ARBORETUM KÓRNICKIE
Rocznik XI – 1966

BOLESŁAW SUSZKA

Dormancy, storage and germination of *Fagus silvatica* L. seeds

INTRODUCTION

The storage and preparation of beech mast for germination for the needs of forestry practice is most commonly performed by methods which utilize the natural climatic conditions. This is hardly surprising, since it is only during the last 15 years that scientific conditions have been provided for the storage of beech seeds in a fully controlled environment. This environment, made possible by the modern refrigeration equipment, permits the prolongation of the seed storage without loss in viability and germinability, for at least $3^1/_2$ years from collection. The application of such methods is at present limited to only a few countries in which the foresters have access to sufficient cold-storage facilities giving continuous service at constant temperatures within the range of −5° to −10°C.

In comparison with the studies on the storage of beech mast, research dealing with the phenomenon of dormancy, conditions for breaking it, and conditions of germination have been given little attention. As a result the dormancy of beech seeds is at present little known. Even where the new methods of storing of beech mast are employed the preparation of seeds for germination is conducted under uncontrolled conditions of the environment, which is shaped directly or indirectly by the fluctuating and uncertain climatic factors.

The studies reported here concern the response of beech mast to the action of controlled positive temperatures (°C) and their utility in the process of breaking dormancy. The results of experiments described here represent the first part of more extensive studies to be conducted on beech mast.

Until recently it has been generally believed that the seeds of beech can be stored in a viable condition and full germinability for only one winter. The studies conducted in many countries on the short term storage of beech mast by the traditional methods has lead to the conclusion that the seed germinate best in the spring when they were protected after collection from desiccation and stored during the winter at a lowered temperature, slightly above 0°C (1, 2, 5, 7, 8, 9, 10, 11, 18, 19). Rohmeder (16) has established that 17% is the critical moisture content* below which beechnuts should not be dried.

* All the values for moisture content in this paper are given as a percentage of fresh weight.

As a rule it is recommended that after collection the seeds be stocked loosely, in conditions that provide careful drying, and at the same time maintain the moisture content above the critical value. The next stage of preparation of these seeds for spring germination involves the storing in pits or ditches, placing in earth mounds, stratification in moist sand, storing under a forest canopy or even stocking loosely in conditions permitting the preservation of sufficient moisture content. This requirement actually appllies to all the conditions for storage suggested above. Immediately before sowing it is recommended to soak the seeds if they do not show signs of germinating and then to stock the swollen seeds, turning them over frequently, in cool conditions, or to stratify them at low temperature until abundant germination takes place (15, 18, 19).

The state of our knowledge about the properties of beechnuts has been much increased by the studies conducted in the last few years by Rohmeder, Nyholm, Buszewicz and others.

Rohmeder (16) has found in 1951 that the deep dormancy characteristic of freshly collected beechnuts can be overcome by stratification in moist sand at a temperature of 4°—6°C. The period of such stratification depends according to that author on the method of treating beechnuts before stratification and on their moisture content. It can vary from a few weeks to a few months. In the Woody-Plant Seed Manual (2) already in 1949 it has been suggested, that the stratification of beechnuts at 5°C for a period of 90 days and perhaps even for 60 days should be sufficient to prepare them for germination. Nyholm (15) has stressed the need to soak the beechnuts before stratification in water for 24 hrs, if they had been overdried (e.g. 15%).

The problem of storing beechmast for several years has been studied in Denmark by Nyholm (13, 14), in England by Buszewicz (3,4) and West Germany by Schönborn (17). All three investigators have established the existance of a strict relation between the moisture content of the seeds and their resistance to the action of low temperatures, which are necessary to lower the metabolic activities in the seeds in a radical way during long storage. The results of these studies can be summarized as follows:

1. The storage of fully viable beechnuts for at least a period of $3^1/_2$ years after collection is possible.

2. Regardless of the period of storage it is necessary to stock the seeds from the time of collection in the autumn to January or February of the first winter, in a loose fashion at a temperature of about 1°-10°C, a high air moisture content (above 75% relative humidity) and a moisture content of the nuts not getting below 18—20%. Such conditions ensure the breaking of dormancy during the stocking period.

3. Beechnuts with a moisture content of 20—30% can be stored in aerated jute sacks for one winter, and in tightly sealed polyethylene bags, 0,2 mm thick, for two winters after collection at a storage temperature of —4° or —5°C.

4. Beechnuts will sustain a drying to a 2% level of moisture content, with a drying temperature no greater than 20°C.

5. When moisture content is lowered the minimal temperature that the beechnuts will sustain is also lowered.

6. A quick lowering of the moisture content of freshly collected seeds to 8—10% can be achieved without any special equipment simply by turning the nuts frequently while stocked loosely in a thin layer.

7. The optimal conditions for the storing of beechnuts over several years are created by the partial drying to a moisture level of 8—11% after stocking until January/February, followed by storage at a low temperature (—5° to —15°C). The most advantageous pattern was provided by a moisture content of 8—10% and a storage temperature of —10° or —15°C.

8. In order to maintain the low moisture content of the beechnuts it is necessary to use tightly sealed bags or containers (paper bags placed in 0,2 mm thick polyethylene sacks sealed by heat, containers made of polysterol or stainless steel, glass bottles).

9. The defreezing of beechnuts on completion of the storage time should be performed in a cool shaded place.

10. Before sowing it is recommended to apply a short (a few weeks) stratification of the seeds in cold temperature in order to obtain their maximal germinability.

Messer (10), making use of the results of scientific research and of the experience of some West German nurserymen, who store beechnuts in open containers at low temperatures (e.g. —7°C), has conducted in 1958 and 1959 successful trials with storage of many tons of beechnuts at a moisture content of 24—28% in polyethylene sacks at a temperature of —4°C until the second spring after collection.

In contrast to the actual state of our knowledge about the conditions of storage of beechnuts over several years the problem of breaking of seed dormancy and germination cannot be considered as sufficiently understood and documented by scientific research. So far Nyholm (13) was the only investigator who characterized the course of temperature changes, air humidity and moisture content of the seeds during the autumn-winter stocking under most favourable conditions preparing the seeds for germination. In an experiment started simultaneously with the stocking, the beechnuts germinated in the period between the 63rd and 133rd day of stratification at 5°C. The late date on which stratification (26th of November) was begun permits the suggestion that conditions favourable for the breaking of dormancy occured much earlier, namely in the period between ripening and falling of the mast to the ground and the start of stratification. In another experiment of Nyholm (14), in which the stratification of beechnuts at 5°C was started earlier, on the 7th of November, the seeds have germinated later, in the period between the 77th and 147th day of stratification. The same seeds stocked before stratification for 79 days, loosely, in appropriate conditions, and then stratified at 5°C germinated earlier, between the 14th and 119th day of stratification. The shortening of the time to germination can be considered as proof that the initial stages of the processes of breaking dormancy have taken place during the stocking of beechnuts. In Nyholm's (15) experiments even earlier germination was obtained when beechnuts of a Bulgarian provenance collected in 1963 were used. These seeds were for a relatively long time stocked, in fact until the 6th of March. In view of their rather considerable drying up (to 15,3% moisture content), they were soaked for 24 hrs in water, and on having reached a moisture content of 32% they were stratified at temperatures of 0°, 2°, and 5°C. The germination of these seeds resulted, depending on the temperature, after stratification for 21 to 98 days in 0°C, 28 to 112 days in 2°C and 21 to 105 days in 5°C.

According to Nyholm (14) freshly collected seeds germinate slowly as a result of their physiological state. As an example he mentions that the germination of beechnuts stocked in appropriate conditions for 63 days spread over a period from the 14th to the 133rd day of stratification. The normal spring germination of beechnuts should end after 35—42 days of stratification according to Nyholm.

In the experiments of Schönborn (17) on the partial drying of freshly collected beechnuts to various levels of moisture content (from 18% to 2%) the first signs of germination of these seeds during stratification at 4°C was noticed after 84 days. When at this time transferred to room temperature they gradually germinated for a further 56 days. These seeds have shown no signs of a lowered germination ability after drying to the critical range of moisture levels. In the case of stored beechnuts the existence of such a critical range has been established between 12 and 20% of moisture content.

Nyholm (14) claims that the action of a lowered temperature of 1°—5°C for a period of 1½ month on stocked beechnuts with a moisture content of over 17—18% is a satisfactory condition for the full completion of all the processes leading to germination and recommends to terminate the stocking at the beginning of January after a quick lowering of the moisture content. On having reached about 11% moisture content such preconditioned beechnuts can be stored. On the other hand Schönborn (17) believes, that the preparation of seeds for germination by means of stocking under proper conditions should last a little longer, until January or February. Neither of these authors takes into consideration the treatment to which the beechnuts are exposed in the time period between falling from the tree and the beginning of stocking. The need for stratification on termination of the storage period, which they both stress, underlines the fact that the processes leading to the full preparation for germination have not been completed during stocking.

The problem of optimal temperature for the germination of the beechnuts requires further investigations just as the problem of dormancy. In the Woody-Plant Seed Manual (2) an alternating cycle of 20° and 30°C night and day temperatures, is recommended for germination. Tyszkiewicz (19) recommended for the same purpose a temperature of 18—20°C. In 1956 Holmes and Buszewicz (6) have found that beechnuts germinate much more quickly at temperatures in the range 1,7°—4,4°C than in the used temperatures of the range 21°—28°C. Similarily Nyholm (13) believes that the temperatures from 0° to 5°C are most advantageous for a rapid and abundant germination. This makes it all the more surprising that the instructions of ISTA* concerning seed testing recommend the transfer of stratified beechnuts to a temperature of 20°C when signs of abundant germination appear (15). Nyholm (15) studied in detail the reaction of beechnuts to the transfer from stratification temperatures of 0° and 5°C to that of 25°C. From the percentages illustrating the course of germination which he reports it is clear that such a transfer is not advantageous.

When planning the studies reported below the author has made use of the results reported to date. Storage was conducted in tightly sealed bottles kept at low temperatures. In the studies on the dormancy of these seeds the author thought it necessary to use for the studies seed which were not stocked but experimented upon immediately on having fallen off the trees. This was intended to avoid any unexpected influence of thermal conditions that might obscure the true course of the process leading to the breaking of dormancy.

PURPOSE OF THE STUDIES AND METHODS

For the studies nuts of the common beech (*Fagus silvatica* L.,) were used, collected in the period 1–11.X.1964 during the falling of the mast from old trees growing in the Arboretum of the Institute of Dendrology of the Polish Academy of Science in Kórnik near Poznań. After collection the empty seeds and those damaged mechanically or by insects were removed and the remainder was thoroughly mixed.

The moisture content of the beechnuts was estimated by drying for 24 hours at a temperature of 105°C, and expressed as a percentage of fresh weight. The soundness of the seeds was estimated by the cutting tests.

For the stratification medium a moist mixture of sand and peat was used (1 : 1 by volume) with the peat sieved through a 5 mm mesh. This medium was mixed with beechnuts and packed into glass jars. Every 10 days all the stratified samples were checked, noting the number of decaying and germinating seeds. Seeds with a radicle (root) 3 mm long were considered as having germinated. Decayed and germinating seeds, and possibly also the nuts found to be empty during stratification were counted and removed every time they were checked.

All the experimental variables were repeated 4 times, with 50 nuts per replicate. Only in experiment 4 did the number of replicates differ from the accepted standard. The results reported are based on the mean values, which were used for the graphing of the results of germination and decaying (cumulative curves).

The beechnuts were dried in dry basement rooms at a temperature of about 20°C while stocked in a thin layer, frequently turned.

For storing beechnuts glass bottles were used with a ground stopper. The bottles were filled to capacity with the nuts. Lanoline was used to grease the ground gla s stoppers. After closing the stoppers the bottle necks together with the stoppers were dipped in paraffine wax. Each bottle was opened only once to remove all the nuts from it.

All the experimental studies were conducted in the phytotron of the Institute of Dendrology and Kórnik Arboretum PAN. Deviations from the applied positive temperatures did not exceed ∓0.5°C and from temperatures of −10°C reached as much as ∓1,5°C.

The studies conducted in the autumn-spring season of 1964/65 comprised 4 separate experiments.

* International Seed Testing Association

EXPERIMENT 1

Purpose: To establish the length of dormancy of fresh seeds by subjecting them to a cold-followed-by-warm stratification.

Pattern of the experiment: see fig. 1

Temperatures of the cold stratification: 3°, 5° and 10°C.

Temperature of warm stratification: 20°C.

Stratification begun: 12.X.1964.

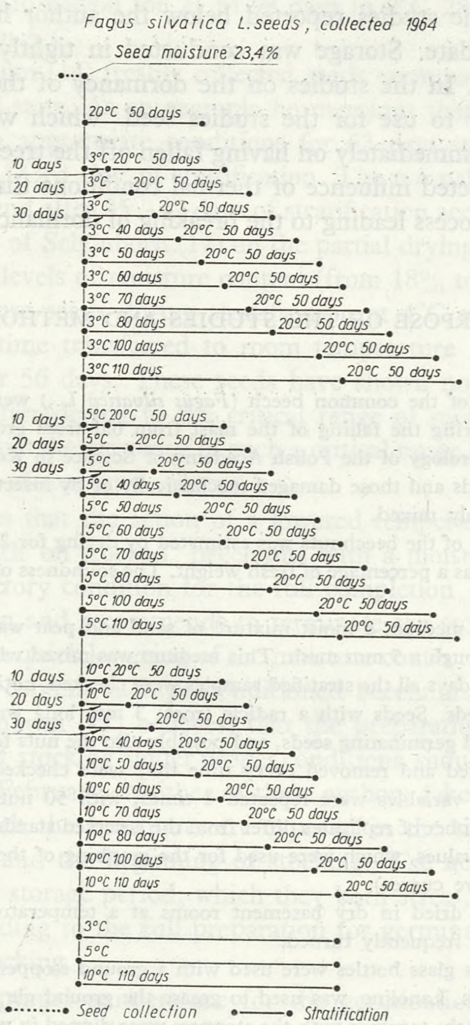

Fig. 1. Pattern of the experiment 1 conducted in the season 1964/65 on the cold-followed-by-warm stratification of fresh *Fagus silvatica* L. seeds

EXPERIMENT 2

Purpose: To study the course of breaking of dormancy in fresh seeds, stratified at constant temperatures.

Pattern of the experiment: see fig. 2a.
Stratification temperatures: 1°, 3°, 5°, 10°, 15°, 20,° 25° and 30°C.
Moisture content of the beechnuts: 23,4%
Stratification begun: 12.X.1964.

N. B.: After 100 days of stratification at temperatures of 1°—15°C one of the four replicates was transferred to a temperature of 20°C and after 110 days the same was done with another of the replicates.

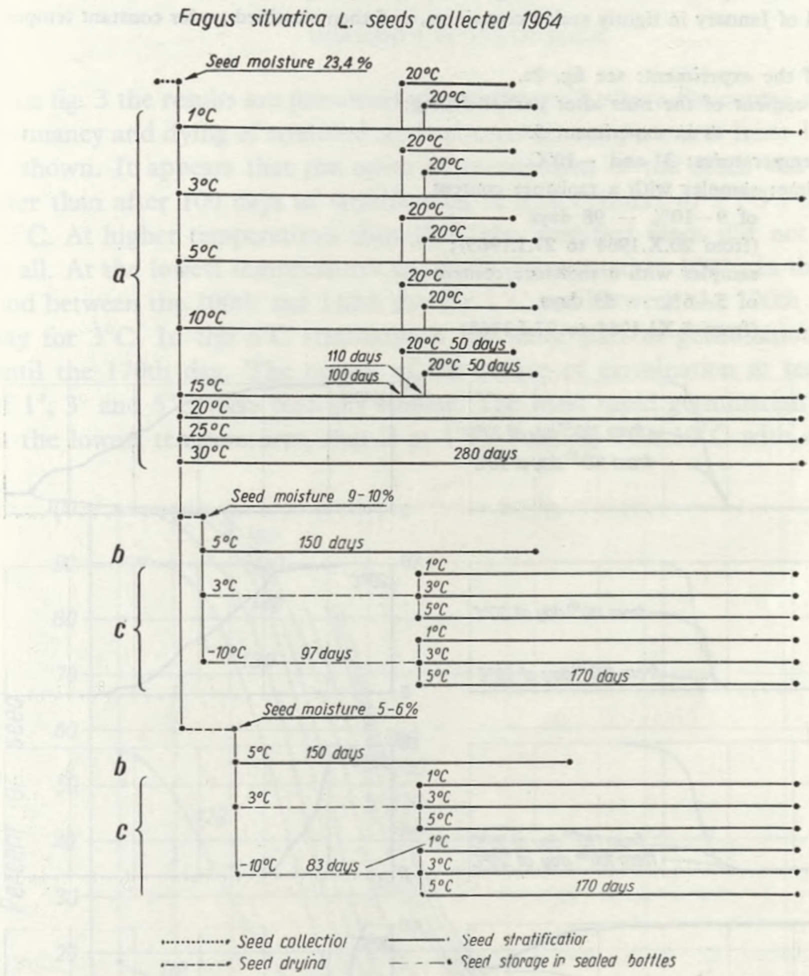

Fig. 2. Patterns of the experiments 2, 3 and 4 conducted in the season 1964/65 on the stratification of fresh (*a*), partly dried (*b*) and partly dried and stored (*c*) seeds of *Fagus silvatica* L.

EXPERIMENT 3

Purpose: To study the course of breaking dormancy in beechnuts partly dried immediately after collection and stratified at a constant temperature.

Pattern of the experiment: see fig. 2b.
Stratification temperature: 5°C.

Moisture content of beechnuts after partial drying: 10,0%, 9,5%, 9,1% and 5,7%.
Stratification begun: moisture content 9–10% — 20–22.X.1964
moisture content 5–6% — 5.XI.1964

EXPERIMENT 4

Purpose: To study the course of breaking dormancy in partly dried seeds stored after drying until the end of January in tightly sealed containers, and then stratified under constant temperatures.

Pattern of the experiment: see fig. 2c.
Moisture content of the nuts after partial drying: as in experiment 3.
Storage temperatures: 3° and −10°C.
Storage time: samples with a moisture content of 9–10% — 98 days (from 20.X.1964 to 27.I.1965); samples with a moisture content of 5–6% — 83 days (from 5.XI.1964 to 27.I.1965)

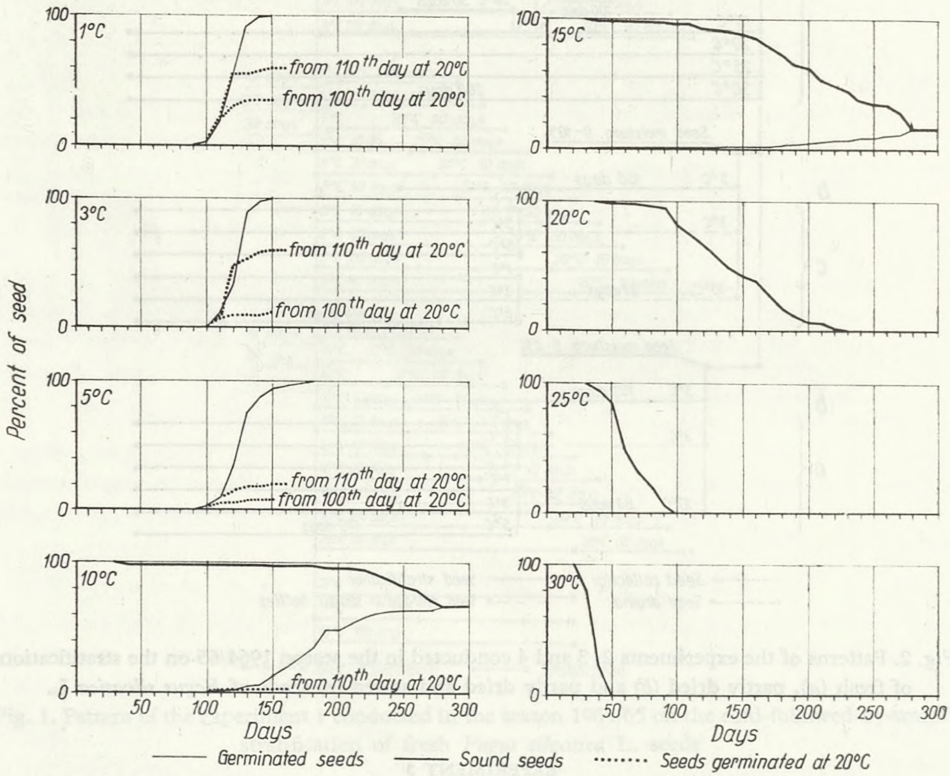

Fig. 3. Fresh seeds of *Fagus silvatica* L. (moisture content 23,4% of fresh weight), stratified immediately after collection. Germination of the seeds and their viability during stratification at constant temperatures of 1°, 3°, 5°, 10°, 15°, 20°, 25° and 30°C and during cold-followed-by-warm stratification involving a 100 or 110 day period in temperatures of 1°, 3°, 5°, 10° or 15°C and a 50 day period at 20°C

Stratification temperatures: 1°, 3° and 5°C.
Stratification begun: 27.I.1965
N. B.: All the variables of experiment 4 are based on 3 replicates except the stratification at 5°C which is represented by only one replicate.

RESULTS

DORMANCY OF FRESH SEEDS

In fig. 3 the results are presented of experiment 2 where the course of breaking dormancy and dying of stratified seeds at constant temperatures from 1° to 30°C is shown. It appears that the onset of germination of the seeds was noted not later than after 100 days of stratification at temperatures of 1°, 3°, 5°, 10° and 15°C. At higher temperatures than 15°C the stratified seeds did not germinate at all. At the lowest temperatures the seeds germinated in 100% in the time period between the 100th and 140th day for 1°C and between the 100th and 150th day for 3°C. In the 5°C stratification the latter part of germination extended until the 170th day. The curves of the course of germination at temperatures of 1°, 3° and 5°C were basically similar. The most rapid germination was noted at the lowest temperatures, that is at 1°C. Starting with 10°C with an increase

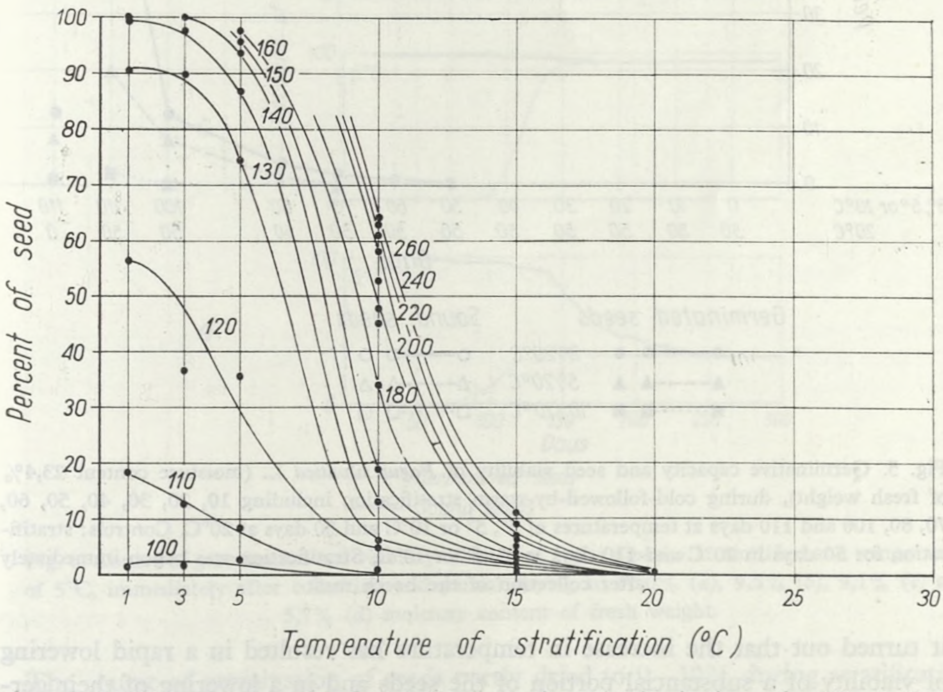

Fig. 4. Relation between temperature and the course of germination in the seeds of *Fagus silvatica* L. (moisture content 23,4% of fresh weight) during stratification begun immediately after collection of the beech mast. The numbers near the curves, indicate days of stratification

in stratification temperature there was a hastening and an increase in the process of seed dying and a rapid decline in the percentage of germinating seeds.

The relation between stratification temperature and rate of beechnuts germination is presented in fig. 4. From this relation it can be seen that the temperature of 1°C provided the best conditions for a rapid germination.

In this experiment one of the replicates was transferred after 100 days and another after 110 days, that is in the early phase of germination, to a temperature of 20°C. This transfer was made in the hope that the supposed favourable temperature of 20°C would hasten the germination process. Contrary to expectations

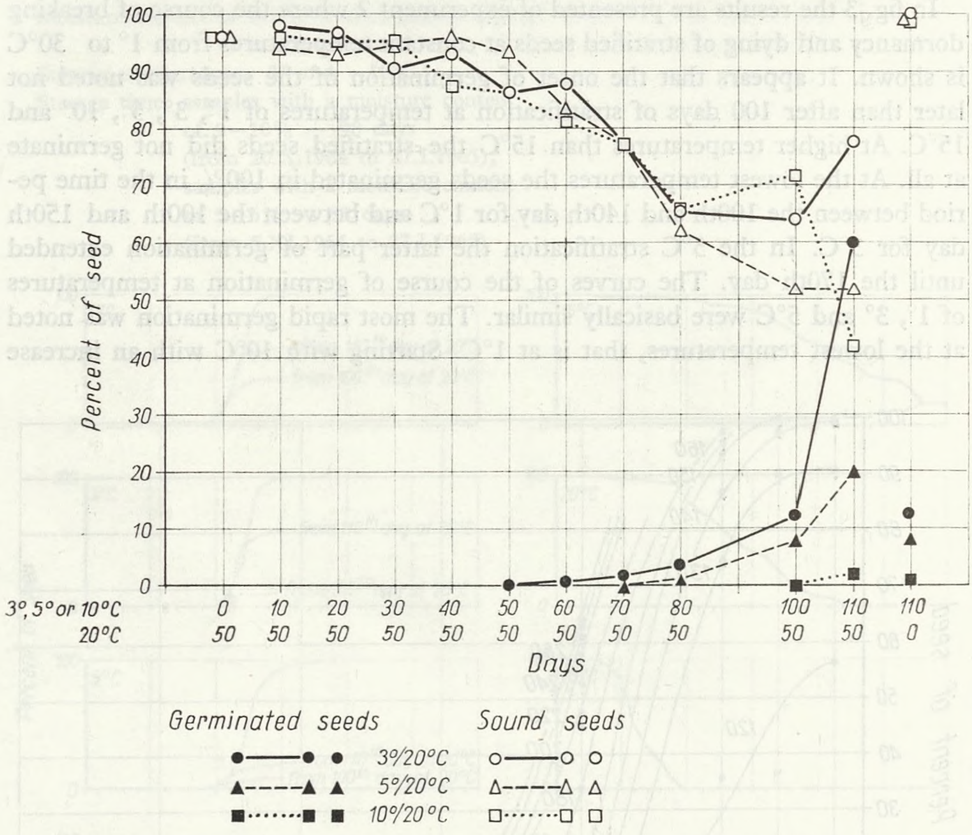

Fig. 5. Germinative capacity and seed viability of *Fagus silvatica* L. (moisture content 23,4% of fresh weight), during cold-followed-by-warm stratification including 10, 20, 30, 40, 50, 60, 70, 80, 100 and 110 days at temperatures of 3°, 5° or 10°C and 50 days at 20°C. Controls: stratification for 50 days in 20°C and 110 days at 3°, 5° or 10°C. Stratification was begun immediately after collection of the beech mast

it turned out that the increase in temperature has resulted in a rapid lowering of viability of a substancial portion of the seeds and in a lowering of their germinability (fig. 3).

This observation has been confirmed by another experiment (exp. 1) which has yielded the following result: a stratification temperature of 20°C acting for 50 days on fresh beechnuts stratified earlier at 3°, 5° and 10°C has resulted in the lowering of their viability. Seeds in the early phase of germination are most sensitive to an increase in temperature (fig. 5).

DORMANCY OF PARTLY DRIED SEEDS

A lowering of the moisture content of fresh beechnuts from 23% to 9–10% or 5–6% has resulted in a decline of germination of seeds stratified at 5°C only in the case of the seeds which were dried to the lower moisture content (exp. 3).

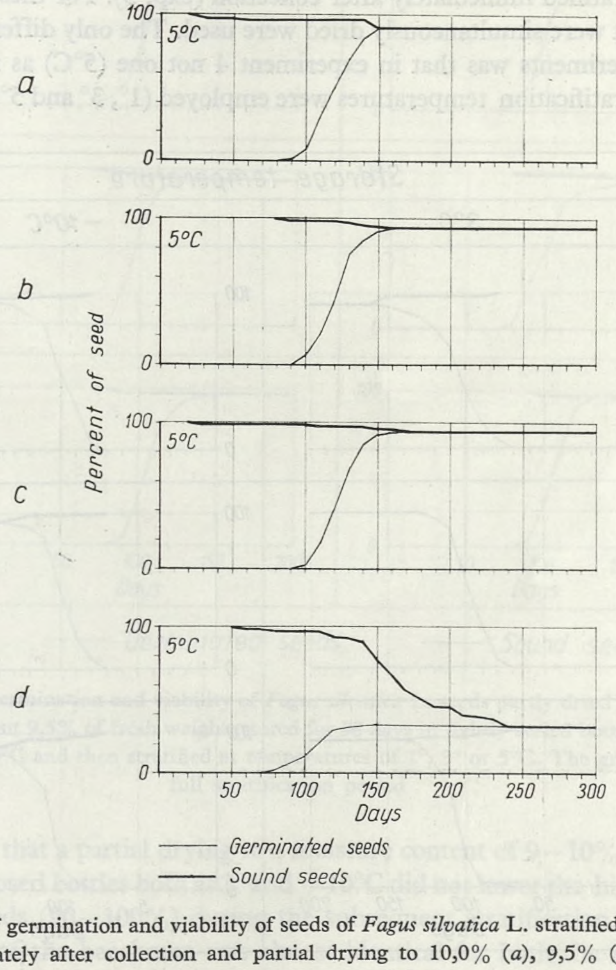

Fig. 6. Course of germination and viability of seeds of *Fagus silvatica* L. stratified at a temperature of 5°C, immediately after collection and partial drying to 10,0% (*a*), 9,5% (*b*), 9,1% (*c*) and 5,7% (*d*) moisture content of fresh weight

The course of germination of seeds partly dried to 9–10% during stratification at 5°C was almost the same as in the case of fresh seeds with a moisture content of 23% (fig. 6). Seeds partly dried to the indicated moisture content levels, germinated similarly as the fresh seeds not earlier than after 100 days of stratification and with the same rate. The only difference was that in the stratified samples of seeds which were partly dried there was a small proportion of decayed seeds.

DORMANCY OF PARTLY DRIED SEEDS, STORED BEFORE STRATIFICATION FOR 98 OR 83 DAYS IN TIGHTLY SEALED CONTAINERS

Studies on the stratification of seeds stored after partial drying (exp. 4) are very much connected with the exeriments on the breaking of dormancy in partly dried seeds stratified immediately after collection (exp. 3). For these experiments beechnuts that were simultaneously dried were used. The only difference between these two experiments was that in experiment 4 not one (5°C) as in experiment 3 but three stratification temperatures were employed (1°, 3° and 5°C). Beechnuts

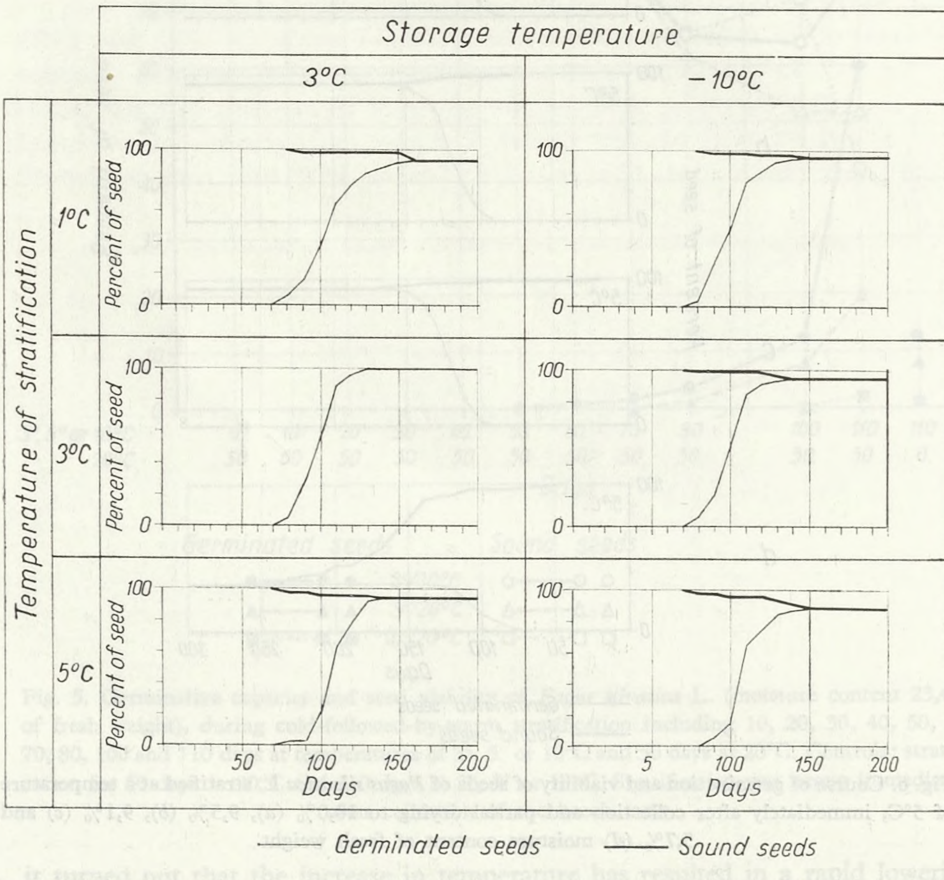

Fig. 7. Course of germination and viability of *Fagus silvatica* L. seeds partly dried after collection to a 10,0% moisture content (of fresh weight), stored for 98 days in tightly sealed bottles at a temperature of 3° or −10°C, and then stratified at temperatures of 1°, 3° or 5°C. The graphs cover the full stratification period

were stored in tightly sealed bottles at two temperatures (3° and −10°C). The date of completion of the storage period (27th of January) was chosen so that after about 100 days of stratification the seeds would start to germinate in early May that is at the desired time.

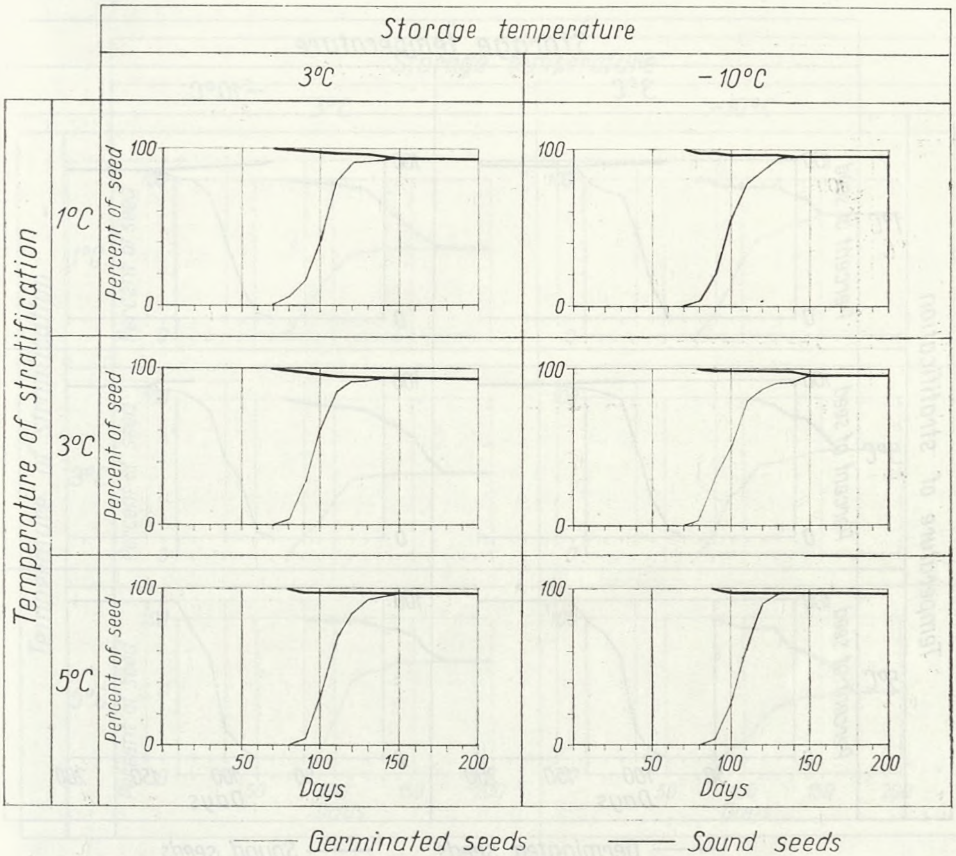

Fig. 8. Course of germination and viability of *Fagus silvatica* L. seeds partly dried after collection to a moisture content 9,5% of fresh weight, stored for 98 days in tightly sealed bottles at temperatures of 3° or −10°C and then stratified at temperatures of 1°, 3° or 5°C. The graphs cover the full stratification period

It turned out that a partial drying to a moisture content of 9−10% and storage for 98 days in closed bottles both at 3° and −10°C did not lower the high germinability of the seeds (90−100%) during the subsequent stratification. The cours- of germination of the beechnuts was almost identical for both the storage temperatures (fig. 7, 8 and 9).

The seeds partly dried to 5−6% moisture content germinated very much worse. A lowering of their germinability was noticed after 83 days of storing at 3° and −10°C and stratification at 1°, 3° and 5°C. From the graphs presented in fig. 10 it appears that the lowering of germinability was a result of loss of viability in a part of the seeds. The cause of this phenomenon is likely to be found in excessive drying of the seeds.

It was of particular interest to note that germination was hastened during stratification in comparison with the germination of beechnuts stratified without

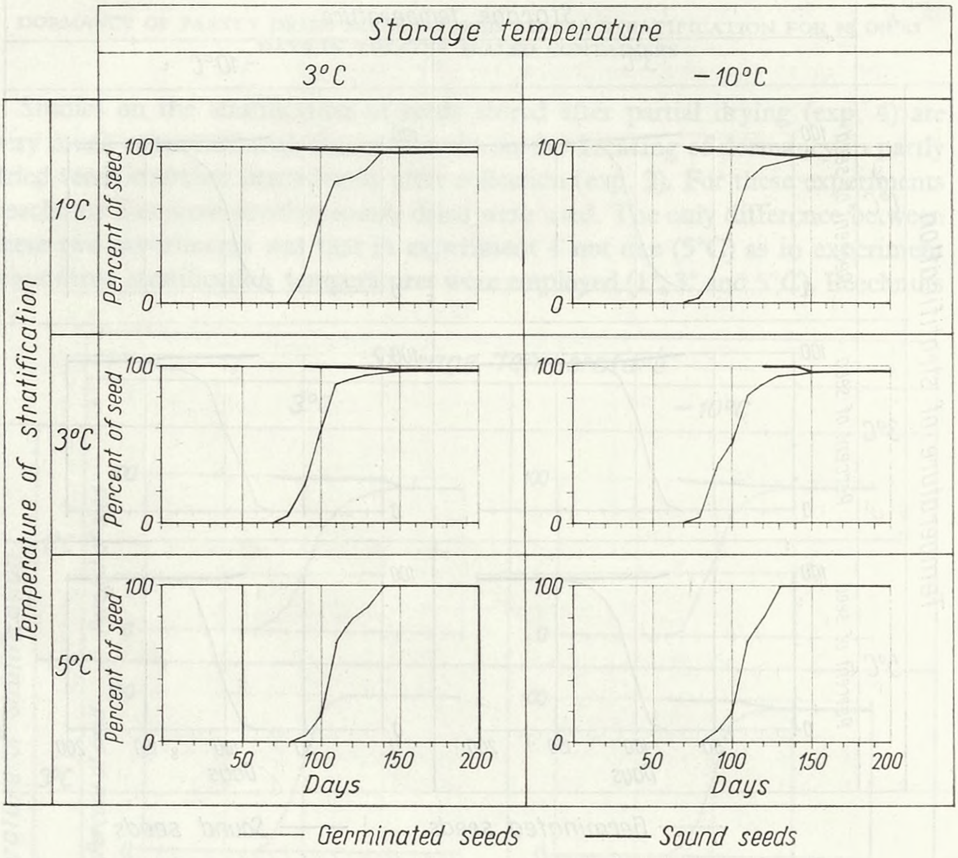

Fig. 9. Course of germination and viability of *Fagus silvatica* L. seeds partly dried after collection to a moisture content 9,1% of fresh weight, stored for 98 days in tightly sealed bottles at temperatures of 3° or −10°C and then stratified at temperatures of 1°, 3° or 5°C. The graphs cover the full stratification period

drying immediately after collection or the stratification of partly dried seeds without storage. In the case of this experiment germination commencement took place after 80 days of stratification and not after 100 as was the case with the other variants. Thus the hastening of the onset of germination was of the order of 20 days. This phenomenon was not dependent on the storage temperature but to some extent though not significantly, it was affected by the temperature of stratification, since at the highest of the stratification temperatures used (5°C) the onset of germination was slightly later than at the lower temperatures

(1° and 3°C). It needs to be stressed that the hastening of germination reported here does not apply to the seeds which germinate latest. The cumulative period during which the stratified seeds that were previously stored, had germinated was 50—70 days.

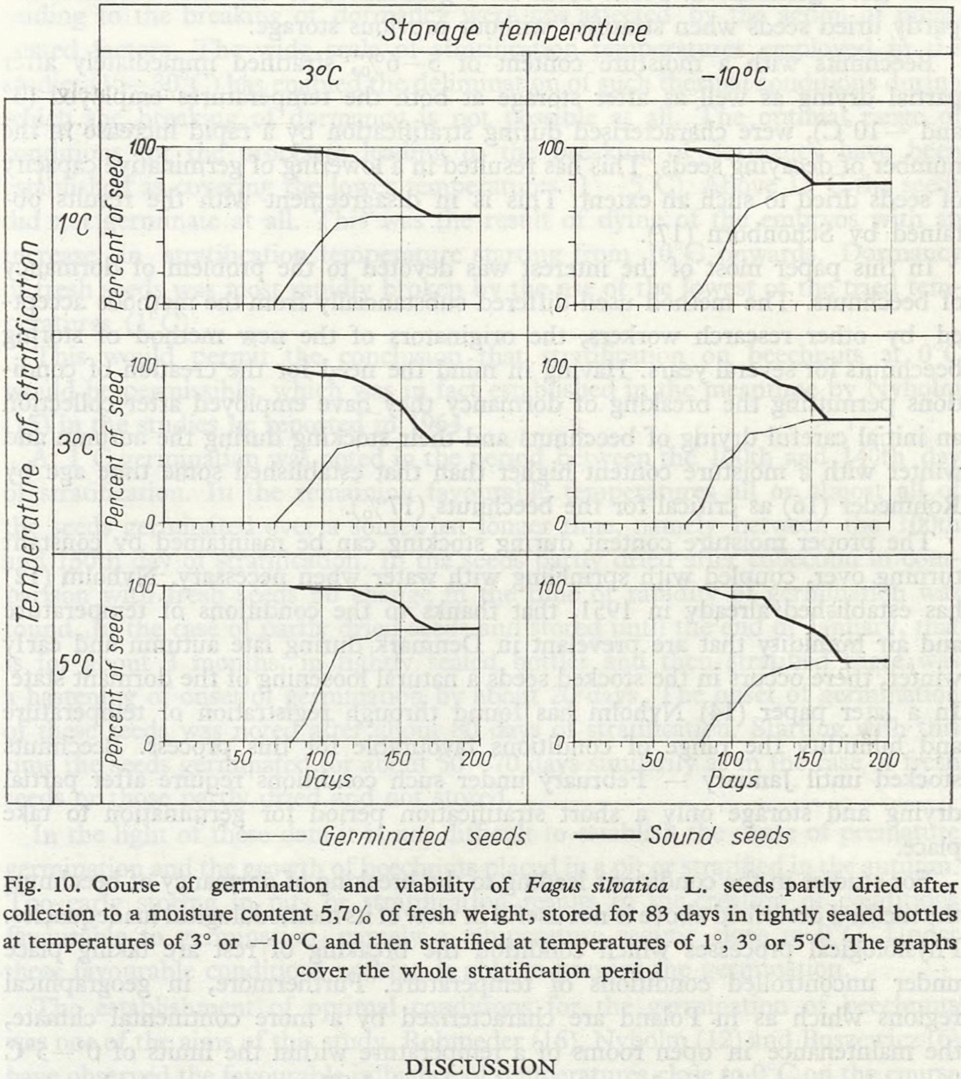

Fig. 10. Course of germination and viability of *Fagus silvatica* L. seeds partly dried after collection to a moisture content 5,7% of fresh weight, stored for 83 days in tightly sealed bottles at temperatures of 3° or —10°C and then stratified at temperatures of 1°, 3° or 5°C. The graphs cover the whole stratification period

DISCUSSION

Making use of the results of studies conducted by Nyholm, Buszewicz and Schönborn beechnuts were partly dried to two moisture levels (9—10% and 5—6%) after which they were stored in sealed containers at two different temperatures (3° and —10°C). The breaking of dormancy was studied in fresh seeds with a moisture content of 23,4% stratified immediately after collection, in seeds partly dried after collection and stratified immediately and seeds partialy dried in a similar fashion but stored before stratification for 3 months under conditions specified above.

Beechnuts partly dried to 9—10% moisture content have not suffered from storage at both storage temperatures. During stratification all or almost all the seeds have germinated. Fresh seeds have germinated to the same extent as the partly dried seeds when stratified without previous storage.

Beechnuts with a moisture content of 5—6%, stratified immediately after partial drying as well as after storage at both the temperatures employed (3° and −10°C), were characterised during stratification by a rapid increase in the number of decaying seeds. This has resulted in a lowering of germinative capacity of seeds dried to such an extent. This is in disagreement with the results obtained by Schönborn (17).

In this paper most of the interest was devoted to the problem of dormancy of beechnuts. The method used differed substancially from the methods accepted by other research workers, the originators of the new method of storing beechnuts for several years. Having in mind the need for the creation of conditions permitting the breaking of dormancy they have employed after collection an initial careful drying of beechnuts and their stocking during the autumn and winter with a moisture content higher than that established some time ago by Rohmeder (16) as critical for the beechnuts (17%).

The proper moisture content during stocking can be maintained by constant turning over, coupled with sprinkling with water when necessary. Nyholm (12) has established already in 1951, that thanks to the conditions of temperature and air humidity that are prevelant in Denmark during late autumn and early winter, there occurs in the stocked seeds a natural loosening of the dormant state. In a later paper (14) Nyholm has found through registration of temperature and humidity the range of conditions favourable for this process. Beechnuts stocked until January — February under such conditions require after partial drying and storage only a short stratification period for germination to take place.

For studies in the conditions leading to the breaking of dormancy of beechnuts the method described above is not useful in view of its methodological inadequacies. Physiological processes which condition the breaking of rest are taking place under uncontrolled conditions of temperature. Furthermore, in geographical regions which as in Poland are characterized by a more continental climate, the maintenance in open rooms of a temperature within the limits of 0°—5°C is not always possible in the autumn-winter period. Thus, such a method was not acceptable in precise studies, and therefore the author has decided to treat the beechnuts in a different fashion. Instead of stocking the seeds they were stratified in a peat-sand medium under strictly controlled temperature conditions. The stratification of fresh beechnuts was started immediately after collection. The seeds partly dried after collection were stratified immediately on having reached the required moisture content, and those partly dried and stored were stratified immediately on completion of the storage period. The partial drying of beechnuts took place at a temperature close to 20°C and therefore at a tempera-sure at which the processes which condition the breaking of dormancy can no longer operate. In this way in the studies of the author the action of uncontrolled thermal factors was eliminated. The results obtained on the course of the process leading to the breaking of dormancy were not affected by the action of unexpected factors. The wide scale of stratification temperatures employed in the studies (1°—30°C) has enabled the delimination of such thermal conditions during which the breaking of dormancy is not possible at all. The optimal range of conditions for the processes leading to the breaking of dormancy have been established as covering the lower temperatures (1°—5°C). Above 15°C the seeds did not germinate at all. This was the result of dying of the embryos with an increase in stratification temperature starting from 10°C onwards. Dormancy of fresh seeds was most rapidly broken by the use of the lowest of the tried temperatures (1°C).

This would permit the conclusion that stratification on beechnuts at 0°C would be permissible, which was in fact established in the meantime by Nyholm (15) in the studies he reported in 1964.

At 1°C germination was noted in the period between the 100th and 140th day of stratification. In the remaining favourable temperatures all or almost all of the seeds germinated over a somewhat longer time, namely between the 100th and 150th day of stratification. In the seeds partly dried after collection in comparison with fresh seeds no change in the time or rapidity of germination was found. In the case of partly dried seeds and stored until the end of January, that is for about 3 months, in tightly sealed bottles and then stratified there was a hastening of onset of germination by about 20 days. The onset of germination of these seeds was noted after about 80 days of stratification. Starting with this time the seeds germinated for about 50—70 days similarily as in the case of fresh seeds or those partly dried and not stored.

In the light of these data it is not difficult to establish the cause of premature germination and the growth of beechnuts placed in a pit or stratified in the autumn. Too early storing in pits or stratification results in the creation of conditions favourable to germination, namely a temperature regime close to 0°C. Under these favourable conditions nothing is able to prevent the germination.

The establishment of optimal conditions for the germination of beechnuts was one of the aims of this study. Rohmeder (16), Nyholm (12) and Buszewicz (6) have observed the favourable influence of temperatures close to 0°C on the course of germination. On the other hand several authors recommend constant or alternating temperatures higher than 20°C (2, 15, 19) for germination tests of beechnuts. Rules for germination test specified for beechnuts by ISTA also involve a stratification of the nuts in a moist sand at a temperature of 4°C and then transfer to a temperature of 20°C after the first signs of germination are observed. Nyholm (15) having transfered stratified beechnuts to 25°C has shown that a change of temperature in the early phase of germination will not demonstrate the full germinative capacity which can only be shown by stratification at a lowered temperature (0° and 5°C) for a period of at least 9—10 weeks which conditions permit higher values of germinative capacity to be obtained. From Nyholm's numerical data clearly a conclusion can be drawn, even though it has not been stated by anyone, that a raising of temperature during germination tests of beechnuts is not an effective procedure. The results obtained in this study in the experiments conducted under conditions almost identical with those recommended by the ISTA rules (ISTA: 4° and 20°C, author: 3° or 5° and 20°C) are not ambiguous. They show that the transfer of stratified seeds not germinating yet or starting to germinate to 20°C is a harmful treatment, lowering their viability and as a result their germinative capacity. The author believes that germination tests of beechnuts should be conducted under conditions of stratification in constant temperatures of 1° or 3°C and recommends that the existing norms for these test be changed accordingly.

SUMMARY

In the autumn-spring season 1964/65 experiments were conducted in the Institute of Dendrology and Kórnik Arboretum of the Polish Academy of Sciences near Poznań, on the breaking of dormancy and germination of seeds of the common beech (*Fagus silvatica* L.) of local origin. In the studies, fresh seeds (moisture content — 23,4% of fresh weight), seeds partly dried immediately after collection to a moisture level of 5—6% and 9—10% and seeds dried to the same levels and then stored for 3 months in tightly sealed bottles at temperatures of 3° and —10°C were used. For the stratification of fresh seeds the following temperatures were used: 1°, 3°, 5°, 10°, 15°, 20°, 25° and 30°C. Partly dried seeds were stratified at 5°C and the dried and stored seeds were stratified at 1°, 3° and 5°C. The partial drying of the beechnuts was conducted at a temperature of about 20°C. In the experiments on the influence of a single transfer to another temperature the stratified seeds were moved to a temperature of 20°C.

From the results obtained the following conclusions have been drawn:

1. The optimal conditions for the breaking of dormancy of beechnuts are provided by a stratification at temperatures of 1°—5°C, with the fresh seeds germinating best at temperatures of 1°C and partly dried and stored seeds at temperatures of 1° and 3°C.

2. Stratification at temperatures in the range 10°—30°C results in the dying of beechnuts. The dying results all the more rapidly and concerns more seeds the higher is the stratification temperature. Above 15°C all the seeds die.

3. During stratification at the optimal temperature conditions the onset and termination of germination occurs on the following days of stratification: fresh beechnuts 100 and 140 (1°C) or 100 and 150 days (3° and 5°C), seeds partly dried to a moisture content of 9—10%, 100 and 150 days (5°C), similarily dried seeds stored before stratification in bottles at 3° or —10°C, 80 and 130—150 days.

4. The partial drying of beechnuts to a moisture content of 9—10% and storage in sealed bottles at a temperature of 3° and —10°C for 98 days, that is until the end of January has maintained the viability and germinative capacity of the seeds at an almost unchanged level.

5. The partial drying of the seeds to a moisture level of 5—6% has resulted in a reduction of seed viability and therefore of germinative capacity of a fair proportion of the beechnuts during stratification of both the partly dried nuts and those partly dried and stored for 83 days in the conditions specified above.

6. The raising of stratification temperature to 20°C has resulted in a loss of viability and germinative capacity of a part of the seeds. Beechnuts in the period immediately preceeding the onset of germination are most sensitive to the raising of the temperature.

LITERATURE

1. Anon — 1962. Collection and storage of acorns and beech mast. Forestry Commission Leaflet No 28.

2. Anon — 1948. Woody-Plant Seed Manual. U.S. Department of Agriculture. Misc. Publ. No 654.

3. Buszewicz G. M. — 1962. The longevity of beechnuts in relation to storage conditions. Rep. For. Res. For. Comm. London, 1961 — 116 : 126.

4. Buszewicz G. M. — 1964. Forest tree seed. Rep. For. Res. For. Comm. London, 1963 : 13—16.

5. Dušek V. — 1963. Příčiny neúspěšných výsevů bukvic v letošnim roce. Lesnická Práce, 42 (9) : 392—393.

6. Holmes G. D., and Buszewicz G. — 1957. Forest tree seed investigations. Rep. For. Res. For. Comm. London, 1955/56 : 15—19.

7. Holmes G. D., and Buszewicz G. — 1958. The storage of seed of temperate tree species. For. Abstr. Vol. 19, Nos 3 and 4.

8. Jaroš P. — 1952. Jak přezimovaly a po vysetí na jaře 1952 klíčily bukvice sklizně 1951/52? Lesnická Práce, 31 (5) : 206—208.

9. Machaniček J. — 1964. Kratkodobe skladovaní bukovych a jedlovych semen. Lesnická Práce, 43 (11) : 483—485.

10. Messer H. — 1960. Die Aufbewahrung und Pflege von Eicheln und Bucheln. J. D. Sauerländers Verlag, Frankfurt am Main. Pp 44.

11. Molotkov P. I., Molotkova I. I., and Poljakov A. F. — 1959. Vyraščivanie sejancev buka v uslovijah Karpat. Lesn. Hoz., 12 (5) : 32—35.

12. Nyholm I. — 1951. Bøgeoldens spiringsforhold. Dansk Skovforen. Tidskr., 36 (12) : 634—644.

13. Nyholm I. — 1954. Opbevaring af bøgeolden. Dansk Skovforen. Tidskr., 39 (3) : 153—159.

14. Nyholm I. — 1960. Flerårig opbevaring af bøgeolden. Dansk Skovforen. Tidskr., 45 (10) : 377—415.

15. Nyholm I. — 1965. Redegørelse for spiringen i laboratorium og i marken af bulgarsk bøgeolden importeret vinteren 1963—64. Dansk Skovforen. Tidskr., 50 : 127—139.

16. Rohmeder E. — 1951. Beiträge zur Keimungsphysiologie der Forstpflanzen. Bayerischer Landwirtschaftsverlag, München. Pp. 140.

17. Schönborn A. — 1964. Die Aufbewahrung des Saatgutes der Waldbäume. Bayerischer Landwirtschaftsverlag. München. Pp. 158.

18. Winkler H. — 1955. Das Saatgut unserer heimischen Nadel- und Laubhölzer. Neumann Verlag, Radebeul und Berlin. Pp. 96.

19. Tyszkiewicz S. — 1949. Nasiennictwo Leśne. Instytut Badawczy Leśnictwa, ser. D, nr 2, Warszawa. Pp. 357.

BOLESŁAW SUSZKA

Spoczynek, przechowywanie i kiełkowanie nasion buka zwyczajnego (Fagus silvatica L.)

Streszczenie

W sezonie jesienno-wiosennym 1964/65 r. przeprowadzono w Zakładzie Dendrologii i Arboretum Kórnickim PAN w Kórniku koło Poznania badania nad ustępowaniem spoczynku i kiełkowaniem nasion buka zwyczajnego (*Fagus silvatica* L.), miejscowego pochodzenia. Badano nasiona świeże (wilgotność orzeszków 23,4% w stosunku do świeżej wagi), nasiona podsuszone natychmiast po zbiorze (5—6% i 9—10% wilg.) oraz nasiona podsuszone jak wyżej i przechowywane przez 3 miesiące w zamkniętych szczelnie butlach w temperaturach 3° i —10°C. Do stratyfikacji stosowano następujące temperatury: w przypadku nasion świeżych: 1°, 3°, 5°, 10°, 15°, 20°, 25° i 30°C, w przypadku nasion podsuszonych 5°C, w przypadku nasion podsuszonych i przechowywanych w podanych powyżej warunkach 1°, 3° i 5°C. Podsuszanie bukwi przeprowadzono w temperaturze około 20°C. W doświadczeniach nad jednorazową zmianą temperatury stratyfikacji przenoszono stratyfikowane orzeszki do temperatury 20°C.

Z uzyskanych wyników wyciągnięto następujące wnioski:

1. Optymalne warunki dla ustępowania spoczynku nasion buka zwyczajnego stwarza stratyfikacja w temperaturach 1°—5°C, przy czym nasiona świeże kiełkują najbardziej energicznie w temperaturze 1°C, nasiona podsuszone i przechowywane w zamkniętych zbiornikach — w 1° i 3°C.

2. Stratyfikacja w temperaturach zakresu 10°—30°C przyczynia się do zamierania nasion buka. Zamieranie nasion przebiega tym szybciej i obejmuje tym więcej nasion, im wyższa jest temperatura stratyfikacji, powyżej 15°C zamierają wszystkie nasiona.

3. Podczas stratyfikacji w optymalnych warunkach termicznych początek i koniec kiełkowania przypada na następujące dni stratyfikacji: orzeszki świeże 100 i 140 (1°C) lub 100 i 150 dni (3° i 5°C), orzeszki podsuszone do 9—10% wilgotności 100 i 150 dni (5°C), orzeszki tak samo podsuszone, przechowywane przed stratyfikacją w butlach w 3° lub —10°C 80 i 130—150 dni.

4. Podsuszenie bukwi do 9—10% wilgotności i przechowywanie w zamkniętych szczelnie butlach w temperaturze 3° i —10°C przez 98 dni, tj. do końca stycznia, pozwoliło na zachowanie żywotności i zdolności kiełkowania nasion na prawie niezmienionym poziomie.

5. Podsuszenie bukwi do 5—6% wilgotności spowodowało podczas stratyfikacji orzeszków uprzednio podsuszonych oraz orzeszków podsuszonych, a następnie przechowywanych przez 83 dni w podanych powyżej warunkach utratę żywotności i w efekcie zdolności kiełkowania przez znaczną część nasion.

6. Podwyższenie temperatury stratyfikacji do 20°C spowodowało utratę żywotności i zdolności do kiełkowania przez część nasion. Najbardziej wrażliwe na podwyższenie temperatury okazały się nasiona w okresie bezpośrednio poprzedzającym początek kiełkowania.