~30°/3°C (16 weeks at 20~30° with the warm phase alternating cyclically 16+8 hrs/day, and next for 15–18 weeks at 3°C, i.e. until the first seedlings appear),
– warm-cold stratification in the medium 20~30°/3°C (16 weeks at 20~30° with the warm phase alternating cyclically in a two-day cycle 24+24 hours and next for 15–18 weeks at 3°C, i.e. until the first seedlings appear).

Following stratification, seed germination tests were carried out at 3°C as well as in cyclically alternating at 3~10°, 3~15°, 3~20° and 3~25°C (16+8hrs/day), and the seedling emergence test was conducted at 3~20° (Fig. 4).

The effect of drying the seeds after overcoming dormancy on their germination and emergence capacities was also examined. The seeds were dried at room temperature (21–22°C), in a forced weak airstream to the moisture content of 8,7% (after the warm-cold

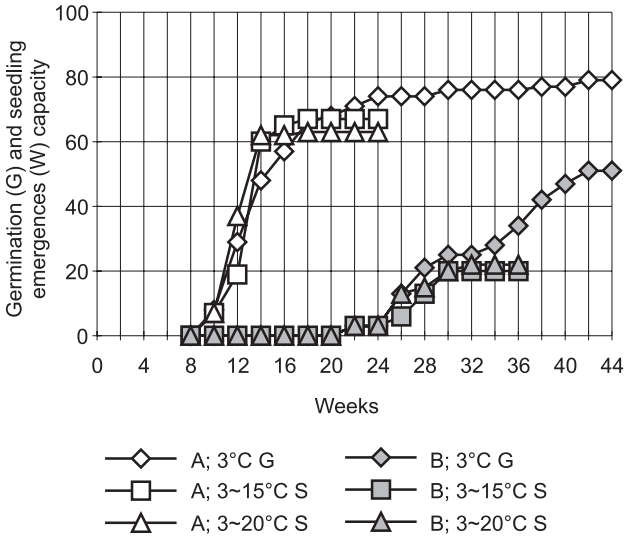


Fig. 4. *Crataegus monogyna* Jacq.The course of seed germination (G) at 3°C and seedling emergence (S) at 3~15°C and 3~20°C of two seedlots (A – bright symbols, B – grey symbols), scarified prior to stratification at 3°C in concentrated sulphuric acid for 120 min.

Warm phase of stratification	Cold phase stratification	Germination test G Seedling emergence test S	
		3~25°C	G
		3~20°C	S
25°C		3~20°C	G
20~30°C (8+16hrs/day)		3~15°C	G
20~30°C (24+24hrs/day)		3~10°C	G
16 and 20 weeks	3°C 16–18 weeks i.s.g.	3°C	G

i.s.g.- initiation of seed germination

Fig. 3. *Crataegus monogyna* Jacq. Design of the experiments 1455, 1456, 1457. Seeds collected in 2000

Table 5. *Crataegus monogyna* Jacq. Seeds collected in 1999 stored at –3°C after drying. Seed germination and emergence capacity after warm- followed-by-cold stratification at 25°/3°, 15~25°/3°, 20~30°/3°C with the warm phase lasting 16 and 20 weeks. Germination and emergence tests were carried out in the laboratory at 3~20°C (16+8h./day). Results related to full seeds only. Experiments 1339, 1340, 1341

Seed lot	Thermal combination of stratification			Temperature of the test		
	Warm phase		Cold phase 3°C	Germination	Seedling emergence	
				3~20°C mean %	3~20°C mean %	nursery
	°C	weeks	weeks	%	%	%
1339	25°C	16	13	92	88	73
		20	14	96	90	76
	20~30°C	16	13	94	91	93
		20	14	96	94	77
	15~25°C	16	13	93	87	81
		20	14	89	88	60
mean %				**93**	**90**	**77**
1340	25°C	16	15	96	93	75
		20	15	97	98	74
	20~30°C	16	14	96	92	85
		20	15	95	92	72
	15~25°C	16	14	89	90	70
mean %				**94**	**93**	**75**
1341	25°C	16	17	92	92	56
	20~30°C		16	96	94	43
	15~25°C		17	80	88	25
mean %				**89**	**91**	41

Dates of sowing:
Seed lot 1339 – 2.04.01
Seed lot 1340 – 6.04.01
Seed lot 1341 – 20.04.01

stratification at the temperature 25°/3°C and up to the 11,0% moisture content (after the warm-cold stratification at the temperature 20~30°/3°C).

Results

From the experiments carried out in the year 1999/2000 it follows, that the breaking of dormancy of common hawthorn is influenced by the time of collection. Germination capacity of seeds from fruits collected too early (when green) for seedlots no 1339, 1340 and 1341 was 0%. Only seed lot no. 1341, collected at the end of August 1999 (2nd term), after the cold stratification at 3°C for 42 weeks and the germination test at 3~20°C for 10 weeks germinated in 21%.

Seeds from fruits collected when fully ripe (3rd term) germinated best (Table 4). The seeds of two lots no.1339 and 1341 germinated better after having been dried to the moisture content of 9,4–11,6% than fresh seeds with the moisture content 23,0–28,0%.

The percentage of germination of seed lot no. 1340 was the highest (92%) after the cyclically alternating stratification at 20~30°C (16+8 hrs/day) for 16 weeks followed by cold stratification at 3°C for 14 weeks (seeds dried after the pick-up up to the moisture content of 11,6%) and 70% (fresh seeds of the moisture content 28,0%). In the case of all three seed lots, the combination 20~30°/3°C for 16+16 weeks proved most effective.

In the year 2000/2001 further research was carried out on seeds dried in 1999 after collection to the moisture content of 8,7–10,1% and stored at the temperature –3°C for 11 months in airproof containers, in the thermal variants presented in Fig. 2. After stratification germination and emergence tests were carried out in the laboratory at the temperature 3~20°C (16+8 hrs/day) and in spring the seeds were sown in the nursery.

In all thermal combinations employed, high seed germination and seedling emergence capacity were achieved after stratification of the seedlots that were examined in the laboratory. The average germination capacity was: for the seedlot no. 1339 – 93%, for the seedlot no. 1340 – 94%, and for the seedlot no. 1341 – 89%. The capacity of seedling emergence in the labo-

Table 6. *Crataegus monogyna* Jacq. Comparison of non-stored and stored seeds the effect of seeds storage for 11 months at –3°C on th germination and seedling emergence capacity after stratification different thermal combinations. Results are related to full seeds only. Experiment 1339, 1340, 1341

Seed lot no.	Fresh seeds						Seeds stored at –3°C for 1 year					
	warm phase		cold phase		germination capacity at 3~20°C		warm phase		cold phase		germination capacity at 3~20°C	
	°C	weeks	°C	weeks	%	mean %	°C	weeks	°C	weeks	%	mean %
1339	25°	16	3°	15	81	**90**	25°	16	3°	13	92	**93**
	20~30°			14	93		20~30°				94	
	15~25°			14	96		15~25°				93	
1340	25°	16	3°	15	88	**90**	25°	16	3°	15	96	**94**
	20~30°				96		20~30°			14	96	
	15~25°				86		15~25°			14	89	
1341	25°	16	3°	17	98	**97**	25°	16	3°	17	92	**89**
	20~30°				98		20~30°			16	96	
	15~25°				96		15~25°			17	80	

ratory for all three seedlots ranged from 90 – 93%. The average capacity of seedling emergence in the nursery was 77%, 75% and 41% respectively. Only in the case of early sowing in the nursery (the beginning of April) the high percentage of seedlings emergence was achieved: for the seedlot no. 1339 – 93% and for the seedlot no. 1340 – 85% in contrast to the late sown seed lot 1341.

For all seedlots, the best results of germination and seedling emergence in the laboratory and in the nursery were achieved after the warm-cold stratification at 20~30°/3°C with the warm phase cyclically alternating in a cycle 16+8 hrs/day, lasting 16 weeks and the cold phase lasting 15–18 weeks.

Seed germination at 3~20°C (16+8 hrs/day) of seeds stratified when fresh achieved 90–97% and after 1-year dry storage 89–93% (Table 6).

Table 7. *Crataegus monogyna* Jacq. Seed germination and seedling emergence capacity (in %) after scarification with concentrated sulphuric acid for 45 or 120 minutes. Results related to full seeds only. Experiments 1339, 1340

Seed lot no.	Stone treatment		Capacity of		
	96% H_2SO_4 scarification	cold stratification	germination	seedling emergence	
		3°C	3°C	3~15°C	3~20°C
	minutes	weeks	%	%	%
1339	45	13	65	48	44
	120	10	79	67	63
1340	120	23	51	20	22

Table 8. Comparison of seedling emergence capacity at 3~20°C after warm- followed-by-cold stratification at 20~30°/3°C with the warm phase lasting 16, 20 weeks and that after scarification with concentrated sulphuric acid for 45 and 120 minutes followed by cold stratification at 3°C.Results related to full seeds only. Experiments 1339, 1340

Seed lot no.	Non-scarified stones			Scarified stones		
	thermal combinations of stratification		capacity of seedling emergence 3~20°C			
	warm phase 20~30°C	cold phase 3°C		scarification	stratification 3°C	seedling emergence 3~20°C
	weeks	weeks	%	minutes	weeks	%
1339	16	13	91	45	13	44
	20	14	94	120	10	63
	mean %		92	mean %		**53**
1340	16	14	92	–	–	–
	20	15	93	120	22	22
	mean %		**92**			

Table 9. *Crataegus monogyna* Jacq. Seeds collected in the year 2000. Seed germination and seedling emergence (%) in different thermal combinations, after the warm- followed-by-cold stratification at 25°/3°C(A); 20~30°/3°C the warm phase 8+16 hours/day (B) and 20~30°/3°C with the warm phase 24+24 hours/2 days (C). Results are related to full seeds only. Experiments 1455, 1456,1457

Seedlot no.	Thermal combination of stratification			Temperature					
	warm phase		cold phase 3°C	germination					seedling emergence
				3°C	3~10°C	3~15°C	3~20°C	3~25°C	3~20°C
	°C	weeks	weeks	%	%	%	%	%	%
1455	A	16	18	81	80	73	80	83	77
	B			84	85	97	92	99	91
	C			90	77	79	81	81	85
1456	A	16	14	98	99	97	98	99	96
	B		15	98	95	98	97	95	96
	C	20	15	94	97	98	98	98	95
1457	A	16	18	85	81	94	92	–	85
	B		16	88	94	90	84	–	88
	C		18	86	90	83	88	–	88
mean %				89.3	88.7	89.9	90.0	92.5	89.0
gen. mean %				90.0					

After chemical scarification the stones were stratified at 3°C in the moist medium. Extending the duration of stratification of stones to 120 minutes resulted in an increase of germination and emergence capacity of the seedlot no. 1339 seeds. After 45 minutes of scarification, the germination capacity at 3°C was 65% and after 120 minutes 79%. Also the seedling emergence at 3~15°C and 3~20°C (16+8 hrs/day) increased from 48 to 67% and from 44 to 63% respectively. Seedlot no. 1340 seeds required a longer, 23-week stratification phase at 3°C, and at the same time the seeds reacted with an decrease of the germination and emergence capacity (Fig. 3, Table 7).

After the warm-followed-by-cold stratification at 25°/3°C with 16- and 20-week warm phase it turned out that the seedling emergence at 3–20°C was much higher (92%) than after chemical scarification followed by cold stratification at 3°C (53%) (Table 8).

High germination capacity of the seedlots examined, collected in the season 2000/2001, was achieved in the germination tests at temperatures 3~10°, 3~15°, 3~20° and 3~25°C, carried out after stratification irrespectively of the thermal combination of stratification (on average 90%). Also in the seedling emergence tests at 3~20°C the seedlings emerged at a high percent (on average 89% – Table 9).

After the warm-followed-by-cold stratification at 25°/3°C or 20~30°/3°C the seeds were dried to the moisture content of 8,4% or 11,0% respectively. After drying, the germination tests at 3~10°, 3~15°, 3~20° and 3~25°C were carried out, as well as the seedling emergence tests at 3~20°C. Drying seeds after stratification resulted by a considerable decrease in their germination and emergence capacity at 3~25°C (95% seeds not dried, 52% dried seeds); however, it did not have any effect on the germination capacity of the seeds at 3~15°C (Table 10).

Discussion

For seeds of the common hawthorn, warm-cold stratification at 25°C for 5 months and then at 3°C for the subsequent 5 months is recommended by Nyholm (1975). Similarly Gordon and Rowe (1982) as well as Nikolaeva and others (1985) advocate stratifying the seeds first at 20–25°C for 4–8 weeks, and then at 1–5°C for 12–16 weeks followed by sowing into the soil.

Suszka in the years 1983/1984 (unpublished data) investigated overcoming of dormancy of 5 seedlots of *Crataegus monogyna* seeds. After stratification in the moist medium at 25°/3°C (8, 12,16 +16–18 weeks) and germination tests at 3~20°C (16+8 hrs/day), only two seedlots of germinated in 55–60%, and the remaining ones merely 12–15% .

Warm-followed-by-cold stratification with the constant warm phase at 25°C for 8, 12, 16, weeks and cold phase at 3°C until the first seedlings started to appear in the investigations presented here proved equally effective as warm-cold stratification with a cyclical warm phase at temperature of 20~30°/3°C (Fig. 1, Table 2).

Only cold stratification at 3°C applied in the experiments (18, 32 and 36 weeks depending, on the seedlot) and subsequent germination tests at 3~20°C (16+8 hrs/day), confirms the results obtained by Bärtels (1982) and the recommendations of Hrynkiewicz and others (1987), that after the sowing of seeds into the soil after the only cold stratification for 60–180 days or one year the expected seedling emergence in the first spring is strongly reduced.

Table 10. *Crataegus monogyna* Jacq.Effect of seed drying after warm-followed-by -cold stratification on germination (G) and emergence (S) capacity. Results related to full seeds only. Experiment 1456

Warm phase stratification		Cold phase stratification		Temperature of the germination and seedling emergence	Seeds after stratification					
					not dried			dried		
					G		S	G		S
°C	weeks	°C	weeks	°C	%	mean %	%	%	mean %	%
				3°	98			84		
				3~10°	99			87		
25°	16	3°	14	3~15°	97	**98.0**		98	**70.2**	
				3~20°	98		96	63		72
				3~25°	99			19		
20~30°				3°	98			88		
8+16				3~10°	95			94		
hrs/day	16	3°	15	3~15°	98	**96.6**		95	**83.8**	
				3~20°	97		96	90		82
				3~25°	95			52		

In the investigations carried out by Tyszkiewicz and Dąbrowska (1953) fruits were picked early "when green" and the seeds extracted from them were instantly sown into the soil, but the results were unsatisfactory and irregular emergence appeared only in the second spring. Those findings have also been confirmed in this work (the best results were achieved when the seeds were collected when fully ripe).

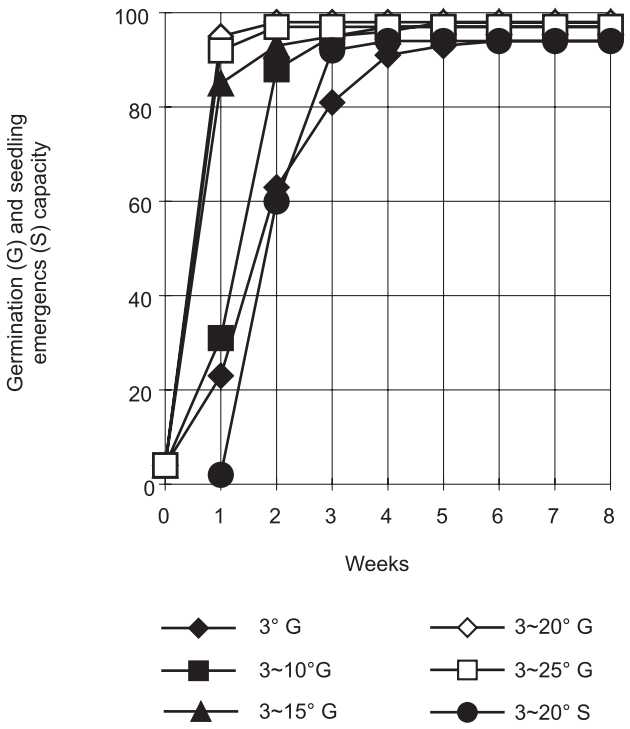


Fig. 5. *Crataegus monogyna* Jacq. The course seed germination (G) at 3°, 3~10°, 3~15°, 3~20°, 3~25°C and seedling emergence (S) at 3~20°C after stratification warm-followed-by-cold, ciclically variable 20~30°C for 16 weeks and cold phase at 3°C for 18 weeks. Experiment 1456

Scarification of the stones in concentrated sulphuric acid for 45 minutes to 2 hours prior to the cold stratification is recommended by St.-John (1982) Buszewicz and Holmes (1995) , although it has not been confirmed by the present study, as the germination and emergence results obtained were by half lower then after the warm-cold stratification.

For the three seedlots examined in two years 1999/2000 and 2000/2001, the warm-followed-by--cold stratification with the warm phase at the alternating temperature 3~20°C (16+8 hrs/day or 24+24 hours) and the cold phase at 3°C lasting to the appearance of the first seedlings proved most effective. This combination ensured high germination capacity and seedlings emergence both in the laboratory at 3~20°C and in the nursery in spring (about 90%).

Conclusions

1. The most advantageous period for collecting the fruits of the common hawthorn (*Crataegus monogyna* Jacq.) falls on October, when they are fully ripe. The stones extracted from the fruits must be dried at room temperature to the moisture content of about 10%.
2. The dormancy of the common hawthorn seeds can be overcome by their stratification in a moist medium in each of the three thermal to the time when the first seedlings start to appear:
– 25°/3°C (16 weeks at 25°C followed by 14–18 weeks at 3°C, i.e.)
– 20~30°/3°C (16 weeks at 20~30°C (16+8 hrs/day) followed by 14–18 weeks at 3°C)
– 20~30°/3°C (16 weeks at 20~30°C (24+24 hrs) followed by then 14–18 weeks at 3°C)
3. An extension of the warm stratification phase to 20 weeks was unnecessary for the seedlots examined here.

4. Having been stratified, the seeds germinate vigorously (in 3–5 weeks) and at a high percentage at temperatures of 3~10°, 3~15°, 3~20° and 3~25°C, (16+8 hrs/day) and the seedlings emerge at 3~20°C (16+8 hrs/day) in 4–6 weeks.
5. Storage for one year at –3°C in the case of the seeds dried after harvest to the moisture content of 10% does not reduce their germination capacity.
6. Common hawthorn seeds can be dried at room temperature up to the moisture content of about 10% after stratification 25°/3°C or 20~30°/3°C without any adverse effect on their germination capacity at the temperature 3~15°C (16+8 hrs/day).
7. Scarification only stones in concentrated sulphuric acid for 120 minutes followed by stratification at 3°C has an adverse effect on seed emergence capacity at the temperature 3~20°C (16+8 hrs/day).
8. It is recommended that stratified seeds should be sown into the still cool soil at the end of March or the beginning of April, as the increased temperature induces the secondary dormancy in seeds.

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