ARBORETUM KÓRNICKIE
Rocznik XVIII — 1973

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The after-ripening and germination of *Armeniaca sibirica* Lam. and *Amygdalus pedunculata* Pall. seeds

INTRODUCTION

In the autumn of 1967 I have obtained through the courtesy of A. Svoboda from the Botanical Garden of the Czechoslovak Academy of Sciences in Pruhonice nr. Prague samples of seeds [1] of the Siberian apricot (*Armeniaca sibirica* Lam.) and the pedunculate almond (*Amygdalus pedunculata* Pall.), which have been collected by him and M. Kučera in natural stands in Mongolia during the summer of 1966. These seeds have been used for studies on the thermal conditions needed for their after-ripening and germination.

The Siberian apricot is characterized by fruits with a drying and inedible pericarp. It occurs in eastern Siberia (Dauria), in the Far East (Primorskij Kraj) in eastern and southeastern Mongolia and in northern China on dry stony southern slopes, on stone rubble and on rocks in association with Rhododendron, Cotoneaster and in places with the Pallas apple (*Malus pallasiana* Juz.) (Kostina, 1936; Lozina-Lozinskaja, 1954). Within the genus *Armeniaca* Mill. the Siberian apricot is a species most resistant to low temperatures common in its natural conditions (down to −50°C) and to draught and for this reason it has been utilized in the breeding of new cultivars and as a stock for the grafting of cultivated apricot varieties.

Literature information on the conditions for the breaking of dormancy in apricot seeds concerns almost exclusively the cultivated varieties of *Armeniaca vulgaris* and its hybrids. Comparative data for the common apricot with the Siberian one has been reported only by Piskarev (1937) according to whom the seeds stratified in the winter following the year of collection require for after-ripening 100 days of stratification at 5°C in the case of *A. vulgaris* and 50 - 60 days in the case of *A. sibirica*.

Data given by other authors for the seeds of cultivated apricot varie-

[1] In this paper the term "seed" is used without any further explanation and is meant to include the undamaged endocarp (stone).

ties are very diverse. Lalatta (1959) recommends a 120 - 150 day cold stratification. Probocskai (1964) a 75 - 105 day stratification in moist sand at 5° - 12°C, Bolotskij (1954) a 65 day storing in crushed ice in a room at about 2°C following a prior soaking and swelling of the seeds, and Hartmann and Kester (1960) recommend a 21 - 28 day stratification at a temperature of 0° - 7°C for the varieties Royal and Blenheim used in California as stocks. Suszka (1962) has studied the seeds of apricot varieties bred in the Kórnik Arboretum, and described initially as *Prunus armeniaca* L. These seeds germinated to almost 100% during a cold stratification at 3°C. Germination began between the 63rd and 84th day and terminated between the 126th and 147th day of stratification in this temperature. Supplying a two week period of warm stratification at 20°C before the cold one has in no case inhibited the germination percentage and in some cases it has slightly improved it.

The pedunculate almond occurs in eastern Siberia (Ang.-Sayan, Dauria) and in northeastern Mongolia on stony montain slopes, covered with a steppe vegetation (Linčevskij and Fedorov, 1941). According to Russian authors (Zamyslova and Lozina-Lozinskaja, 1954) the pedunculate almond is characterized by a high resistance to low temperature and as a result of its considerable decorative value it should be planted in the forest and steppe-forest regions.

In spite of the fact that the genus *Amygdalus* has about 40 species, closer information about the pre-sowing treatment concerns almost exclusively the common almond (*Amygdalus communis* L.), the seedlings of which are used as stocks for the cultivated varieties of almonds. Thus there is a complete absence of information about the pedunculate almond.

Damigella (1965) has established in Italy that an early sowing of the seeds of common almond made immediately after collection reduces the germinative capacity, which will increase with an increase in the duration of seed storage to 30 or 60 days. Storage at a temperature of 2 - 4°C hastens germination of seeds and stratification in moist sand has resulted in an increase of germinative energy and capacity. Views concerning the necessary duration of stratification and its thermal conditions vary considerably. Vasilev (1971) believes that in the conditions of Bulgaria a period of 30 - 40 days of stratification at a low temperature (not lower than 5°C) is sufficient for the after-ripening of the common almond seed. Probocskai (1964) recommends that in the Hungarian conditions a 60 - 75 day stratification in sand at a temperature of 5° - 12°C be used. A dry storage of the seeds for one year reduces the germination of the seeds by about 50% according to that author. Lalatta (1959) has established that in Italy the period of cold stratification of the seeds of common almond should last for 32 - 42 days. Hartmann and Kester (1960) consider already a 21 - 28 day cold stratification

period as being sufficient for the seeds of common almond in the USA where it is used as stocks for the cultived varieties of almonds and sometimes even for peaches. According to Russian authors the stratification period should be longer. Blagoveščenskij and Ivanova (1955) have established that the germination of seeds of common almonds begins after about 60 days of cold stratification at 1° - 2°C. Gluščenko (1951) reports that in Uzbek SSR the stratification should last for 50 - 60 days. The germination of the dwarf almond (*Amygdalus nana* L.) seeds has been studied by Bolotskij (1954) who has observed the appearance of first radicles after 60 - 65 days of storage of soaked seeds on crushed ice, that is at a temperature close to 0°C. Kester (1969) has established experimentally, that the duration of the stratification of hybrid seeds of the cultivated varieties, following removal of the endocarp is determined genetically, it is related to the condition in the parents and depends on their combination. The germination of seeds in the studies conducted by Kester which included various varieties, pollinated by various pollens, occurred at the earliest between the 1.5th and 4th week of stratification at 10°C and at the latest between the 2nd and 20th or between the 4th and 19th week. Single seeds however have even germinated after 27 weeks.

The data reviewed above concern only a few species of apricots and almonds, and demonstrate the great variety of results obtained. This has been caused not only by differences in the use of methods but also by the considerable genetic and geographic differences in the studied material even within one species.

MATERIALS AND METHODS

Seed origin:

1. *Armeniaca sibirica:* Northern Mongolia, elev. 1500 - 2000 m. the Chentijn Nuruu mountain range — eastern part, Mt. Dulan Chan, at the confluence of rivers Iro and Orchon. 21 VIII 1966, A. Svoboda and M. Kučera.

2. *Amygdalus pedunculata:* Northern Mongolia, elev. 1500 - 2000 m. Bogd Ul, Songino, 20 km west of the town Ulaanbaatar, a mountain above river Tuul. 29 VIII and 3 IX 1966, A. Svoboda and M. Kučera.

Seed storage: loosely, at room temperature, in dry conditions, as intact stones.

Experimental design: seed in intact stones have been stratified by the cold method (at 3°C) or by the warm-followed-by-cold method (20°C for 2 weeks and then 3°C), always in conditions of controlled temperature (±0.5°C). In the case of the seeds of the Siberian apricot a further cold stratification at 3°C has been conducted following a 12-day stratification in a cellar at a fluctuating temperature of 5° - 10°C.

Stratification: the seeds were stratified in a moist mixture of sand and powdered peat. Moisture content in the medium was checked at weekly intervals during warm stratification and at every 2 weeks during the cold one.

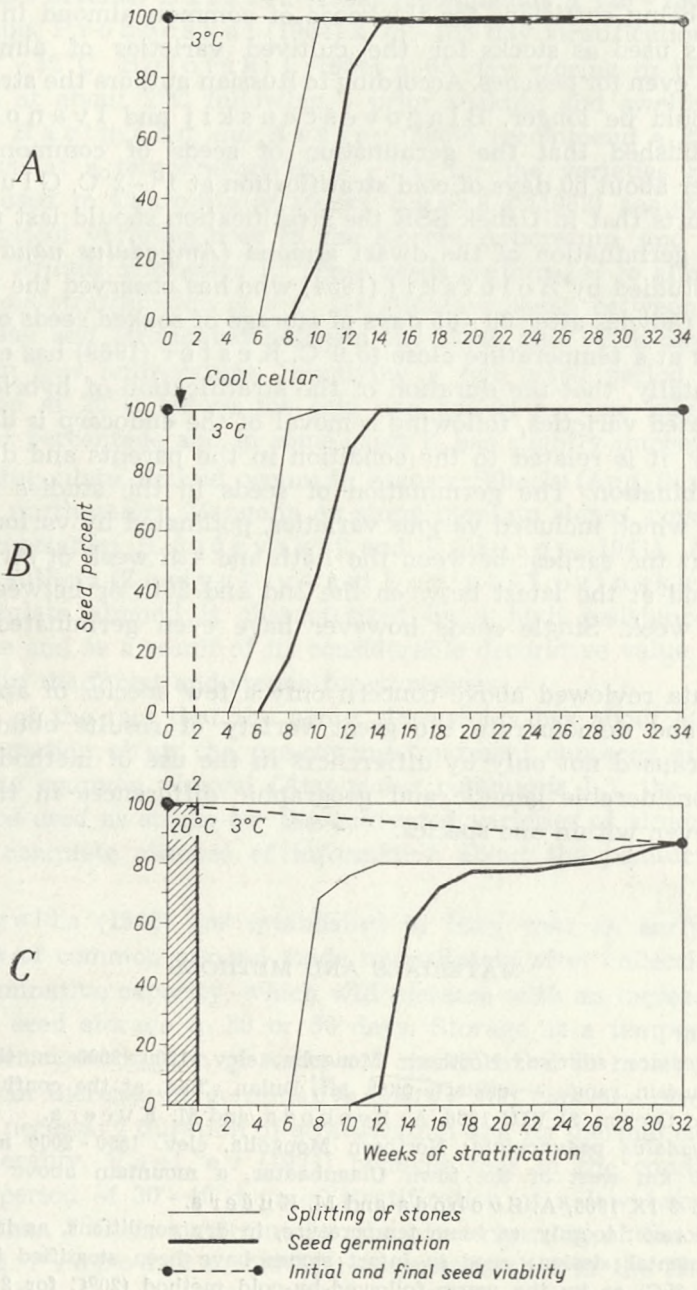

Fig. 1. Stone splitting and seed germination of the Siberian apricot (*Armeniaca sibirica* Lam.) during a cold stratification at 3°C (A), a cold stratification with the first 12 days at 5° - 10°C and then at 3°C (B) and a warm-followed-by-cold stratification with the first 14 days at 20°C and then at 3°C (C). The seeds originate from a natural stand in Northern Mongolia

Replicates: in view of the small or limited number of seeds available for the studies the following quantities were used.

Armeniaca sibirica: 3° and 20°/3°C — 3 replicates with 25 seeds each; cellar/3°C — 1 replicate with 33 seeds.

Amygdalus pedunculata: 3° and 20°/3°C — 2 replicates with 32 seeds each.

Stratification begun:

Armeniaca sibirica: 3° and 20°/3°C — 28 I 1967; cellar/3°C — 26 XI 1966.

Amygdalus pedunculata: 3° and 20°/3°C — 17 I 1967.

Observations: simultaneously with the checking of the moisture content in the medium conducted during the stratification, observations were made of stone cracking and seed germination. Seeds with roots longer than 3 mm have been considered as germinated. Germinated seeds and those with visible decay have been progressively removed from the stratification medium.

RESULTS

ARMENIACA SIBIRICA

On the graph in Fig. 1 the course of stone cracking is presented as well as the progress of germination of the Siberian apricot seeds. In the conditions of cold stratification, germination started first and had a most energetic course. Stones started to crack after 6 weeks and during the following 4 weeks all the stones cracked. Germination started after 8 weeks of the continuous cold stratification (at 3°C) and even earlier, after 6 weeks, in the variant where the seeds were previously held in a cellar at 5° - 10°C. In both these experimental variants germination terminated after 14 weeks of stratification and the period between germination of the first and last seeds lasted for 6 - 8 weeks. It appears therefore that cold stratification of the seeds of Siberian apricot leads to a rapid germination and does not reduce the viability.

During the warm-followed-by-cold stratification a drop in the viability of seeds was observed by about 13% and as a result the germination capacity was also lowered by the same amount. The reason for this drop was undoubtedly the action of the raised temperature (20°C) for the first 2 weeks of stratification. The onset of stone cracking was in comparison with the cold only stratification delayed by 2 weeks, similarily as was the onset of germination, which corresponds to the period of the action of the higher temperature. After an initial rapid germination of the majority of seeds between the 10th and 18th week of stratification the appearance of further radicles was delayed in the case of the warm-followed-by-cold stratification by as much as 34 weeks.

AMYGDALUS PEDUNCULATA

The cracking of stones and germination of the seeds of pedunculate almond (Fig. 2) was completely different during cold stratification (3°C) than during the warm-followed-by-cold (20°/3°C) stratification. The

cold only stratification proved less satisfactory for germination since it has resulted in a serious reduction of seed viability and therefore also of the germinative capacity. An even more striking difference was observed in the course of germination depending on the thermal con-

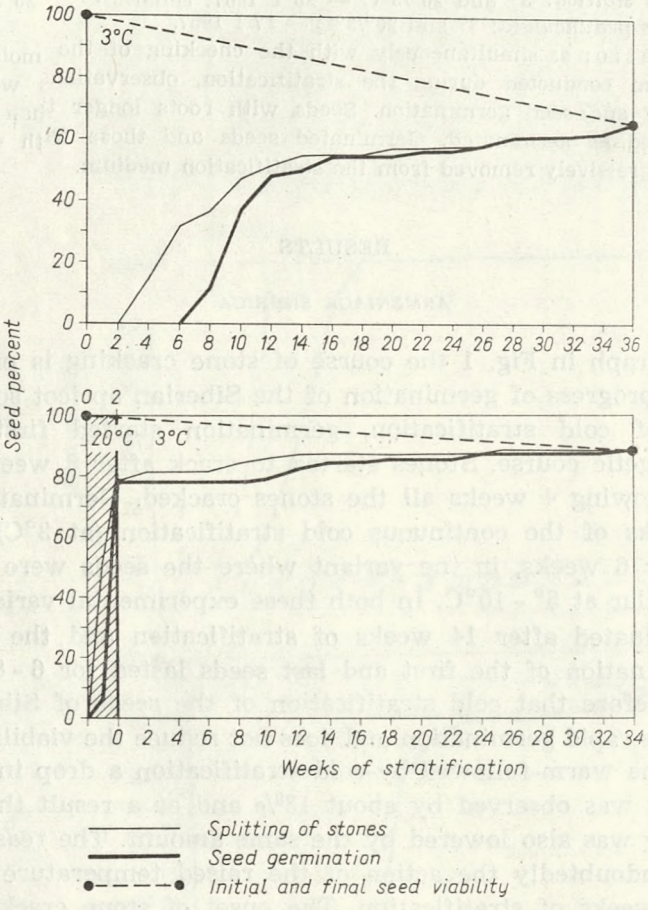

Fig. 2. Stone splitting and seed germination of the pedunculate almond (*Amygdalus pedunculata* Pall.) during cold stratification at 3°C and a warm-followed-by-cold stratification with the first 14 days at 20°C and then at 3°C. The seeds originate from a natural stand in Northern Mongolia

ditions of the stratification. In the warm-followed-by-cold stratification variant over 80% of the seeds cracked and germinated during the first two weeks, that is while the temperature was high (20°C), and in the first week almost half of the seeds were cracked and some have already germinated. After lowering of the temperature to 3°C it took 34 weeks for the further 10% of seeds to germinate.

DISCUSSION

In the course of the experiment results obtained earlier (S u s z k a 1962) have been confirmed, that apricots require different stratification conditions for optimal after ripening than seeds of various *Prunus s. l.* species, such as: *P. avium, P. mahaleb, P. divaricata* var. *cerasifera, P. serotina, P. spinosa, P. fruticosa* and the numerous cultivated varieties of cherries, sour cherries, plums and peaches (S u s z k a, 1962, 1964, 1966, 1967a, 1967b). In all the species mentioned above the germination was more energetic and had a higher percentage during cold stratification at 3°C which was preceded by a 2 week period of warm stratification at 20°C, than during a cold stratification only, while on the other hand the seeds of apricots attained during an exclusively cold stratification a value of the germination capacity close to 100%, so that the positive effect of the warm-followed-by-cold treatment was not observable. In the present study the seeds of Siberian apricot behaved similarily except that the onset of germination was 2 weeks earlier when in the first 12 days of stratification the temperature was slightly higher than 3°C namely 5° - 10°C. Initial warm stratification at a temperature of 20°C has lowered the seed viability and as a result also the germinative capacity. It appears therefore that also the seeds of the Siberian apricot germinate best during an exclusively cold stratification.

The course of germination of the pedunculate almond seeds differed from all the known examples of germination types in any of the species from the genus *Prunus s.l.* stratified in undamaged endocarps, that is in the whole stones. Lacking the possibility of obtaining new seeds of the pedunculate almond from natural stands it still remains an open question whether the experimentally demonstrated extremely rapid germination of the majority of seeds at a warm temperature is a typical response for the species, fixed genetically as an adaptation to the ecological conditions of the site occupied by it. Such a reaction could have also been a one time deviation from the norm caused by the particular climatic conditions existing during the maturation of the seeds used in the experiment. From the literature it is known (Von A b r a m s and H a n d 1956) that the seeds of roses which require for the breaking of dormancy a longer period of cold stratification, can germinate at a higher temperature if the temperature dominating during seed maturation on the bushes was much higher than average. In our case however there is a complete absence of information on the subject, which makes it impossible to give an answer to the question discussed here.

The seedlings of pedunculate almond obtained from the experiment presented here have been planted out and were kept from February

to the spring in a greenhouse, after which they were outplanted in the nursery, where they grew normally without sings of physiological dwarfness.

SUMMARY

1. Seeds of the Siberian apricot (*Armeniaca sibirica* Lam.) from a natural stand in Mongolia have germinated to 100% during a cold (3°C) stratification only. Germination begun and terminated in these conditions between the 8th and 14th week of stratification. Raising the first 12 days of stratification temperature to 5 - 10°C has result in a hastening of the onset of germination by 2 weeks. On the other hand a warm-followed-by-cold stratification run for the first 2 weeks at a temperature of 20°C and then at 3°C has resulted in a certain lowering of seed viability and therefore also in a reduction of their germinative capacity. The germination of seeds took place in these conditions between the 8th and 16th week of the cold phase of stratification.

2. Seeds of the pedunculate almond (*Amygdalus pedunculata* Pall.) collected from a natural stand in Mongolia, when stratified by the warm-followed-by-cold method in intact endocarps have germinated very rapidly (in 83%) during the first 2 weeks of the warm stratification at 20°C. After lowering of the temperature to 3°C the remainder of the sound seeds was very slow to germinate. A cold only stratification at 3°C has resulted in a lowering of the viability of the seeds and as result also of the germinative capacity, while at the same time onset of germination was delayed and extended considerably in time. In these conditions the majority of seeds germinated between the 6th and 16th week of stratification.

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BOLESŁAW SUSZKA

Ustępowanie spoczynku i kiełkowanie nasion moreli syberyjskiej (Armeniaca sibirica Lam.) i migdała szypułkowego (Amygdalus pedunculata Pall.)

Streszczenie

W 1967 r. badano w Zakładzie Dendrologii i Arboretum Kórnickim Polskiej Akademii Nauk w Kórniku kiełkowanie nasion 2 gatunków: *Armeniaca sibirica* Lam. i *Amygdalus pedunculata* Pall. Nasiona zostały zebrane na naturalnych stanowiskach w Mongolii północnej przez A. Svobodę i M. Kučerę z Ogrodu Botanicznego Czechosłowackiej Akademii Nauk w Pruhonicach koło Pragi. W badaniach tych zastosowano dla nasion obydwu gatunków stratyfikację chłodną (w 3°C) i ciepło-chłodną (20°C przez 2 tygodnie, potem 3°C), a dla nasion *Armeniaca sibirica* dodatkowo jeszcze stratyfikację w 5° - 10°C przez pierwsze 12 dni, potem w 3°C. Wszystkie nasiona stratyfikowano w nienaruszonym endokarpie.

Wyniki badań są następujące:

1. Nasiona *Armeniaca sibirica* kiełkowały w 100% podczas stratyfikacji wyłącznie chłodnej w 3°C. Kiełkowanie rozpoczynało się i kończyło w tych warunkach między 8 a 14 tygodniem stratyfikacji. Podwyższenie temperatury pierwszych 12 dni stratyfikacji do 5° - 10°C przyczyniło się do przyspieszenia początku kiełkowania o 2 tygodnie. Stratyfikacja ciepło-chłodna (20°/3°C) przyczyniła się do obniżenia żywotności nasion, a w efekcie również i ich zdolności kiełkowania.

Kiełkowanie przebiegało w tym przypadku między 8 a 16 tygodniem chłodnej fazy stratyfikacji.

2. Nasiona *Amygdalus pedunculata* stratyfikowane sposobem ciepło-chłodnym kiełkowały bardzo energicznie (w 83%) w ciągu pierwszych 2 tygodni stratyfikacji ciepłej w 20°C, po obniżeniu temperatury do 3°C reszta nasion kiełkowała bardzo powoli. Stratyfikacja wyłącznie chłodna w 3°C przyczyniła się do obniżenia żywotności nasion, a w następstwie tego i zdolności kiełkowania, przy równoczesnym opóźnieniu początku i rozciągnięciu długości okresu kiełkowania. Większość nasion skiełkowała w tych warunkach między 6 a 16 tygodniem stratyfikacji.

БОЛЕСЛАВ СУШКА

Прекращение покоя и прорастание семян Armeniaca sibirica Lam. и Amygdalus penduculata Pall.

Резюме

В 1967 г. исследовалось прорастание семян обоих видов. Они были собраны на их естественных местонахождениях в Северной Монголии сотрудниками Арборетума в Прухоницах (около Праги) А. Свободой и М. Кучерой. В этих исследованиях применялась холодная (3°C) и тепло-холодная (в течение двух недель 20°, затем 3°) стратификация, и для семян *Armeniaca sibirica* дополнительно ещё стратификация с 5° - 10°C в течение первых 12 дней, а затем с 3°C. Все семена стратифицировались при ненарушенном эндокарпе.

Результаты исследования следующие:

1. Семена *Armeniaca sibirica* прорастали в 100% при холодной стратификации (3°C). Прорастание начиналось и кончалось в этих условиях между 8-й и 14-й неделями стратификации. Повышение температуры первых 12 дней до 5° - 10°C ускоряло начало прорастания на две недели.

Тепло-холодная стратификация (20°/3°C) вызывала снижение жизненности семян, а в результате этого и способности прорастать. В этом случае прорастание проходило между 8-й и 16-й неделей холодной фазы стратификации.

2. Семена *Amygdalus pedunculata,* стратифицированные тепло-холодным способом, прорастали очень энергично (83%) в течение первые двух недель тёплой стратификации (20°C). После понижения температуры до 3°C оставшиеся семена прорастали очень медленно. Холодная стратификация (3°C) снизила жизнеспособность семян, что привело и к понижению их способности прорастать (при одновременном запоздании начала прорастания и растянутости всего периода). В этих условиях большинство семян проросло между 6-й и 16-й неделями стратификации.