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The effect of storing silver maple *(Acer saccharinum L.)* samaras on the germinative capacity of seeds and seedling growth

INTRODUCTION

Seeds of the majority of maple species mature in the autumn. Two species are different in this respect, namely the red maple (*Acer rubrum* L.) and silver maple (*A. saccharinum* L.) the seeds of which mature in late spring, at the turn of May and June. Their seeds are characterized by a complete lack of dormancy (according to Wang and Haddon (1978) some provenances of red maple do produce dormant seeds). In silver maple the lack of dormancy is manifest in the fact that immediately after maturation and falling off the trees the seeds are ready for immediate germination if the conditions are favourable and will start normal growth. These seeds are extremely sensitive to loss of water. Drying of silver maple seeds below 30% of moisture content in the fresh weight causes death of the embryos (Jones 1920, Fowells 1965).

Difficulties in the propagation of silver maple on a larger scale can arrise from two reasons. One of them is the lack of seeds due to frost damage of flowers during flowering and the second is the inappropriate handling of seeds before their sowing, e.g. drying them.

According to Ewart (Holmes and Buszewicz, 1958) seeds of silver maple should be included in the group of microbiotic seeds, readily loosing viability. Jones (1920) reported that the viability of silver maple seeds is strongly connected with temperature of storage and that in a temperature of 0°C they can be stored for 92 days. He has also made trials of storing these seeds in −5°C for a period of 50 days with satisfactory results, however after a longer time the seeds died due to frost injury.

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It was the aim of the present investigation to determine the conditions of storage of silver maple seeds and of the consequences of storage to seed germination and seedling growth.

METHODS

The experiment was conducted in three stages, using seeds collected in the Arboretum of the Institute of Dendrology of the Polish Academy of Sciences in Kórnik in the years 1976, 1979 and 1980.

Experiment I. The experiment in 1976 was of introductory nature into the question of storage of *Acer sacharinum* L. seeds. Freshly collected (on June 11th 1976) samaras of silver maple have been selected and after removing empty and insect attacked ones they were placed into 0.75 l bottles, 300 samaras per bottle, seated and stored at temperatures 1°, 3° and 15°C. Whole samaras used for the experiment contained 43.9% of water in the fresh weight (isolated seeds 49.6%) determined by weight after drying to 105°C for 24 hrs.

Simultaneously with the start of storage a germination test was made with the seeds on filter paper in germinators with distiled water at 20°C in darkness, in 4 replicates with 50 samaras per replicate, and with the wings cut. After the first radicles appeared (1 - 2 cm long), 20 seeds from those in the germination test were outplanted into quartz sand in plastic boxes. These boxes were placed in a phytotron chamber at a constant temperature of 25°C and a 19-hour day with both inflorescent and incadescent light giving 3000 lux at the box level. The growing seedlings were watered daily except for Sundays with distilled water and twice weekly (on Wednesdays and Saturdays) with a Hoagland's nutrient solution modified by Went (1957).

After 20, 40 and 60 days of growth the height of the seedlings was measured, length of each internode, length of the petioles and length and width of the leaves and after 60 days additionally the dry weight of the roots and the aerial parts after drying in 105°C for 24 hrs.

After 4 and 8 months of storing seeds in various temperatures the moisture content was checked in them, their germinative capacity established and the growth of seedlings followed exactly in the same manner as for series germinated at the start of the experiment.

Experiment II. In the experiment established from the 1979 collection of seeds use was made of the results obtained in 1976. The samaras of silver maple have been collected on June 4th and 5th 1979. A part of the freshly collected samaras with a moisture content of 44.3% in the fresh weight (in seeds 49.9%) has been placed 300 to a bottle sealed and stored at 1° and −1°C. The remaining samaras have been dried at room temperature to 34.9% of moisture content (39.9% in seeds) and then placed in bottles and stored as above. During storage half of the bottles was opened once a month and using a pressure pump they were aerated through a piece of tubing positioned inside the bottles to return the air in the bottles to its normal composition. Each time this treatment lasted for 2 min.

At the start of the experiment and after 5 and 10 months of storage the germinative capacity of the seeds was tested on filter paper. Seeds which germinated in these trials have been outplanted 10 per box with guartz sand and the growth of the seedlings was observed. The seedlings grew in the same conditions as in the previous experiment, with the only difference that the day was reduced to 17 hrs and the seedings were watered with Hoagland's solution only once a week, giving tap water on all other days.

Experiment III. The collection of whole samaras was made from the ground on June 12th and 13th 1980 from under the same trees as in previous years. The seed fall took place after three days of persistent rains. The samaras after surface drying were still very moist and contained 51.8% of water in the fresh weight (seeds removed from the pericarps had 60.0%). With this moisture content they were placed into storage at −1° and −3°C in sealed bottles of 0.75 l capacity, 320 samaras per bottle.

Before the start of storage and after 4, 6, 12, 18 and 24 months of storing the samaras in the above mentioned conditions the germination tests were performed on moist filter paper and after planting the seeds into guartz sand the growth of the seedlings was observed as in the second experiment. Only the frequency of watering the plants with the nutrient medium was increased from once to twice a week.

RESULTS

Experiment I. Samaras of silver maple collected from the ground immediately after falling from the trees have had a high moisture content in fresh weight 43.9% (in seeds 49.6%). They germinated 94.5% within 20 days in the germination test on filter paper.

After 4 months of storage of the whole samaras in tightly sealed bottles in 3° and 15°C the seeds have completely lost their germinative capacity. Seeds stored for the same time period at 1°C still germinated to 71.5%. After a further 4 months of storage also these seeds did not germinate.

The quality of the seedlings obtained from freshly collected seeds and from those stored for 4 months in tightly sealed bottles at a temperature of 1°C is presented in Table 1.

Experiment II. Similarily as in experiment I the samaras of

Table 1

Description of silver maple seedlings obtained from fresh seeds and from those stored 4 months at 1°C and after 60 days of growth (Exp. I)

Seedling characers (mean of 20)	From unstored seeds	From seeds stored 4 months
Height in mm	328.1	251.5
No. of leaves	14.4	11.0
Petiole length in mm	26.5	23.5
Leaf length in mm	59.6	54.5
Leaf width in mm	58.9	51.9
Dry wt. in g		
aerial part	1.21	0.58
root	0.29	0.19

silver maple were characterized by a high water content of 44.3% (in seeds 49.9%). When tested for germination on filter paper they germinated 86.0%. After drying the samaras to 34.5% of water content (in seeds 39.9%) the germination capacity dropped by 24% to 62.0%. Also the dry weight of the seedlings obtained from the partially dried seeds was 32% lower compared to the dry weight of seedlings obtained from seeds that were not partially dried.

The results of germination and the conditions of the seedlings from seeds stored for 4, 5 and 10 months in various temperatures and with various levels of water content in the seeds are presented in Tables 2

Table 2

Germination capacity of not dried (49.9% water content in fresh weight) or partially dried after collection (to 39.9%) seeds of silver maple stored in samaras for 4, 5 and 10 months in sealed or periodically (once a month) aerated bottles (Exp. II)

Months of storage	Not dried seeds Storage temperature				Partially dried seeds Storage temperature			
	1°C		−1°C		1°C		−1°C	
	Not aerated	Aerated	Not aerated	Aerated	Not aerated	Aerated	Not aerated	Aerated
0	86.0				62.0			
4	5.0	66.5	69.5	68.9	3.5	28.5	37.5	32.5
5	0.5	51.5	64.0	76.0	5.0	17.0	19.5	18.0
10	0.0	39.5	59.0	55.0	0.0	0.0	3.0	6.5

Table 4

Germinative capacity of freshly collected and stored seeds of silver maple in % (Exp. III)

Storage temperature	Duration of storage in months					
	0	4	6	12	18	24
−1°C	99.5	98.5	93.5	12.5 + 17.0*n*	82.5 + 6.5*n*	4.0*n*
−3°C	99.5	98.0	92.5	90.5	91.0 + 5.0*n*	2.5*n*

n – abnormally germinating seeds

Table 3

Description of 60-day seedlings obtained from fresh (44.3% water content in fresh weight of samaras) or partially dried after collection (to 34.9% water content) seeds of silver maple stored in 1° or −1°C for 5 or 10 months (Exp. II)

Seedling characters (mean of 10)	Months of storage	Not stored seeds		Not dried seeds				Partialy dried seeds			
				Storage temperature				Storage temperature			
				1°C		−1°C		1°C		−1°C	
		Not dried	Partially dried	Not aerated	Aerated	Not aerated	Aerated	Not aerated	Aerated	Not aerated	Aerated
Height in mm	0	146.5	140.1								
	5			–	92.2	93.4	128.9	–	127.3	70.7	103.0
	10			–	153.8	160.3	157.1	–	–	82.0	100.6
No. of leaves	0	8.8	6.9								
	5			–	6.4	6.8	6.4	–	7.8	6.5	6.7
	10				11.2	10.0	10.8	–	–	7.0	7.4
Petiole length in mm	0	15.3	12.4								
	5			–	9.1	8.7	12.7	–	11.0	7.7	10.2
	10			–	17.1	13.1	13.9	–	–	10.9	12.4
Leaf length in mm	0	41.5	35.6								
	5			–	26.3	27.0	37.8	–	32.2	24.9	29.9
	10			–	40.6	37.7	38.6	–	–	23.3	31.8
Leaf width in mm	0	38.3	32.8								
	5			–	23.4	26.2	35.6	–	28.6	24.9	30.0
	10			–	37.1	34.9	34.4	–	–	18.5	30.1
Dry weight in g aerial part	0	0.332	0.206								
	5			–	0.283	0.352	0.506	–	0.180	0.093	0.153
	10			–	0.381	0.325	0.363	–	–	0.085	0.147
root	0	0.140	0.115								
	5			–	0.126	0.300	0.361	–	0.082	0.059	0.072
	10			–	0.118	0.143	0.150	–	–	0.037	0.064

and 3. Best results were obtained without partial drying when stored at $-1°C$ and the aeration was of no significance.

Experiment III. The initial high germinative capacity of silver maple seeds (99.5%) declined only slightly, by 3%, after 18 months of storage at a temperature of $-3°C$ and by 10.5% when stored at $-1°C$. For unexplained reasons after 12 months of storage in $-1°C$ the germinative capacity declined substantially to 29.5%. This decline must have been accidental because after 18 months the seeds again germinated to a high percentage (89.0%). Thereafter the germinative capacity of the seeds declined rapidly almost to zero after 24 months of storage

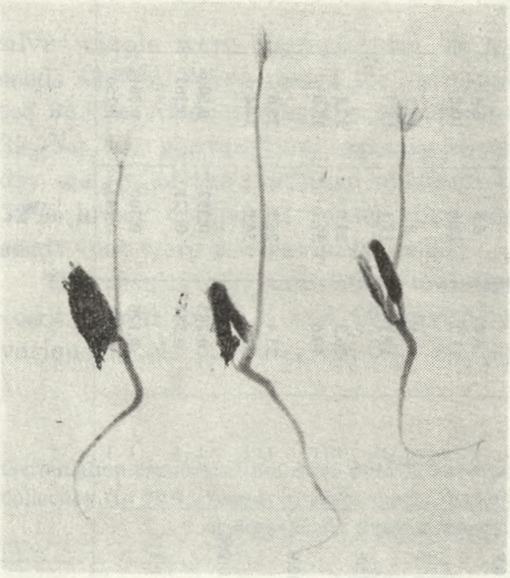

Fig. 1. Normally germinating seeds of silver maple freshly collected or stored for 18 months at $-3°C$. Phot. E. Szubert

Fig. 2. Abnormally germinating seeds of silver maple after 18 months of storage at $-1°$ or $-3°C$. Such seeds are marked in Table 4 with letter „n". Phot. E. Szubert

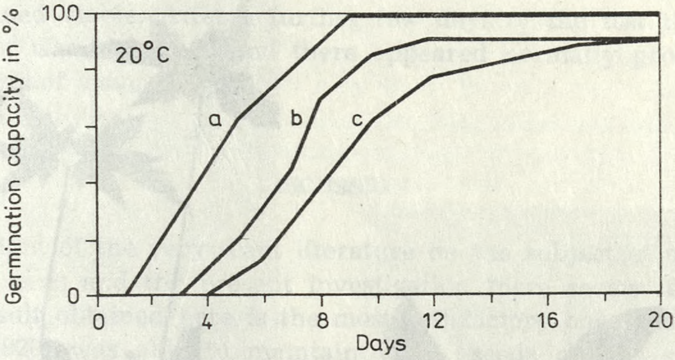

Fig. 3. Comparison of the course of germination of freshly collected (a) or stored for 12 (b) or 18 (c) months seeds of silver maple at a temperature of −3°C

at both the storage temperatures (to 4% in —1° and to 2.5% in −3°C, Table 4).

During the germination tests on filter paper no anomalies were observed when fresh seeds or those stored for 6 months were germinated (Fig. 1). Manifestations of abnormal germination started only after

Table 5

Description of 60 day seedlings of silver maple obtained from freshly collected seeds and those stored for 12 and 18 months. The initial water content of seeds removed from the pericarps was 60.0% of fresh weight (Exp. III)

Seedling characters (means of 10)	From fresh seed	From seed stored for 12 months		18 months	
		−1°C	−3°C	−1°C	−3°C
Height in mm	221.2	193.0	209.6	97.8	130.9
Internode length in mm	40.2	27.5	35.0	23.8	27.3
Petiole length in mm	20.2	16.2	21.4	13.6	18.0
Leaf length in mm	47.0	37.4	49.9	34.0	40.4
Leaf width in mm	43.6	36.4	44.6	30.1	35.7
Dry weight in g					
aerial part	0.567	0.318	0.426	0.179	0.279
root	0.222	0.085	0.118	0.074	0.112
Total	0.789	0.403	0.544	0.253	0.391

Table 6

Mean increment of seedling height obtained from freshly collected seed and from those stored for 18 months at −3°C in tightly sealed bottles (Exp. III)

Days	Mean increment of seedling height in mm: From freshly collected seed	From stored seed
0 - 20	114	94
20 - 40	62	32
40 - 60	34	5
0 - 60	210	131

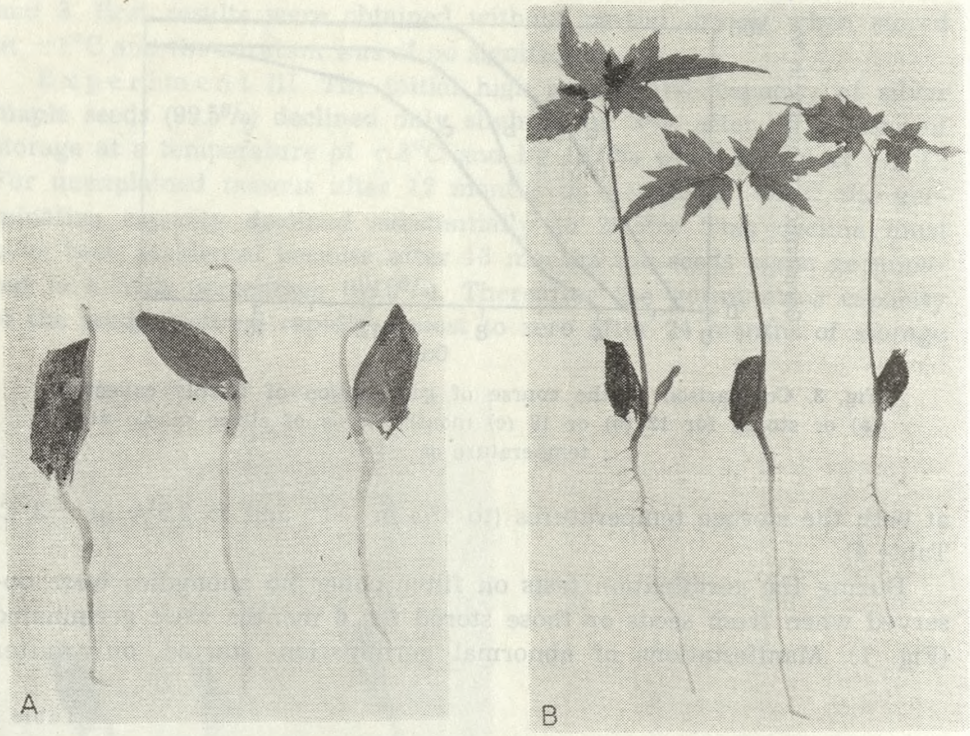

Fig. 4 A — germinating seeds of silver maple after 18 months of storage at −1°C or −3°C. Scars after aborted embryo leaves are visible. B — the same seeds after 9 days of growth. The second pair of leaves has already developed. Phot. E. Szubert

12 months in −1°C and after 18 months of storage in —3°C. In Fig. 2 the abnormally germinating seeds are shown with aborted radicle tips and the appearance of adventitious roots. After 24 months of storage all the germinating seeds, both after −1°C and after −3°C storage were characterized by having abnormal root development.

The course of germination did no undergo any significant changes after 18 months of storage at −3°C compared to the course of germination for fresh seeds. However there was a distinct delay in the onset of germination of the stored seeds (Fig. 3).

The growth of seedlings from seeds after 1 year (12 months) storage in both the temperatures was normal but weaker. Seedlings from seeds stored in —1° or −3°C were smaller by 13% and 5% respectively in relation to the non-stored seeds. The hight of the seedlings declined very markedly after 18 months of storage, respectively by 56% and 41% compared to the seedlings obtained from fresh seeds (Table 5 and 6). This was accompanied by the abortion of the first leaf pair in all seedlings. In the first phase of the growth of the epicotyl in its apical part there were visible remains of the aborted embryo leaves, however the apex remained viable. After a further few days of the test the growth of the shoot was continued and there appeared normally growing consecutive pairs of leaves (Fig. 4).

DISCUSSION

In the light of the very scant literature on the subject of storing silver maple seeds and the present investigation there seems little doubt that the result obtained here is the most satisfactory one obtained ever. Jones (1920) was able to maintain viable seeds of this species for 5 months without reducing the germination capacity by placing these seeds above the water surface in tightly sealed containers held at 10°C. After a longer period of storage in these conditions he observed abnormal development of the hypocotyls during germination tests. In another experiment Jones stored silver maple seeds in −5°C for 50 days, however due to frost injury of the seeds he discontinued this experiment.

Our investigations have shown that one should not dry silver maple seeds below a certain critical value of about 40% water content in fresh weight. At this level of water content and storage for 10 months at −1°C the seeds still germinated to a high 59%.

On the basis of results obtained in the third experiment it can be said that any drying of the seeds of silver maple is detrimental to their germination. A high water content in mature samaras (51.8%) assured the maintenance of a germination capacity to a level of 91.5% for a period of 18 months when stored at −3°C in tightly sealed bottles. After that time some symptoms of ageing appeared in the form of a small percentage of abnormally germinating seeds (5%). The lack of the first leaf pair in the seedlings grown from seeds stored for 18 months at −1° and —3°C indicates that these parts of the embryo are sensitive to long term storage in low temperatures. After 24 months of storage the germination capacity was almost down to zero. This may be the result of the utilisation of reserve materials essential for the germination of seeds or of the suffocation of the seeds due to an excess of CO_2 in the bottles. This latter explanation seems less likely because in the second experiment the periodic aeration of the seeds stored in —1°C has had almost no effect on the viability of seeds.

The decline in seed viability is correlated with an increase in the frequency of chromosomal aberrations in stored seed (Roberts 1972). As a consequence of these changes one observes the later abnormal germination of seeds, reduced seedlings growth (Figs 2 and 4) and the appearance of malformed leaves.

The viability of seeds with a high water content may be substantially reduced as a consequence of the pathogenic action of fungi (Dorywalski and Wojciechowicz 1959, Morelet 1974) which can destroy the whole store of seeds in a very short time. Reduction of storage temperature below 0°C (to −1° and —3°C) favours the reduction in metabolic processes in the seeds themselves and in the fungi occurring on their surfaces.

CONCLUSIONS

1. The partial drying of freshly fallen samaras of silver maple leads to a reduction in the germination capacity of these seeds.
2. Samaras of silver maple intended for storage should be characterized by a high water content no less than 50% of their fresh weight.
3. The storage of samaras in tightly sealed containers at −1° or —3°C assures the maintenance of a high germination capacity on an almost unchanged level for 18 months. After a longer storage period the germination capacity rapidly declines.
4. As the duration of storage extends one observes a delay in the onset of seed germination.
5. Seedlings obtained from seeds stored for 18 months are characterized by a lack of the first pair of leaves due to abortion of embryo leaves during long term storage. The further growth of the seedlings is normal.
6. As the storage time extends silver maple seedlings attain ever smaller dimentions after sowing in identical conditions.

SUMMARY

The germination capacity of silver maple seeds that easily loose viability can be maintained at an almost unchanged level for 18 months. The conditions for the maintenance of high germinability is the storage without any drying after collection in tightly sealed containers at −1° or —3°C. The samaras should have a high initial water content about 50% of their fresh weight. The size of seedlings declined with the duration of storage.

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Wpływ przechowywania skrzydlaków klonu srebrzystego (Acer saccharinum L.) na zdolność kiełkowania nasion i wzrost siewek

Streszczenie

Zdolność kiełkowania nasion klonu srebrzystego łatwo tracących żywotność można utrzymać na prawie nie zmienionym poziomie przez 18 miesięcy. Warunkiem zapewniającym zachowanie wysokiej zdolności kiełkowania tych nasion jest przechowywanie skrzydlaków bez jakiegokolwiek podsuszania po zbiorze, w szczelnie zamkniętych pojemnikach w −1° lub −3°C. Skrzydlaki powinny charakteryzować się wysoką zawartością wody wynoszącą powyżej 50% w świeżej masie.

Wysokość siewek była tym niższa, im dłużej przechowywano nasiona.

Влияние хранения крылаток клена серебристого (Acer saccharinum L.) на способность прорастания семян и рост сеянцев

Резюме

Способность прорастания легко теряющих жизнеспособность семян клена серебристого можно сохранить на почти постоянном уровне в течение 18 месяцев. Условием необходимым для сохранения высокой способности прорастания этих семян является хранение крылаток без какого-либо подсушивания после сбора, в плотно закрытых контейнерах при −1° или −3°C. Крылатки должны характеризоваться значительным содержанием воды, составляющем более 50% свежего веса.

Высота сеянцев была тем ниже, чем дольше хранились семена.