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Storage of acorns of the English oak (*Quercus robur* L.) over 1-5 winters*

From the 6 987 900 ha of state forest in Poland 4.9% i.e. 343 000 ha are stands with such deciduous species as English oak (*Quercus robur* L.), durmast oak (*Q. petraea* Lieblein), European ash (*Fraxinus excelsior* L.), Norway maple (*Acer platanoides* L.), sycamore maple (*A. pseudoplatanus* L.) and elm (*Ulmus* L.) species (GUS 1978). The annual demand for acorns, assuming an area annually planted with oak to be 7 560 ha (Tyszkiewicz, 1964), can be calculated as 650 tons. Taking into account the fact, that transportation of acorns for long distances is inadvisable and that mast years of oaks are separated by 3 - 8 bad seed years, it would be useful to store acorns for periods longer than over one winter only.

Many methods have been elaborated in Russia, in Poland, in Germany and in Czechoslovakia making storage of acorns over one winter possible, all basing on the natural climatic and environmental conditions. Acorns of the English oak can be stored in the forest under an insulating cover and snow by methods developed by Turskii, Rudzki, Heyer or Abianc, in pits digged out in standy forest soil according to Turkskii, Suchecki, Lototskii or in the Allemann's shed (Tyszkiewicz, 1949). Also other methods of storage over one winter have been developed like storing in running water (Jenss, 1931; Jones, 1958) or in pits walled with bricks permitting also an aeration of the stored acorns from below (Vincent, 1955). The efectiveness of all these methods is highly dependent on the weather conditions. When the winter is mild or relatively warm it is not possible to maintain a temperature close to 0°C around and between the acorns. The results is that an intensive pregermination of stored acorns starts and many of them die and decay.

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Mattis and Khavronin (1969) describe the first known attempt to store acorns of *Q. robur* for a longer period, performed by Sobolev in Russia in the year 1908. The acorns were placed in a wooden box (70×70×150 (height) cm) in alternating layers with moist sawdust. In the winters the boxes were stocked in a cellar but every Spring and Summer they were held in an ice-shed at a temperature not exceeding 5°C. This method is claimed to have retained over 4 winters the ability of seedlings to emerge after sowing the acorns in the nursery.

The first attempts to store acorns at controlled temperature conditions for periods longer than over one winter only were reported by Roe (1946), who has used for his experiments acorns of the Northern red oak (*Q. borealis* Michx.) collected in 1941, which till the Spring of 1942 were stored in sacs at 4.4 - 10.0°C to be afterwards divided into 2 seed lots: one was stored since that time in cloosed tins, and the other in burlap sacs, both in a refrigerated chamber at 4.4°C. After 30 months acorns stored in the sacs were no more able to germinate but those from the tins germinated still in 50%, and after 41 months still in 24 - 36%, depending on their vertical distribution in the tin: acorns close to the bottom pregerminated more.

Pravdin (1952) has stored acorns of Q. robur collected in 1949, stocked to the first Spring under snow cover and afterwards placed in net-sacs in an ice-shed, where temperature in the summer was close to 0°C and in the winter it remained in the range from −1° to −2°C. After 28 months germinative capacity of acorns was still unchanged 66%, like at the start of storage. Two other Russian investigators have also stored acorns of *Q. robur* over 2 winters: Lototskiĭ (1952) and Podgurskiĭ (1953). Both have used for storage pits digged out in a sandy soil to a depth of 3 or 2 m. In Lototskiĭ's method acorns were placed in layers 5 - 6 cm thick alternately with layers of sand, flooded abundantly with water so, that the sand filled the space between the acorns. From a depth of 1.3 - 1.5 m the pit was covered with an insulating layer. Podgurskiĭ has filled shallow boxes (100×150 - 200××15 cm) with acorns to half their height (7 cm) and the remaining space was filled with moist stand. The 8 layers of boxes were stocked in a pit and again an insulation layer was used to cover the boxes. In the second Spring 82% of acorns had roots 2 - 20 cm long, (average 7 cm). When sown after cutting down the roots to 1 cm, seedlings emerged in 95 - 100%.

Important results were obtained by Holmes and Buszewicz (1956) in England, who have used acorns of *Q. robur* with an initial viability of 90% and with a water content of 45.9% in the fresh weight. When acorns were mixed with dry peat in closed but not sealed containers permitting gaseous exchange with the outer air and placed at 2.2°C, seedling emergence in a nursery bed after 42 months was still 52%.

When moist peat or moist sand was used as the storage medium, only 24% and 11% of acorns have produced seedlings respectively. The high water content of acorns was retained over the whole storage period. When stored at −12°C in ice or in initially moist peat at −4°C in sealed or closed but not sealed containers, and also when stored at room temperature, acorns have lost their viability in a very short period.

Mattis (1966) has stored acorns of *Q. robur* collected in 1964 for 15 months after having stocked them over the first winter in thin polyethylene sacs in conditions not described. Afterwards the acorns were stored in sacs of thick polyethylene in portions of 12, 24 and 48 kg in a refrigerator at 0 - 5°C, in a cellar and at room temperature. Viability of acorns stored in the refrigerator decreased fom the initial 93% to 75%, their water content increased from 39% to 43.2% (recalculated from author's dry weight basis data) and 48% of acorns germinated during storage. Some years later this method of storing acorns over 2 winters was improved (Mattis and Khavronin, 1969) by covering the pit with a layer of snow 2 m high pressed hard with the help of a caterpillar tractor and afterwards covered by 2 insulating layers, both 0.5 m thick, of sawdust and straw (outer layer).

In Czechoslovakia Ančak (1972) has obtained better results when acorns of *Q. robur* were mixed with dry sand than with dry peat, and when the depth of pits was 1.5 m (depths of 0.5 m, 1.0 m, 2.0 m and 2.5 m were also tried). After 27 months the initial germinative capacity of 93% decreased to 53% and the length of roots of the already germinated acorns was 2 - 8 cm. In summer temperature in the pit at 1.5 m was 13.6°C what enhanced the growth of roots.

In Poland the problem of long-term storage of acorns has not been studied until the year 1970 when the here reported studies were started, conducted over 5 winters in controlled thermal conditions. In 1973 a similar Polish study was started by Janson (1979), who has stored acorns of *Q. robur* over 2 winters only. His best results (seedling emergence in the nursery of 60% after Spring sowings) were obtained when acorns with an initial water content of 41.0% were stored at −2° in dry sand in boxes lined with polyethylene.

In this paper we present results of studies performed in the years 1963 - 1964 and 1970 - 1976 on storage of *Q. robur* acorns. At first the optimal thermal conditions for germination of acorns and the growth of their epicotyls had to be found as well as the hydration level at which acorns can retain viability, germinability and ability to form normal seedlings. In the years 1970 - 1971 the results of these early investigations were utilized in a new study on germination and epicotyl growth of 4 Polish oak provenances in a broad range of temperatures. In 1971 a big-scale experiment was started in which storage of acorns of

3 Polish provenances of *Q. robur* over 1 - 5 winters was studied at different temperatures and various methods of storage. Germination tests were performed in laboratory conditions every year in April and September, and in April acorns were also sown in the nursery to test seedling emergence (Suszka, annual reports of project FG-Po-253 for 1971 - 1976).

MATERIAL AND METHODS

In all experiments the same methods of estimation of qualitative seed characters and of the ability to germinate and to form seedlings in laboratory and in field conditions were applied. They are briefly described below:

Collection, predrying and cleaning of acorns: Acorns were collected from the ground after the mass seed fall to be transported by car in net-sacs to Kórnik. They were stocked here for a short period in a shady, cool and dry place in a nonheated attic, in a layer 10 - 15 cm thick, the seed mass was mixed and spread again daily. Simultaneously the seeds were examined and all broken, damaged, insect-attacked, too small ones and sound accorns with an already growing radicle were removed together with other impurities. The stocked acorns were not allowed to loose water below the 40% hydration level (fresh weight basis).

Estimation of seed viability: The cutting test was applied (4×50 acorns, cut in 4 parts) simultaneously with the start of germination tests and also the non-germinated seeds were tested in this way after termination of each germination test.

Estimation of the water content of acorns: After cutting in 4 parts of 4×50 acorns they were weighed before and after drying at 105°C for 48 hours. Water content of acorns was calculated on fresh weight basis.

Germination tests: Germinability was tested for acorns of each experimental variant at various temperatures (see experimental designs), but in the long-term storage experiment only at 20°C. Acorns were mixed with a moist sand/peat medium (1 : 1 by vol.) in glass jars, which were placed at the desired temperatures. At weekly intervals the seeds were checked and the germinated ones (radicle 3 mm long or longer) and the decaying or dead ones were counted and removed. The eventual loss of water in the medium was supplemented, thoroughly mixing in with the medium and acorns. As fully germinated were regarded seeds with not only a growing radicle but also with an actively growing epicotyl, protruding from between the cotyledons.

Long-term storage: Acorns collected in 1971 were stored in 3 different ways:

a) in 10 l milk cans, mixed with air-dry peat-mull in a proportion of 1 : 1 by volume. To make gaseous exchange of acorns with the outer atmosphere possible 3 strips of cardboard were placed between the edge of each milk can and the lid; acorns were collected successively from each can in each Spring and Autumn

b) in 10 l milk cans as in a) but air-dry pine sawdust was used as the storage medium instead of peat,

c) in sealed 5 l polyethylene (0.05 mm thick) bags, which were opened only once, at the end of the planned storage period. For germination tests acorns were removed from the milk cans and bags each Spring and Autumn (April and September), for seedling emergence tests in the nursery only in Spring (April).

Estimation of seedling emergence in the nursery: Seeds collected in 1971 were stored as described above and part of the acorns from each experimental variant (5×100 acorns) was sown each April in the nursery, in a randomized block design with 5 replicates. In each block each variant was represented by 100 acorns sown in rows 3 cm deep, pressed transversively at a distance of 20 cm in seedbeds 120 cm broad. In each row 25 acorns were sown, so each replicate of each variant was sown in 4 succesive rows. After sowing the acorns were covered with a ligh sandy soil. In very dry periods the seedbeds were watered by sprinkling, fertilizers (green manure and NPK) and fungicides were applied as in the normal forest nurseries. The nitrogen fertilizer was top-dressed in an light soluble form in May.

Thermal conditions: All germination tests and storage experiments were performed in air-conditioned or refrigerated chambers, where temperature was maintained with an accuracy of ±0.5°C.

EXPERIMENT 1

Aim of the experiment: Testing germinability at various temperatures of successively dried acorns to find their critical hydration level, below which they should not be dried.

Seed material: Acorns were collected on September 27th 1963 in an old stand of oaks on the bank of the river Warta in Dąbrowa near Śrem, voivodship Poznań (Fig. 1A). Initial water content of acorns was 43.7%.

Drying of acorns: Acorns were spread in a layer not thicker than 2 - 3 cm on tables in a shady, well ventillated non-heated chamber in the building of the Institute of Dendrology at a temperature of 10 - 15°C, drying lasted 46 days in the time between September 28th

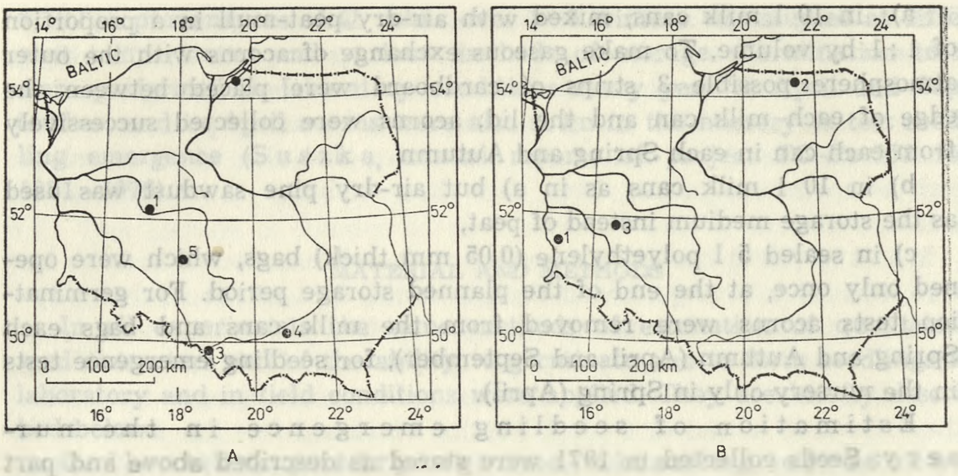

Fig. 1. Sites of collection of acorns of *Quercus robur* L. (A) *1* — Dąbrowa (for experiment 1); *2* — Kadyny, *3* — Harbutowice, *4* — Lubasz, *5* — Głaz (for experiment 2); (B) *1* — Wymiarki, *2* — Srokowo, *3* — Antonin (for experiment 3)

and November 12th, 1963. For germination tests acorns were taken from the drying-room on the dates given below together with the corresponding water content levels:

September 28th	water content		43.7%
October 11th	„	„	37.3%
October 17th	„	„	33.4%
October 27th	„	„	29.5%
November 4th	„	„	26.7%
November 10th	„	„	24.9%
November 12th	„	„	22.6%

G e r m i n a t i o n t e s t s: Acorns were held in the moist stratification medium for 10 weeks at 1°, 3°, 5°, 10°, 15°, 20° and 25°C, after that 2 replicates (2×50 acorns) of each temperature variant were left at the same thermal conditions but the other 2 were transferred to 20° C, in both variants for the next 5 weeks. Germination and growth of epicotyls were observed at weekly intervals.

EXPERIMENT 2

A i m o f t h e e x p e r i m e n t: To find optimal thermal conditions for germination tests of acorns of various Polish provenances of *Q. robur*.

S e e d m a t e r i a l: Acorns were collected from the ground (3 lots) or purchased from a forester (1 lot) in 4 different sites spread over Poland (Fig. 1A). The trees were of an age of 100 - 200 years. Data of collection are shown in Table 1.

Table 1

Data on collection and the onset of germination tests on *Quercus robur* seed (experiment 2)

Seed collection site	Collection or purchase* date	Onset of germination tests date
Kadyny	October 15th, 1970	October 16th, 1970
Harbutowice	October 20th, 1970	October 24th, 1970
Lubasz	October 27th, 1970	October 31st, 1970
Głaz	October 29th, 1970*	October 30th, 1970

Stocking before onset of experiments: Stocking of acorns in open baskets covered with burlap sacs lasted 1-4 days (see Tab. 1).

Germination tests: The acorns were stratified in a moist sand/peat medium at 5°, 10°, 15°, 20° and 25°C (4×50 acorns) for 100 days and in that time germination and the growth of epicotyls were observed at weekly time intervals.

EXPERIMENT 3

Aim of the experiment: To find the optimal thermal condition and storage method for a long-term storage of acorns of *Q. robur*.

Seed material: Acorns were collected from the ground on 3 sites in Poland. These sites are indicated in Fig. 1B. Data on collection and provisional stocking are presented in Table 2.

Stocking of acorns: Duration of the stocking periods is presented in Table 2, these periods lasted from 12 to 22 days. Temperature in the attic where the acorns were stocked was measured daily. The highest and lowest temperatures during stocking of acorns of the various provenances were: Wymiarki 14°C and 4.0°C, Srokowo 12°C and 4.0°C, Antonin 12°C and 4.0°C.

Table 2

Data on collection, stocking and start of storage of acorns of *Quercus robur* (experiment 3)

Seed collection site	Collection date	Stocking in Kórnik in cool conditions		Start of storage in controlled conditions date
		dates	duration days	
Wymiarki	Mid-October 1971	October 18th - November 9th, 1971	22	November 9 th, 1971
Srokowo	Late-October 1971	October 29th - November 11th, 1971	13	November 11th, 1971
Antonin	Late-October 1971	October 27th - November 8th, 1971	12	November 8th, 1971

Table 3

Time-table of experiment 3 on the long-term storage of acorns of *Quercus robur* L.

	Provenance					
	Wymiarki		Srokowo		Antonin	
	start of storage date	duration of storage months	start of storage date	duration of storage months	start of storage date	duration of storage months
Autumn 1971	November 11th	0	November 11th	0	November 8th	0
Spring 1972		5*		5*		5*
Autumn 1972		10		10		10
Spring 1973		17*		17*		17*
Autumn 1973		22		22		22
Spring 1974		29*		29*		29*
Autumn 1974		34		34		34
Spring 1975		41*		41*		41*
Autumn 1975		46		D		46
Spring 1976		D		D		53*

* Laboratory germination tests at 20° C accompanied by sowing in the nursery.
D – Seed stock depleted.

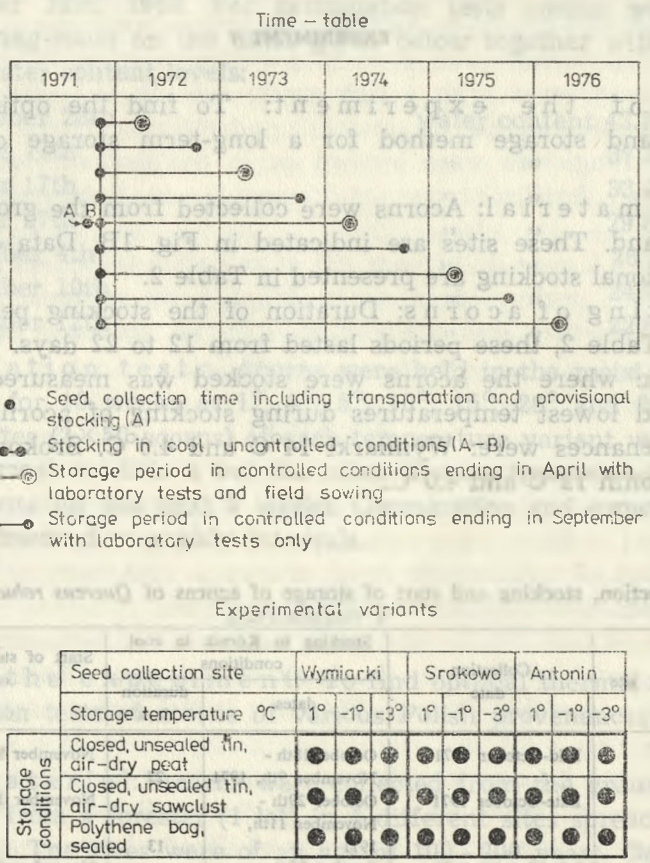

Fig. 2. Design of the experiment 3

Design of the experiment: Acorns of each provenance were stored at 3 temperatures and 3 methods were applied. The design of this experiment is shown in Fig. 2. Duration of the storage periods is shown in Table 3.

RESULTS

GERMINATION AND GROWTH OF EPICOTYLS OF ACORNS WITH VARIOUS WATER CONTENT LEVELS AT DIFFERENT TEMPERATURES (EXPERIMENT 1)

Final results of germination tests of freshly collected or gradually dried acorns are presented in Table 4. From these data it can be seen that the critical hydration level, below which germinability of acorns and ability of the epicotyls to grow starts to decrease, lies between 43.7% and 37.3%. It is also shown that the more the water content of acorns is lowered below this critical value the more intensive is the decrease of their viability — at 22.6%, as a mean value of water content, nearly all acorns have lost their viability.

Germinability of acorns cannot be manifested at temperatures in the range 1 - 3°C, though their viability remains high in these moist--cold conditions even after 15 weeks (105 days). At 5°C radicles start to pierce through the testae and germination is initiated. At 10°C it is already intensive and at 15°C the optimal thermal conditions for the growth of radicles seem to be created. Growth of epicotyls at 1 - 10°C is inhibited or very limited, but it becomes already intensive at 15°C, and at 20°C the number of acorns with growing epicotyl is maximal. In Fig. 3 the cumulative curves for germination and the epicotyl growth are presented. For acorns with a high water content, e.g. 43.7%, the course of germination is most energetic at 15°C and the growth of epicotyls at 20°C. At this latter temperature all (100.0%) acorns exhibited radicle and epicotyl growth, germination being finished after 6 weeks and the appearance of new epicotyls was terminated 3 weeks later. At 25°C both phenomena were already somewhat delayed.

Thus a general conclusion can be drawn from the results of experiment 1: acorns of *Q. robur* should after collection not be dried below a critical hydration level lying between 43.7% and 37.3%, probably below 40.0%. The most energetical seedling emergence in the highest possible percentage is to be expected at 20°C.

The course of germination and the epicotyl emergence from between the cotyledons shown in Fig. 3 illustrates an interesting fact: acorns with the initial water content of 43.7%, which at 1° and 3°C do not germinate but also do not loose viability in the 10-weeks period of the cold-moist treatment, are able to start germination immediately after transfer to 20°C, which is followed 2 weeks later by the emergence of

Table 4

Germination of acorns of *Quercus robur* L. and growth of their epicotyls at various temperatures in stratification conditions, the tests lasting 105 days. Acorns were collected in Dąbrowa near Śrem (experiment 1)

Water content of acorns	Germination of acorns and growth of epicotyls at various temperatures													
	1° C		3° C		5° C		10° C		15° C		20° C		25° C	
[%]	germ. [%]	epic. [%]	germ. [%]	epic. [%]	germ. [%]	epic. [%]	germ. [%]	epic. [%]	germ. [%]	epic. [%]	germ. [%]	epic. [%]	germ. [%]	epic. [%]
43.7	0.0	0.0	0.0	0.0	25.0	0.0	83.0	5.0	97.0	75.0	100.0	100.0	97.2	97.2
37.3	1.7	0.0	8.3	0.0	18.6	0.0	54.1	6.2	82.7	76.1	89.0	88.0	72.0	72.0
33.4	0.0	0.0	0.0	0.0	7.0	0.0	38.0	2.0	62.0	53.0	56.5	51.0	51.0	49.0
29.5	0.0	0.0	2.8	0.0	0.0	0.0	4.2	0.0	26.8	19.6	24.0	20.0	30.4	25.9
26.7	0.0	0.0	0.0	0.0	1.0	0.0	5.3	2.1	19.0	16.7	14,4	14.4	11.0	9.0
24.9	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	3.0	1.0	6.2	3.1	6.9	4.9
22.6											4.0	3.0		

epicotyls. So pretreated acorns need only 5 weeks for formation of complete seedlings with a growing radicle and epicotyl, in contrast to the not cold-pretreated ones which, as was already shown, need at 20°C 10 weeks for the completion of the epicotyl emergence.

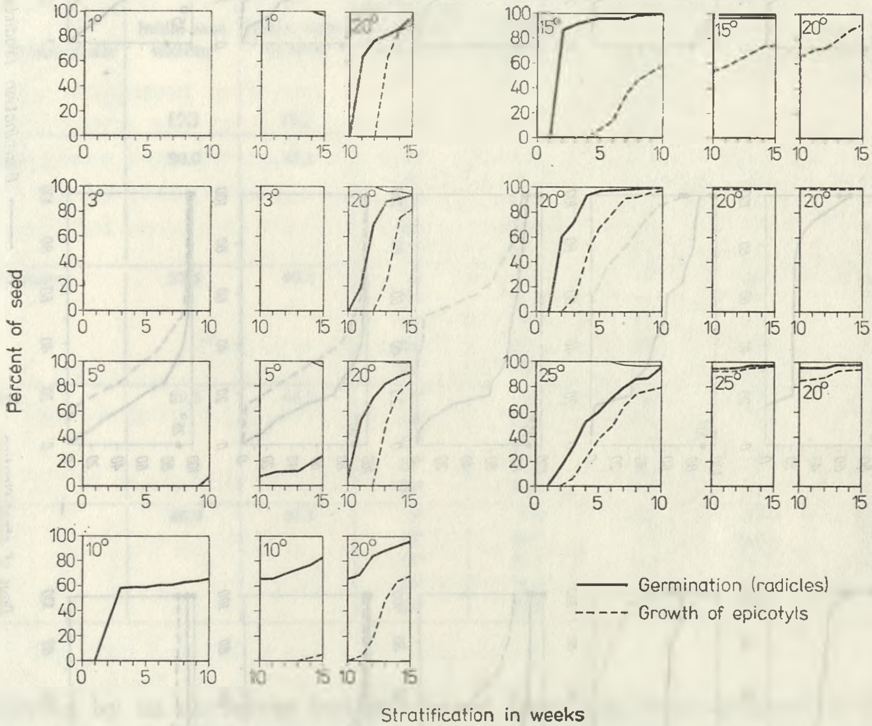

Fig. 3. Course of germination and of the growth of epicotyls of *Quercus robur* L. acorns (initial water content 43.7%) at various temperatures in the range 1 - 25°C when stratified for 15 weeks or when after 10 weeks transferred to 20°C (experiment 1)

Thus a second conclusion can be drawn: cold-moist treatment of freshly collected acorn lasting 10 weeks at 1 - 3°C prevents germination but makes an energetic and high-percent germination and epicotyl emergence in a short period possible.

GERMINATION AND GROWTH OF EPICOTYLS OF ACORNS OF VARIOUS PROVENANCES AT VARIOUS TEMPERATURES (EXPERIMENT 2)

Results of experiment 2, for which acorns of 4 Polish provenances were used, are presented in Table 5. These data demonstrate the fact that acorns originating from Kadyny, Harbutowice and Lubasz were viable in a high percent (87.5 - 90.0%) and that their initial water content was higher than 40% but did not exceed 45.1%. Only acorns not

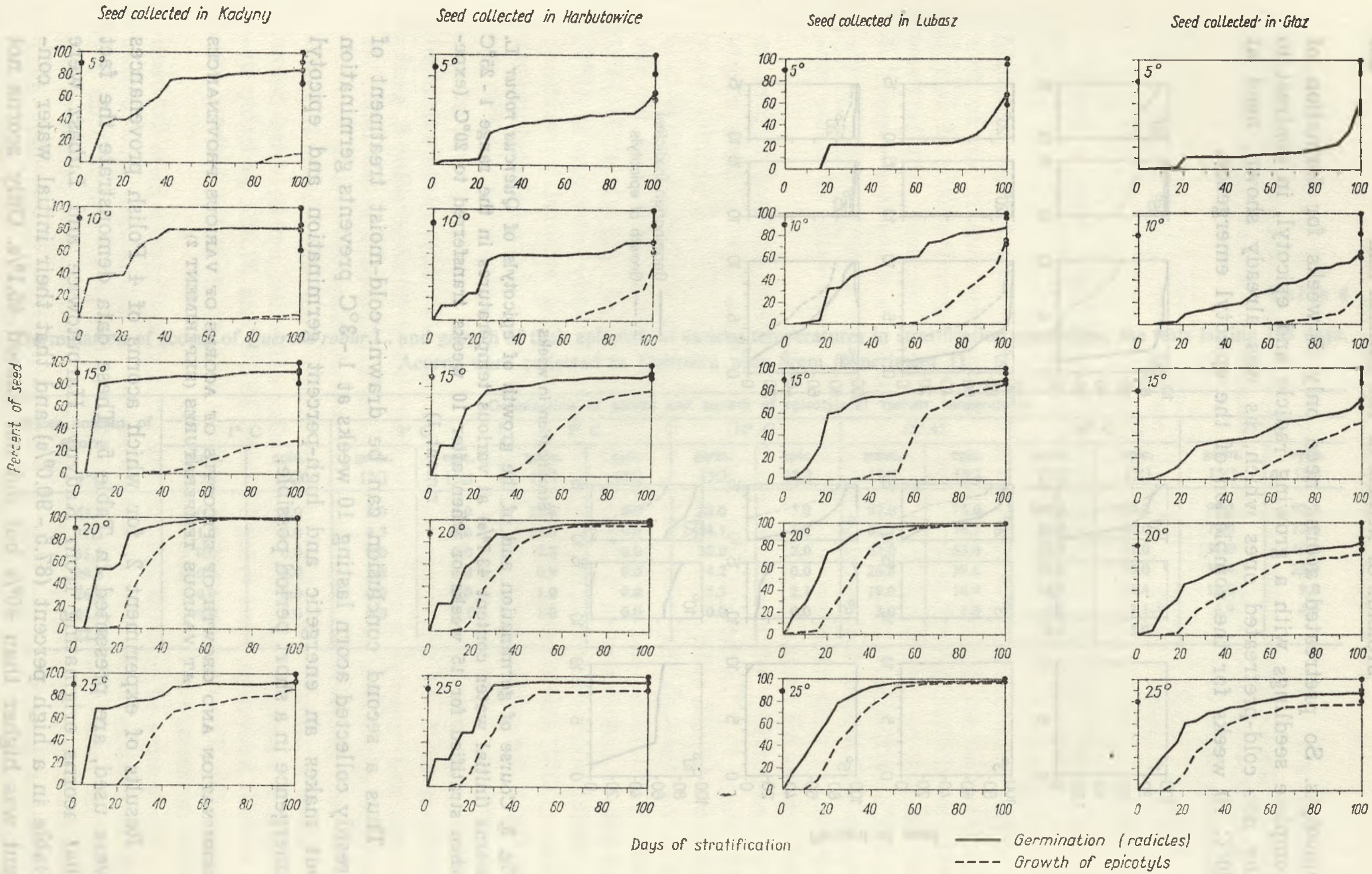

Fig. 4. Germination and epicotyl growth of acorns of 4 provenances of *Quercus robur* L. at various temperatures in the range 5 - 25°C (experiment 2)

Table 5

Results of germination tests in stratification conditions and at various temperatures of *Quercus robur* L. acorns (experiment 2)

Sed collection site	Initial seed viability [%]	Initial water content [%]	Temperature of the germination test [°C]	Results of germination tests lasting 100 days: sound seeds with growing radicle and epicotyl [%]	decayed seeds with earlier emerged radicle [%]	total of decayed seeds [%]	sound non-germinated seeds [%]
Kadyny	90.0	45.1	5°	8.0	11.5	21.5	7.0
			10°	4.0	19.0	36.0	1.5
			15°	30.0	11.5	18.5	0.5
			20°	99.5	0.0	0.5	0.0
			25°	86.5	0.0	8.0	0.5
Harbutowice	87.5	40.8	5°	0.0	5.5	22.5	17.0
			10°	50.0	8.5	21.5	12.5
			15°	77.0	2.0	10.5	0.0
			20°	95.5	2.0	3.5	0.0
			25°	88.0	7.5	12.0	0.0
Lubasz	89.5	44.2	5°	0.0	9.5	13.5	28.0
			10°	74.7	2.7	6.0	9.3
			15°	86.0	1.0	5.0	7.0
			20°	99.0	0.0	0.5	0.0
			25°	97.0	0.0	3.0	0.0
Głaz	80.0	51.1	5°	0.0	10.5	21.5	25.5
			10°	29.0	5.5	25.0	15.0
			15°	51.5	4.0	17.5	15.0
			20°	71.0	5.0	23.0	1.0
			25°	76.5	8.5	20.0	1.5

collected by us ourselves but purchased from the local forester in Głaz had a lower viability (80%) and their hydration level was much higher (51.1%). Acorns of all provenances after 1 - 4 days of stocking were stratified at various temperatures. The course of germination and epicotyl emergence is shown in Fig. 4, and the final results in Table 5.

At 5°C, which was the lowest temperature in the experiment, only growth of radicles was observed in the 100 days of the test, at 10°C radicles started to grow in the first days of the tests but epicotyls started to emerge very late, mostly after 60 - 70 days. At 15°C germination was very intensive but it was only at 20°C that an energetic germination was followed only 2 weeks later by the appearance of growing epicotyls. Both phenomena were terminated after 60 - 70 days of the tests at 20°C. At this temperature the percent of decaying seeds was smallest 0.5 - 3.5%, with the exception of the low-quality seed provenance Głaz — 23.0%) and the percent of sound, non-germinated seed was also lowest (0.0%, Głaz — 1.0%). At 25°C the percentage of emerging epicotyls was again reduced for acorns of two of the 4 provenances.

The general conclusion from experiment 2 is: freshly collected acorns of *Quercus robur* with an initial water content above 40% can be expected to germinate and form growing epicotyls most energetically and in the highest possible percent at 20°C, this finding was confirmed on acorns of different Polish oak provenances.

LONG-TERM STORAGE OF ACORNS IN CONTROLLED THERMAL CONDITIONS (EXPERIMENT 3)

In Fig. 5 an explanation for Figs. 6, 7 and 8 is presented, in the latter ones data are presented for the period from the onset to the end of each storage trial, concerning changes of germinative energy and capacity in laboratory conditions and of seedling emergence in the nursery. In Tables 6, 7 and 8 more detailed numbers are given for the following 7 characteristics:

WC — Water content in %,
P — Seeds pregerminating during storage in %,
E — Seeds with the epicotyl growing during storage in %,
RL — Length of radicles of seeds germinating during storage in cm,
LGE — Laboratory germinative energy (after 20 days at 20°C) in %,
LGC — Laboratory germinative capacity at 20°C in %,
NSE — Nursery seedling emergence in %.

In Tables 6, 7 and 8 these characteristics are presented only for freshly collected seed and for seeds tested every Spring. Because of the negative results of storage in sealed polyethylene bags and of the faster decline of germinability of seeds stored at −3°C, only data for acorns

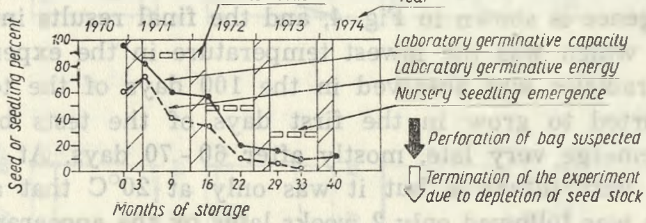

Fig. 5. Explanation for Figs. 6, 7 and 8 (experiment 3)

stored at +1°C and −1°C mixed with air-dry peat or air-dry pine sawdust are presented here. Detailed and complete numbers comprising all storage temperatures and methods were published elsewhere (Suszka, 1976).

Data presented in Figs 6, 7 and 8 indicate clearly that storage of acorns of *Q. robur* in sealed polyethylene bags (filled with 5 l of acorns)

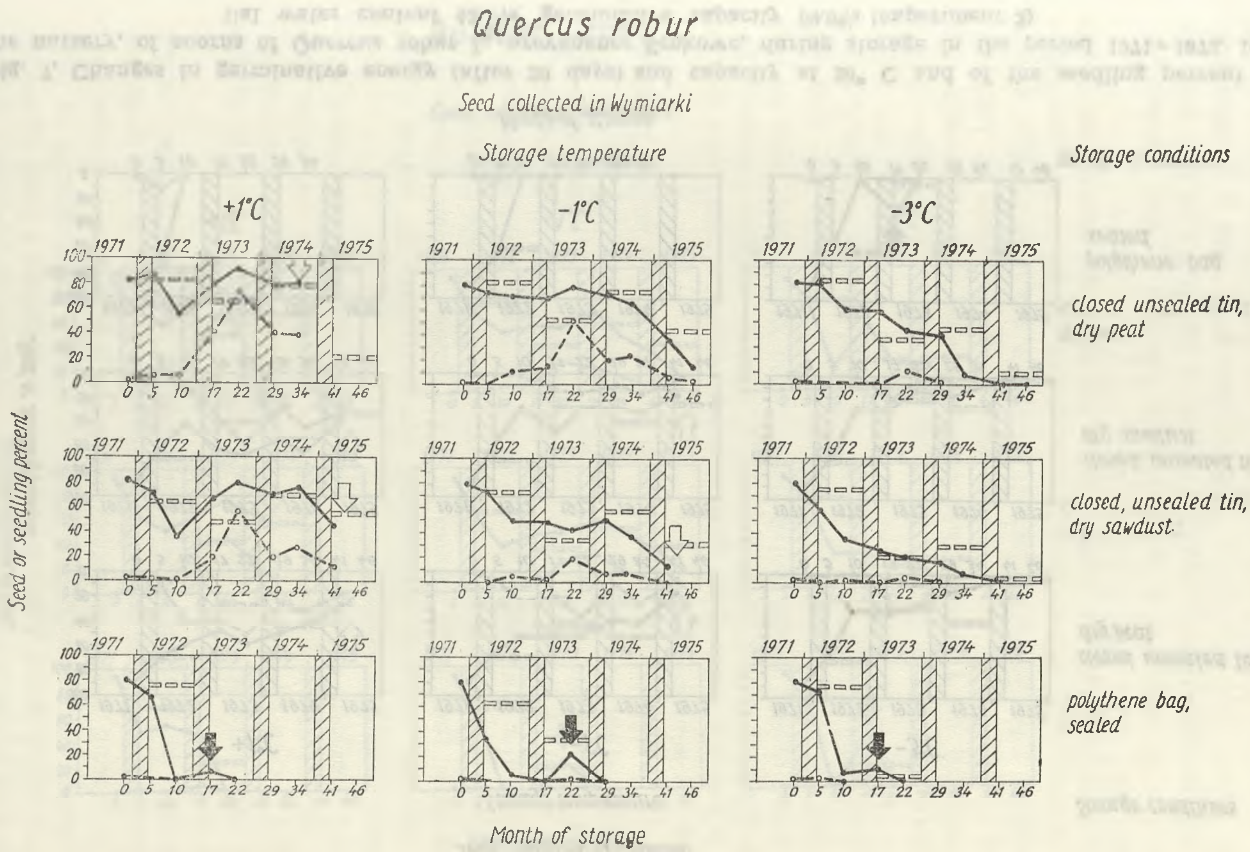

Fig. 6. Changes in germinative energy (after 20 days) and capacity at 20°C and of the seedling percent in the nursery, of acorns of *Quercus robur* L. provenance Wymiarki, during storage in the period 1971 - 1975. Initial water content 45.6%, germinative capacity 81.0% (experiment 3)

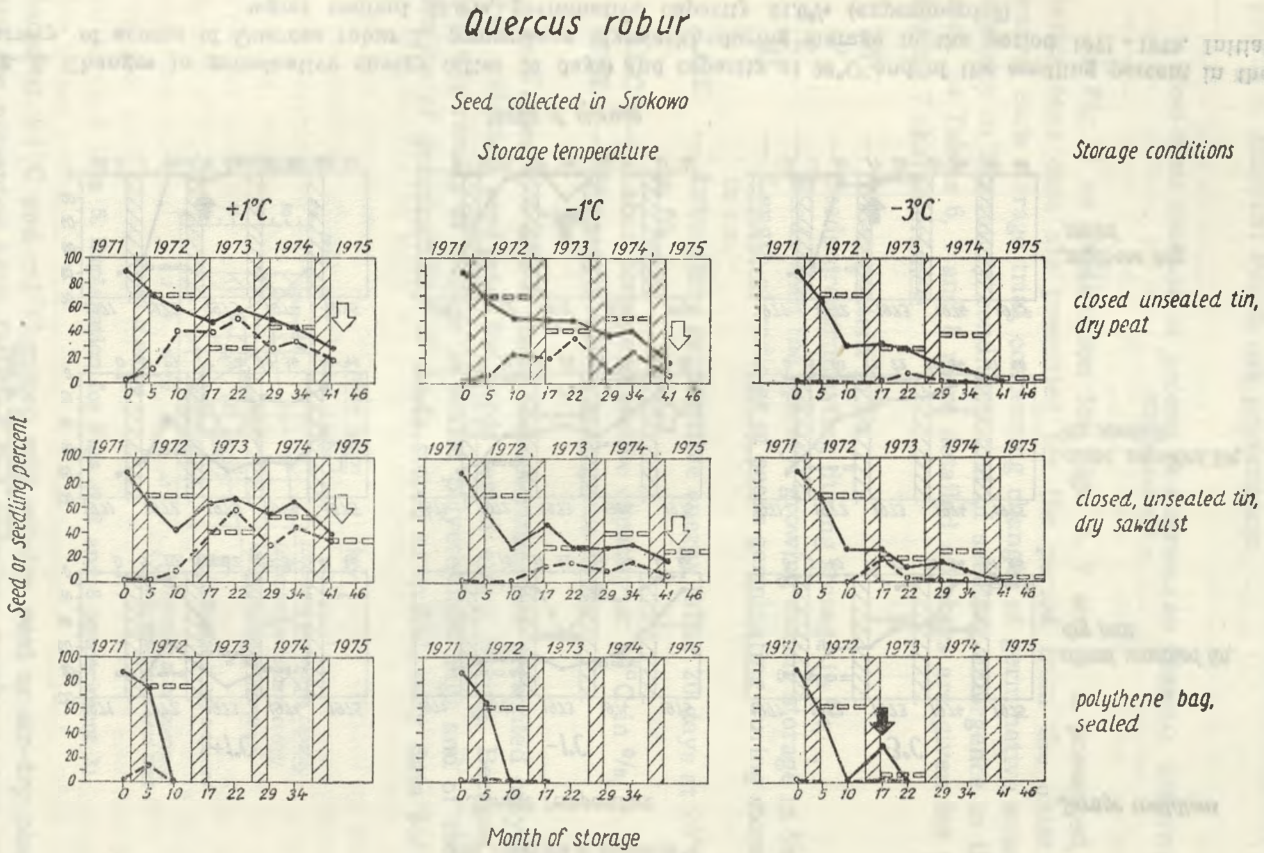

Fig. 7. Changes in germinative energy (after 20 days) and capacity at 20° C and of the seedling percent in the nursery, of acorns of *Quercus robur* L. provenance Srokowo, during storage in the period 1971 - 1975. Initial water content 43.1%, germinative capacity 89.0% (experiment 3)

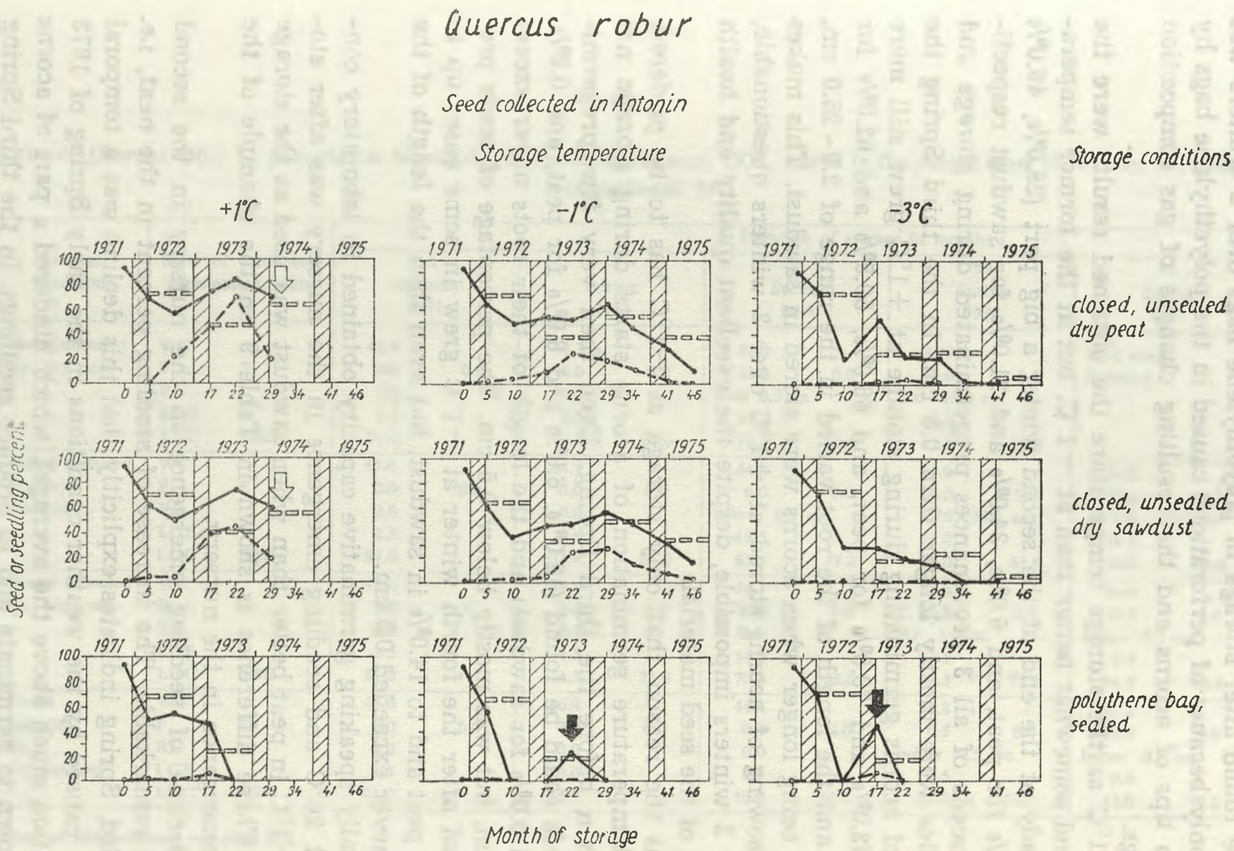

Fig. 8. Changes in germinative energy (after 20 days) and capacity at 20°C and of the seedling percent in the nursery from acorns of *Quercus robur* L. provenance Antonin, during storage in the period 1971 - 1975. Initial water content 42.1%, germinative capacity 93.0% (experiment 3)

is possible only till the first Spring after collection at all temperatures applied i.e. at 1°, −1° and −3°C. Till the Autumn all or nearly all acorns so stored have lost germinability. Some germination and seedling emergence found after storage in polyethylene bags over 2 winters was possible only because of perforations caused in the polyethylene bags by the sharp tips of acorns and the resulting changes of gas composition in the bags.

At +1°C as the storage temperature the obtained results were the highest and somewhat better than at −1°C, but at the former temperature already at the end of the second winter a big part (28.0%, 46.0% and 47.0% for peat, and 6.0%, 34.0% and 21.0% for sawdust respectively) of seeds of all 3 provenances pregerminated during storage and the radicles were mostly longer than 0.5 cm. In the third Spring the number of acorns germinating during storage at +1°C grew still more (75.0%, 62.0% and 70.0% for peat, and 66.0%, 59.5% and 62.0% for sawdust) and the length of the root varied in the range of 2.0 - 25.0 cm, the roots being longer when acorns were stored in sawdust. This makes machine sowing of acorns stored at +1°C over 2 winters questionable, and after 3 winters impossible, despite the excellent quality and health condition of the seed material.

This is the reason that only storage at −1°C has to be prefered. At this temperature germination of acorns starts during storage not earlier than before the third Spring. Even then very few pregerminated seeds could be found (12.0%, 6.0% and 8.0% for peat, and 0.5%, 0.0% and 8.0% for sawdust) and the length of their roots never exceeded 1.0 cm, but was mostly below 0.5 cm. The percentage of seeds pregerminated after the fourth winter at −1°C grew in some cases up to 24.0% in peat and to 14.0% in sawdust, but even then the length of the radicles never exceeded 0.5 cm.

Generally speaking germinative capacity obtained in laboratory conditions at 20°C and seedling emergence in the nursery was after storage at −1°C in peat better than when sawdust was used as the storage medium. These difference is shown in Table 9 on the example of the seedling emergence in the nursery.

The decline of seedling emergence in the nursery in the second Spring is remarkable. The increase of seedling percent in the next, i.e. in the third, Spring indicates explicitly that this decline was a temporal one only, caused by the weather conditions in the early Spring of 1973 (precipitation much above the average), which hindered a part of acorns already sown to germinate and to produce seedlings. In the third Spring after collection 51.4 - 75.8% of acorns still produced sedlings in the nursery when they were stored at −1°C mixed with peat, and 40.2 - - 58.2% when mixed with sawdust. Results obtained in the nursery in the fourth Spring after collection were still noteworthy (36.6 - 40.6%

Table 6

Data on acorns of *Quercus robur* L. provenance Wymiarki, collected in Autumn 1971, stored in the period from November 1971 to September 1975 (experiment 3)*

Temperature of storage	Storage conditions	State of seeds and germination data	Duration of storage in months										
			0 Autumn 1971		5 Spring 1972		17 Spring 1973		29 Spring 1974		41 Spring 1975		53 Spring 1976
	closed unsealed	WC	45.6		44.3		49.0		43.9		Seed stock		
	tin, dry peat	P E	0.0	0.0	0.0	0.0	28.0	0.0	75.0	0.0	depleted		
		RL	0.0		0.0		over 0.5 cm		2.0 - 15.0 cm				
		LGE	2.5		5.5		40.5		40.0				
1° C		LGC NSE	81.0		86.5	81.6	79.5	65.0	77.5	78.6			
	closed unsealed	WC	45.6		44.4		44.4		46.0		46.5		
	tin, dry	P E	0.0	00.	0.0	0.0	6.0	0.0	66.0	0.0	58.0	0.0	Seed stock
	sawdust	RL	0.0		0.0		below 0.5 cm		2.0 - 20.0 cm		1.0 - 10.0 cm		depleted
		LGE	2.5		2.0		18.5		19.0		11.5		
		LGC NSE	81.0		71.0	63.0	65.5	47.2	69.0	68.6	44.0	53.6	
	closed unsealed	WC	45.6		44.6		48.1		47.4		46.9		
	tin, dry peat	P E	0.0	0.0	0.0	0.0	0.0	0.0	12.0	0.0	24.0	0.0	Seed stock
		RL	0.0		0.0		0.0		0.5 - 1.0 cm		below 0.5 cm		depleted
		LGE	2.5		1.5		14.5		20.5		5.5		
−1° C		LGC NSE	81.0		74.5	83.0	70.5	52.0	72.5	75.8	34.5	40.6	
	closed	WC	45.6		46.4		44.4		45.8		47.1		
	unsealed	P E	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	6.0	0.0	Seed stock
	tin,	RL	0.0		0.0		0.0		below 0.5 cm		below 0.5 cm		depleted
	dry sawdust	LGE	2.5		0.0		2.5		7.5		0.0		
		LGC NSE	81.0		73.5	75.6	49.0	34.4	50.5	58.2	12.0	30.2	

* Explanation of abbreviations see page 212.

Table 7

Data on acorns of *Quercus robur* L. provenance Srokowo, collected in Autumn 1971, stored in the period from November 1971 to April 1975 (experiment 3)*

Temperature of storage	Storage conditions	State of seeds and germination data		Duration of storage in months 0 Autumn 1971		5 Spring 1972		17 Spring 1973		29 Spring 1974		41 Spring 1975		53 Spring 1976
1°C	closed unsealed tin, dry peat	WC		43.1		43.8		50.7		49.1		53.7		
		P	E	0.0	0.0	0.0	0.0	46.0	0.0	62.0	16.0	42.0	0.0	Seed
		RL		0.0		0.0		over 0.5 cm		2.0 - 20.0 cm		2.0 - 10.0 cm		stock
		LGE		2.5		13.0		40.0		29.5		18.0		depleted
		LGC	NSE	89.0		70.0	70.2	48.5	29.0	51.0	44.2	28.0		
	closed unsealed tin, dry sawdust	WC		43.1		43.6		45.9		52.8		52.4		
		P	E	0.0	0.0	0.0	0.0	34.0	0.0	59.5	1.0	52.0	4.0	Seed
		RL		0.0		0.0		over 0.5 cm		2.0 - 25.0 cm		2.0 - 20.0 cm		stock
		LGE		2.5		2.0		42.0		30.0		31.0		depleted
		LGC	NSE	89.0		62.0	68.4	63.5	41.6	55.0	52.8	38.0	31.8	
−1°C	closed unsealed tin, dry peat	WC		43.1		44.6		48.2		44.6		46.7		
		P	E	0.0	0.0	0.0		0.0	0.0	6.0	0.0	6.0	0.0	Seed
		RL		0.0		0.0		0.0		0.3 - 1.0 cm		below 0.5 cm		stock
		LGE		2.5		6.0		19.5		9.5		5.0		depleted
		LGC	NSE	89.0		64.0	70.2	50.0	42.0	38.0	51.4	16.0		
	closed unsealed tin, dry sawdust	WC		43.1		41.9		46.5		46.3		45.8		
		P	E	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	20.0	0.0	Seed
		RL		0.0		0.0		0.0		0.0		below 0.5 cm		stock
		LGE		2.5		0.5		14.5		9.0		5.5		depleted
		LGC	NSE	89.0		55.0	71.2	46.0	27.4	28.5	40.2	16.5	25.2	

* Explanation of abbreviations see page 212.

Table 8

Data on acorns of *Quercus robur* L. provenance Antonin, collected in Autumn 1971, stored in the period from November 1971 to April 1976 (experiment 3)*

Temperature of storage	Storage conditions	State of seeds and germination data		Duration of storage in months											
				0 Autumn 1971		5 Spring 1972		17 Spring 1973		29 Spring 1974		41 Spring 1975		53 Spring 1976	
1°C		WC		42.1		43.0		47.1		45.8					
	closed,	P	E	0.0	0.0	0.0	0.0	47.0	0.0	70.0	0.5	Seed			
	unsealed	RL		0.0		0.0		over 0.5 cm		2.0 - 15.0 cm		stock			
	tin,	LGE		0.5		6.0		47.0		21.0		depleted			
	dry peat	LGC	NSE	93.0		68.0	73.2	74.0	45.8	71.0	6.6				
		WC		42.1		43.1		44.0		44.5					
	closed	P	E	0.0	0.0	0.0	0.0	21.0	0.0	62.0	0.0	Seed			
	unsealed	RL		0.0		0.0		over 0.5 cm		0.5 - 20.0 cm		stock			
	tin,	LGE		0.5		3.5		20.5		22.5		depleted			
	dry sawdust	LGC	NSE	93.0		61.5	69.8	63.5	36.6	62.0	55.3				
−1°C		WC		42.1		42.9		48.0		46.1		45.5		47.4	
	closed	P	E	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	18.0	0.0	26.0	0.0
	unsealed	RL		0.0		0.0		0.0		below 0.5 cm		below 0.5 cm		below 0.8 cm	
	tin,	LGE		0.5		1.5		10.5		19.0		2.5		0.5	
	dry peat	LGC	NSE	93.0		64.5	70.8	54.5	35.2	63.0	55.6	27.0	36.6	1.5	13.2
		WC		42.1		41.9		46.2		45.8		46.3		48.2	
	closed	P	E	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	14.0	0.0	12.0	0.0
	unsealed	RL		0.0		0.0		0.0		below 0.5 cm		below 0.5 cm		below 0.5 cm	
	tin,	LGE		0.5		1.0		5.0		27.0		6.0		0.0	
	dry sawdust	LGC	NSE	93.0		60.5	63.0	45.5	33.2	56.0	52.6	30.0	32.2	2.0	11.2

* Explanation of abbreviations see page 212.

Table 9

Seedling emergence in the nursery from *Quercus robur* L. acorns stored at −1°C in closed but unsealed containers in air-dry peat or sawdust over 1 - 5 winters (experiment 3)

Time of sowing	Seedling emergence in the nursery after storage at −1° C in peat or sawdust					
	Provenance					
	Wymiarki		Srokowo		Antonin	
	peat [%]	sawdust [%]	peat [%]	sawdust [%]	peat [%]	sawdust [%]
1st Spring	83.0	75.6	70.2	71.2	70.8	63.0
2nd Spring	52.0	34.4	42.0	27.4	35.2	33.2
3rd Spring	75.8	58.2	51.4	40.2	55.6	52.6
4th Spring	40.6	30.2	–	25.2	36.6	31.2
5th Spring					13.2	11.2

for peat, and 25.2 - 31.2% for sawdust) but it seems that from the economical point of view only storage of acorns of *Q. robur* over the first 3 winters could be justified. There is also another argument against a too prolonged storage, namely the seriously reduced growth of seedlings from acorns stored over 4 and 5 winters. In Fig. 9 the still good growth of seedlings obtained in the first vegatation period from acorns stored over 3 winters at −1°C is presented.

Fig. 9. Seedlings of *Quercus robur* L. obtainted in the first vegetation period from acorns stored over 3 winters at —1°C (phot. K. J a k u s z)

We can conclude from the results of experiment 3: Acorns of *Q. robur* L. of high initial quality and with a water content of 40 - 45% can be stored at −1°C in closed but not sealed containers permitting gaseous exchange with the outer atmosphere. The acorns should be mixed with air-dry peat mull or air-dry pine sawdust in a proportion of 1 : 1 by volume. So stored acorns germinate in a still remarkable percentage even after the fourth winter and in a much more reduced percentage also after the fifth one when tested at 20°C in laboratory conditions, and grow into seedlings in the nursery. At −1°C there is no danger of an intensive pregermination of acorns during storage and the radicles, which became visible not earlier than before the third winter, were never longer than 0.5 cm. It seems to be justified to store acorns in the given above conditions only till the third Spring after collection, and then it can be expected that one seedling will be obtained in the nursery from every 2 acorns.

DISCUSSION

Studies on long-term storage of acorns should be preceded by investigations on the optimal conditions for testing their germinability and the ability of epicotyls to grow, both indicators reflecting well the effects of the foregoing storage. Also the permissible hydration levels of acorns taken for storage should be clearly defined, because of some strong contradictions in the literature concerning this matter. Proper studies on the long-term storage can be conducted only when the mentioned above questions are solved. It is important to compare results of the above mentioned tests, repeated at regular time intervals, not only in laboratory conditions or in sowing tests in the nursery, but simultaneously in both. All this was respected in our studies.

We have found in the work reported here that the optimal temperature for the growth of the radicle and in consequence for the germination of *Q. robur* acorns is 15 - 20°C and for the growth of the epicotyls 20°C. So 20°C was recognized as the most advantageous temperature for the growth of both: the radicle and the epicotyl. Thus seedling emergence should run best at 20°C, when constant temperatures are taken into account. Similar results were obtained much earlier in Czechoslovakia by Zachar (1953) who has found the temperature range 15 - 20°C as the most appropriate for seedling emergence tests of *Q. robur* acorns. In the ISTA-rules (ISTA 1966, 1976) 20°C is also prescribed for germination tests in sand for the acorns of this species, from which only 2/3 of the seed including the embryo axis are used. Basing on the results of our work and on foreign data we decided to test at 20°C the germinability of acorns and the ability of their epicotyls to grow, in stratification tests with weekly repeated checking of all seeds. Only seed exhibiting growth of both: the radicle and the epicotyl were accepted as fully germinating ones. It is absolutely false, to express results of storage experiments through germination data based on the appearance of radicles only, because in some conditions the radicle remains viable even when the embryonal shoot apex is already dead.

We have found that the water content of acorns taken for storage should never lie below 40% and that is should be maintained during storage at or above this level. Many authors represent the opinion that the hydration level of acorns should be held in the range 40 - 45% (Pravdin and Filimonova, 1952; Holmes and Buszewicz, 1956; Evrard, 1956; Filimonova, 1958; Tyszkiewicz 1959; Zhiganov, 1959; Schönborn, 1964). A quite different opinion is represented by Messer (1948, 1960) and Krahl-Urban (1959), who claim that the stored acorns should contain 21.4 - 39.0% of water (numbers obtained through recalculation of data presented by Messer), this range of hydration level being obtainable by reducing the weight of acorns containing initially 38 - 45% of water by 10 - 30%. They represent the opinion, that the critical water content below which acorns should not be dried without a serious danger of loosing viability is 22% (in the fresh weight). This absolutely false recommendation was with full right attacked by Tyszkiewicz (1959), and his opinion, that acorns should never be dried below 40% is fully confirmed by our results demonstrated in the present paper. In a similar way the groundlessness of Krahl-Urban's and Messer's opinion has been exposed by the findings of Schönborn (1964). This latter author has found, studying changes of germinative capacity of *Q. robur* acorns in relation to their water content, that already its reduction from 41.0% to 40.0% causes a decrease of germinative capacity from 92.0% to 80.0%. A decrease of the water content from 36.0% to 35.0% was accompanied by a decrease of germinative capacity from 70.0% to 46.0%. Schönborn (1964) has demonstrated the fact that the deviation from the mean level of water content of acorns of *Q. robur* is in reality very big in a given seed population. In a seed lot with a mean water content of 43.7% in which the water content of each of 100 acorns was estimated separately, 95% of this population are to be found in the range 39.2 - - 48.2% ($\bar{x} \pm 2s$). This fact should never be forgotten when considering data concerning the water content of acorns.

In our studies acorns with an initial water content of 42.1 - 45.6% were used in the storage trials (experiment 3). In all other earlier investigations (experiment 1 and 2) the marginal levels of water content were 40.8% and 45.1%, and only acorns of one provenance contained 51.1% of water. In all variants of the long-term storage experiment 3 an increase of the water content has been observed as storage time was gradually prolonged, all this being in agreement with the reaction of oxidation of sugars: $C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O + 674$ kcal.

An important problem in all discussions on the storage of acorns is the temperature. In our work we based on findings of other research workers but we could ascertain, that most of them have used for their experiments acorns already stocked, sometimes for some months and very often in unknown conditions. In most studies only one seed provenance was used, and what we have found as a very important fact, nobody has tried to store acorns at temperatures in the range between 0° and −2°C. This was the more striking that in most papers a pregermination of acorns during storage was noted at temperatures above 0°C. This makes storage in such conditions senseless, because acorns with radicles cannot be sown neither by hand nor by machine, and cutting off of the long roots, though possible, is unrealizable in mass sowings. For this reason we have applied in our work a sequence of temperature, differing only by 2°C from each other: 1°, −1° and −3°C. This has brought us, on the other hand, very close to the temperature range critical from the point of view of frost hardiness of acorns. The necessity of studying temperatures very close to 0°C was stressed by some investigators (Pravdin and Filimonova, 1952; Holmes and Buszewicz, 1956; Filimonowa, 1958; Zhiganov, 1959; Schönborn, 1964), but only Pravdin and Filimonova have used a temperature spectrum (5°, 0°, −2°, −5°, −10°, −15° and −20°C) wide enough to draw the correct conclusions, unfortunately they have applied it for short-term storage of 3 - 4 months only. Nevertheless they have realized that acorns of *Q. robur*, which at the start of storage do not show any signs of germination, are not damaged during storage of this duration by any of the temperatures in the range from 5° to −5°C, and that they germinate and produce normal seedlings when sown in the nursery. Seeds which pregerminated in the forest before colection or during stocking before storage and whose radicles were already 2 - 4 mm long, have partially lost viability when stored for 3 months at −5°C but they did not at −2°C. Temperatures lower than −5°C have killed all acorns.

In our studies we have found that temperature of −1°C, never tested by anybody, has proved most successful for the long-term storage. Viable and germinable acorns producing still normal seedlings, though of a reduced height, could be found in a still considerable number after such storage even over 5 winters (11.2 - 13.2%, according to the medium, sawdust or peat). Though during storage a gradual decline of germinability could be observed, acorns stored in dry peat over 3 winters germinated at 20°C fully (radicle+epicotyl) in 38.0 - 72.5% depending on the provenance, and in the nursery they grew into normal seedlings in 51.4 - 75.8%. When dry pine sawdust was used as the storage medium the results were somewhat lower but still remarkable, in contrast to the results obtained by Holmes and Buszewicz (1956) for the same media where better results were provided by storage at 2.2°C in sawdust than in peat. In our work acorns stored at −1°C in peat over 1 - 5 winters produced in the nursery equal or higher numbers of seedlings than if they were stored in sawdust. It seems that the better hygroscopic and aeration conditions of peat can explain this superiority. Compared with peat sawdust is such a cheap material that the relatively small decrease of seed germinability can be balanced by the low costs of the sawdust.

At 1°C storage was at least as effective as at −1°C, but at this higher temperature the acorns started to germinate before the end of the second winter and after the third winter radicles grew into roots up to 25 cm long. The percentage of acorns pregerminated during storage at 1°C was for peat and for sawdust very high (62.0 - 75.0% and 59.5 - - 66.0% respectively). When temperature −1°C was applied for storage the first pregerminating seeds have been found in the third Spring after collection. The maximal number of such seeds was 12.0%, the radicles never being longer than 0.5 cm, and that is no obstacle for hand and machine sowing. At −3°C germinability of acorns decreased more than at −1°C.

When air access to the stored acorns was impossible their viability decreased very fast. Even when they were stored in sealed polyethylene bags the used oxygen could not be replaced quickly enough by that penetrating through the thin sheet and anaerobic respiration was initiated. This could be proved by the acrid smell of the acorns, when the polyethylene bags were opened already after 10 months of storage. Similar conclusions were reached by Holmes and Buszewicz (1956) who stored acorns of *Q. robur* in pure CO_2, Ančak (1972) who has stored acorns in pure nitrogen or Janson (1979) who has used tightly sealed glassjars as storage containers. Some light on the amount of CO_2 produced by the acorns is thrown by the results to Zaitseva (1950) who has found that 1 kg of them give off 730 ml at 20°C and still 203 ml when held at 4°C, i.e. 3.6 times less. Tylkowski (1976) has shown in his studies on acorns of *Q. borealis* that their respiration at −1°C is nearly 15 times less intensive than at 20°C.

It should be stressed that our studies differed from those performed by other investigators in many important details: temperature of −1°C has also been applied for storage, storage was extended even until the 5th Spring after collection when some acorns were still viable, acorns were used for storage shortly after collection, studies were performed on acorns from different, and geographically distant provenances, only seeds producing a radicle and an actively growing shoot were regarded as fully germinated, the effects of the gradually prolonged storage were tested in laboratory as well as in the nursery conditions, finally special attention was paid to find methods and conditions for storage inhibiting pregermination of acorns during storage.

It could be proved that a proper temperature, a well defined water content level of acorns and air access are the most important factors in maintaining them viable and germinable during storage. However, it should not be forgotten, that fungal contamination can cause losses of the stored acorns in 4 months of the order of 60 - 98% of the stock (Morelet, 1974). As the most dangerous pathogen the fungus *Ciboria batschiana* has been recognized, causing the black rot of acorns. Application of fungicides can be only preventive and is not always effective (Urošević, 1959; Ančak, 1972; Łukomski, 1973; Morelet, 1974). The most promising results in the chemical control of *Ciboria batschiana* have been obtained by Bonnet-Masimbert and Muller (1977) and by Delatour, Muller and Bonnet-Masimbert (1978). Soaking in solutions of Benomyl or Methylthiophanate followed by an additional powdering of acorns of *Q. robur* with Thirame has stopped or slowed down during storage at 4°C lasting 24 months the spread of the fungus between acorns but it remained ineffective in case of previously contaminated acorns. Delatour (1978) elaborated a new effective method of controlling *Ciboria batschiana* by an 8-hours soaking of acorns in water at 38°C i.e. by a thermotherapeutic method, but its effectiveness was tested during storage at 4°C lasting 5 - 6 months only.

SUMMARY

From the presented results of studies on acorns of the English oak (*Quercus robur* L.) the following conclusions can be drawn:

1. Drying of acorns to a level of water content lower than 40% causes an irreversible decrease of viability, at 22 - 25% all acorns are already dead.

2. Tests for germinability and growth of epicotyls of non-pregerminated acorns should be performed by stratification in a moist sand/peat medium at 20°C.

3. Acorns should be taken for storage shortly after collection, and their initial water content should be maintained at 40 - 45% (fresh weight basis).

4. Acorns stored in 10 l milk cans at −1°C can retain germinability and ability to grow into seedlings in nursery conditions even until the 5th Spring after collection, though this germinability decreases gradually, but strongest after the third Spring. The stored acorns should be mixed in a proportion of 1 : 1 by volume with air dry peat-mull or air-dry pine sawdust, separating them from each other and protecting against dessication.

5. From the economic point of view it is justified to store acorns, over 3 winters in conditions defined above for outdoor sowings, under the stipulation that the initial quality of such acorns is high.

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BOLESŁAW SUSZKA, TADEUSZ TYLKOWSKI

Przechowywanie żołędzi dębu szypułkowego (Quercus robur L.) przez 1 - 5 zim

Streszczenie

W Instytucie Dendrologii PAN w Kórniku przeprowadzono badania nad kiełkowaniem żołędzi polskich proweniencji dębu szypułkowego (*Quercus robur* L.) w różnych temperaturach zakresu 1 - 25°C, uwzględniając przy tym nie tylko wzrost korzenia, ale i epikotylu. Celem tych badań było ustalenie optymalnych warunków próby kiełkowania żołędzi tego gatunku. Badano również zmiany zdolności kiełkowania żołędzi w zależności od temperatury i poziomu zawartości wody, który obniżano po zbiorze stopniowo od 43,7 do 22,0%. Po ustaleniu warunków optymalnych dla laboratoryjnych prób kiełkowania przeprowadzono badania nad wieloletnim przechowywaniem żołędzi dębu szypułkowego przy zastosowaniu trzech temperatur (1°, —1° i —3°C) i trzech sposobów przechowywania: 1) w 10-litrowych nieszczelnie zamkniętych bańkach do mleka w zmieszaniu z suchym torfem, 2) jak wyżej, lecz w suchych trocinach sosnowych, 3) w szczelnie zaspawanych 5-litrowych workach z folii polietylenowej o grubości 0,05 mm. Do wszystkich wymienionych powyżej badań używano żołędzi nieuszkodzonych i jeszcze nie kiełkujących. Żołędzie przechowywano przez 4 - 5 zim w zależności od wielkości posiadanych zapasów. Ich żywotność sprawdzano w regularnych odstępach czasu w laboratoryjnych próbach kiełkowania i w próbach wschodzenia w szkółce.

Z wyników badań można wyciągnąć następujące wnioski:

1. Podsuszenie żołędzi do poziomu zawartości wody poniżej 40% (w świeżej masie) pociąga za sobą stopniowy, nieodwracalny spadek żywotności. Po obniżeniu zawartości wody do 22 - 25% wszystkie żołędzie są martwe.

2. Próby kiełkowania i wzrostu epikotyli żołędzi powinny być przeprowadzane w wilgotnym podłożu (piasek z torfem) w 20°C.

3. Do przechowywania powinny być pobierane żołędzie jak najwcześniej po zbiorze, a ich początkowa zawartość wody nie powinna przekraczać zakresu 40 - 45%.

4. Żołędzie przechowywane w 10-litrowych bańkach do mleka w —1°C mogą zachować zdolność kiełkowania i zdolność wschodzenia w szkółce nawet do piątej wiosny po zbiorze. Podczas przechowywania obniża się stopniowo ich żywotność. Spadek ten jest najsilniejszy po trzeciej wiośnie. Przechowywane żołędzie powinny być zmieszane w stosunku objętościowym 1 : 1 z suchym miałem torfowym lub suchymi trocinami sosnowymi, które oddzielają żołędzie od siebie i zapobiegają wysychaniu.

5. Z ekonomicznego punktu widzenia jest uzasadnione przechowywanie żołędzi przez 3 zimy w warunkach określonych powyżej. Żołędzie tak przechowane nadają się do wysiewów gruntowych, powinna je jednak cechować wysoka jakość początkowa po zbiorze.

БОЛЕСЛАВ СУШКА, ТАДЕУШ ТЫЛЬКОВСКИ

Хранение желудей дуба черешчатого (Quercus robur L.) в течение 1 - 5 зим

Резюме

В Институте Дендрологии ПАН в Курнике исследовалось прорастание желудей польских провененций дуба черешчатого (*Quercus robur* L.) в различных температурах в пределах от 1 до 25°C. В этих опытах принимали во внимание не только рост корней, но и эпикотилей. Целью этих исследований было определение оптимальных условий для пробы проращивания желудей этого вида. Изучались также изменения в способности прорастания желудей в зависимости от температуры и уровня содержания воды, который постепенно уменьшали от 43,7 до 22,0%. После определения оптимальных условий для лабораторных проб проращивания, были проведены исследования многолетнего хранения желудей дуба черешчатого при различных температурах (1, −1, и −3°C) и трех способах хранения: 1) в 10-литровых неплотно закрытых бидонах из-под молока, в перемешку с сухим торфом, 2) как выше, но в перемешку с сухими сосновыми опилками, 3) в герметически запаянных 5-литровых мешках из полиэтилена толщиной в 0,05 мм. Во всех вышеуказанных опытах применялись здоровые, не проросшие желуди. Их хранили в течение 4 - 5 зим, в зависимости от величины запасов. Жизнеспособность проверяли в одинаковых промежутках времени лабораторными пробами на проращивание и пробами всхожести в питомнике.

По результатам исследований можно сделать следующие заключения:

1. Подсушивание желудей до уровня содержания воды ниже 40% (в пересчете на свежую массу) ведет постепенно к необратимой потере жизнеспособности. Уменьшение уровня содержания воды до 22 - 25% ведет к гибели желудей.

2. Пробы проращивания и роста эпикотилей желудей необходимо проводить во влажном субстрате (песок с торфом) при 20°C.

3. Желуди необходимо закладывать для хранения как можно раньше после сбора. Начальное содержание воды в них должна быть равным 40 - 45%.

4. Желуди хранимые в 10-литровых бидонах из-под молока при −1°C, сохраняют способность прорастания в питомнике даже до 5 весны после сбора. Во время хранения постепенно уменьшается их жизнеспособность Это уменьшение наиболее существенно после 3 весны. Желуди во время хранения должны смешиваться, в соотношении 1 : 1, с сухим торфом или сухими сосновыми опилками, отделяющими их друг от друга и предохраняющими желуди от высыхания.

5. По экономическим соображениям целесообразным является хранение предназначеных для посева и питомнике желудей, в выше указанных условиях, в течение 3 зим, лишь в том случае, когда они характеризуются высоким исходным качеством.