ODC 181.524 + 232.315.2 + 176.1 *Acer saccharum*

Storage Requirements for SUGAR MAPLE Seeds

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ABSTRACT

Sugar maple seeds, collected from three trees in northern Vermont, were stored at four temperatures (18, 7, 2, and –10°C) in combination with four seed moisture contents (35, 25, 17, and 10 percent). Seed moisture content and storage temperature significantly affected keeping ability, and these factors were highly interrelated. Seeds from all trees kept best at the lowest temperature and lowest moisture content tested.

SUGAR MAPLE (*Acer saccharum* Marsh.) is one of our most valuable hardwood trees. Because of its economic importance to both the wood-using and maple-syrup industries, sugar maple has become the object of intensive seeding and planting research by the Northeastern Forest Experiment Station laboratory at Burlington, Vermont. One phase of this research, which is reported in this paper, deals with seed storage. Some early results of this research were reported by Yawney (*1968*).

Sugar maple produces good seed crops at intervals varying from 2 to 7 years (*USDA 1948; Harlow and Harrar 1958*). Because of irregularity in seed production, we investigated the requirements for long-term storage to provide an adequate seed supply during poor crop years.

The purpose of determining the proper storage environment for any seed is to maintain it at the lowest possible level of metabolic activity without impairing its viability. In general, the critical factors for maintaining seeds in storage are temperature and seed moisture content (*Crocker and Barton 1957*).

The storage requirements for seed of many of our important tree species have been adequately defined, but the seed of sugar maple has received little attention. Information in the *Woody Plant Seed Manual* (*USDA 1948*) indicates only that sugar maple seeds will remain viable for at least a year in either open or sealed containers when stored at 36° to 40°F. However, suitable moisture content is not indicated. Stanley and Butler (*1961*) reported that sugar maple seed can be dried to a moisture content of about 5 percent without lowering germination, but gave no further recommendations.

In view of this limited information, we studied the effects of different combinations of storage temperatures and seed moisture contents on the keeping ability of sugar maple seed.

METHODS AND MATERIALS

We collected sugar maple seeds from three mature trees in northern Vermont during 2 weeks in late September and early October 1962. The percentages of the samaras containing seeds in the three collections were 68, 55, and 72. The empty samaras were not removed from the collections.

The experiment was designed to test the effects of four seed moisture contents—35, 25, 17, and 10 percent (dry-weight basis)—in all combinations with four temperatures—18, 7, 2, and −10°C—for a total of 16 storage conditions.

Each tree collection (seedlot) was kept separate. We were able to air-dry the seedlots slowly to 17 percent moisture content in an unheated building. Drying to 10 percent moisture content required transferring the seedlots to a heated room. The length of time required to dry the seeds varied from 30 to 60 days, depending upon the initial moisture content and the final moisture content specified for storage.

Each sample, consisting of 150 samaras, was stored in a 6-oz. glass jar and sealed with a rubber-lined metal screw cap (fig. 1) to insure moisture content stability. Facilities for maintaining the prescribed temperatures included kitchen-type refrigerators for 18° and 7°C, a walk-in cooler for 2°C, and a chest-type freezer for −10°C. (The assistance given by the Champlain Valley Fruit Co., Burlington, Vermont, by providing space for their 2°C facility during the study is gratefully acknowledged.)

Because of the unknown effects of storage in sealed containers, we stored additional samples from each collection in each temperature facility in open jars. In these samples no attempt was made to maintain the seed at fixed moisture contents. At the start of the experiment these samples had an initial moisture content of about 22 percent.

Seed moisture content in each storage facility was monitored throughout the course of the study.

We used germination as the criterion of

Figure 1.—A storage sample consisting of 150 sugar maple samaras in a 6-oz. jar.

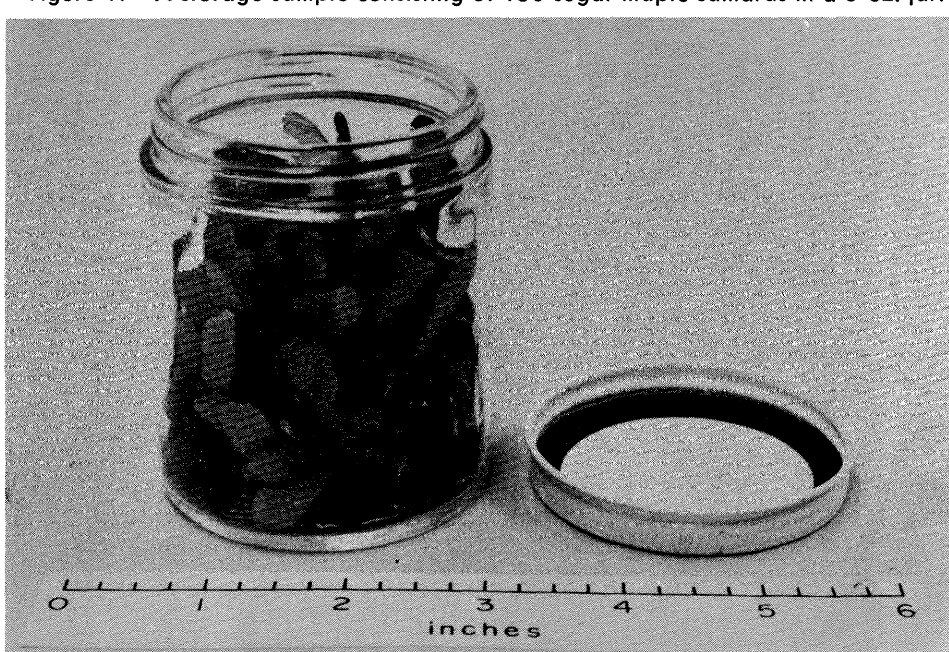

Figure 2.—Sugar maple seeds germinating in a test sample.

seed viability. We considered a seed germinated as soon as its radicle became visible (fig. 2). Germination tests were made before storage, at the end of 6 months, and then annually for 4 additional years. Viability was determined on the basis of three 150-samara samples from each seedlot for each storage condition. Thus, at the end of each storage period, we tested 144 samples from sealed containers and 36 samples from open containers.

Each sample was germinated separately, following the procedure described for sugar maple seeds by Carl and Yawney (*1966*). We soaked the samples in tap water for 24 hours and then placed them on moist germination paper in plastic boxes. We kept them in darkness at 2 to 4°C in a walk-in cooler for 90 days followed by 2 weeks in a greenhouse at about 23°C. At the conclusion of each germination test, we opened the remaining samaras to determine the number of seeds that failed to germinate. The ungerminated seeds plus the germinants were used to calculate the percentages of germination.

The sealed and open containers represented two experiments; therefore, the data were analyzed separately. The design of the experiment for the sealed-container series was that of a 3 x 4 x 4 x 5 factorial (3 seedlots, 4 moisture contents, 4 temperatures, and 5 storage periods), and for the open containers a 3 x 4 x 5 factorial (3 seedlots, 4 temperatures, and 5 storage periods). Viability was recorded in percentages, which were transformed (arc-sin) for use in the analysis.

RESULTS AND ANALYSIS

The germination tests before storage indicated that viability was 97 percent for tree 1, 98 percent for tree 2, and 99 percent for tree 3. Results of our germination tests made at the end of 6, 18, 30, 42, and 54 months are summarized for the sealed containers in table 1 and for the open containers in table 2.

Sealed-container experiment.—During the study, the deteriorating effects of unfavorable storage conditions on sugar maple seed followed a distinct pattern that was similar for all three seedlots. Samples stored at the highest temperatures and highest moisture contents were the first to be affected.

At the end of 6 months, complete loss of viability was recorded in all samples stored at 18°C and 35 percent moisture content. As storage continued, samples previously unaffected showed signs of deterioration as loss of viability progressed gradually into the lower treatment levels with each succeeding year.

When the study was completed, we found that only 4 out of the 16 storage conditions tested maintained the seed with little or no loss in viability. These conditions were −10°C in combination with 17 percent moisture content; and 7, 2, and −10°C in combination with 10 percent moisture content.

Our analysis of the data in table 1 verified the obvious significance of temperature, seed moisture, and storage period. Differences between seedlots were also found to be highly significant. Moreover, the analysis revealed that not only were all these factors highly significant, but that all interactions between them were as well.

Open container experiment.—Losses in viability in samples stored in the open con-

Table 1.—*Effects of seedlot, moisture content, temperature, and time on the viability of sugar maple seed stored in sealed containers, in percent*

Seed moisture content (percent)	Storage temperature (°C)	(Seedlot 1:) months in storage—					(Seedlot 2:) months in storage—					(Seedlot 3:) months in storage—				
		6	18	30	42	54	6	18	30	42	54	6	18	30	42	54
35	18	0[1]	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	7	83	0	2	0	0	86	0	2	0	0	99	0	1	0	0
	2	95[2]	8	1	0	0	94	19	0	0	0	95	4	0	0	0
	−10	95	93	87	1	0	94	88	93	8	2	95	99	86	1	0
25	18	44	0	2	0	0	0	0	0	0	0	2	0	0	0	0
	7	95	65	3	0	0	96	23	0	0	0	100	51	0	0	0
	2	95	85	50	7	0	97	89	9	0	0	100	99	69	1	14
	−10	97	95	96	46	7	96	98	98	3	9	93	99	98	3	14
17	18	62	0	0	0	0	15	1	0	0	0	40	0	1	0	0
	7	95	86	0	0	0	96	62	0	0	0	100	94	5	0	0
	2	97	93	82	58	60	99	94	73	4	0	100	98	98	83	14
	−10	97	96	93	92	86	97	98	97	92	95	99	99	100	97	98
10	18	90	55	1	1	0	94	68	0	0	0	100	95	9	0	0
	7	89	91	91	93	85	93	95	95	92	92	100	100	100	98	96
	2	93	93	89	91	94	97	95	96	93	96	100	100	99	100	99
	−10	95	95	97	89	94	96	96	96	97	94	99	98	99	99	99

[1]Viability percentages are averages of 3 samples.
[2]Percentages within the shaded area are not significantly different from each other.

Table 2.—*Effects of seedlot, temperature, and time on the viability of sugar maple seed stored in open containers, in percent*

Storage temperature (°C)	(Seedlot 1:) months in storage—					(Seedlot 2:) months in storage—					(Seedlot 3:) months in storage—				
	6	18	30	42	54	6	18	30	42	54	6	18	30	42	54
18	67[1]	0	2	0	0	93	0	1	0	0	98	2	1	0	0
7	97[2]	58	41	28	10	98	62	52	50	11	100	95	87	80	50
2	94	76	19	0	0	96	81	3	0	0	100	99	40	1	0
−10	96	98	97	71	63	98	98	98	96	90	99	100	100	98	98

[1]Viability percentages are averages of 3 samples.
[2]Percentages within the shaded areas are not significantly different from each other.

Table 3.—*Moisture contents of samples stored in open containers in each temperature storage facility at different periods during the study*

Storage temperature (°C)	Approximate relative humidity	(Seedlot 1:) months in storage— Initial	6	18	30	42	54	(Seedlot 2:) months in storage— Initial	6	18	30	42	54	(Seedlot 3:) months in storage— Initial	6	18	30	42	54
	Percent			Percent						Percent						Percent			
18	26	24[1]	6	6	6	—	—	19	9	7	6	—	—	23	9	8	8	—	—
7	60	24	18	12	11	7	8	19	17	10	10	7	7	23	17	11	11	8	8
2	84	24	23	18	18	20	17	19	22	16	16	17	14	23	22	17	17	22	19
−10	81	24	21	18	21	21	18	19	15	15	16	19	18	23	17	16	17	17	16

[1]Moisture contents are averages of 10 samples.

tainers (table 2) generally reflected the effects of storage condition found in the sealed-container series. Again, 18°C proved to be the most detrimental to seed viability, while maximum viability was maintained at −10°C. The relative humidities and the seed moisture contents in each storage unit are given in table 3.

An analysis of variance showed, as with the sealed samples, that seedlot, storage temperature, storage period and all their interactions were also highly significant.

DISCUSSION

This study clearly demonstrated that long-term storage of sugar maple seed is possible. The length of time that seeds remain viable is influenced by storage temperature, seed moisture content, and seedlot, and that all of these factors interact with each other in their effects.

In view of the total interaction, very little can be said about the individual contribution of each variable, but it appears that moisture content is probably the most important. The inferences that can be drawn from the data are as follows: (1) there were differences in storability between seedlots; (2) both storage temperature and seed moisture content influence seed viability over extended periods, and that these factors interact in their effects; (3) the effect of the interaction of temperature and moisture content changes in degree with seed from different trees; and (4) the degree of these changes is not necessarily consistent from one storage period to the next.

Differences between the keeping quality of the three seedlots were probably due to the stage of maturation of the seed at the time of collection. We noted that samaras from tree 1 were bright green in color, giving a fresh appearance; they were firmly attached to the peduncles and did not separate easily. In contrast, samaras from tree 3 were yellow in color, with orange and brown mottling, and were easily shed from the tree. Seeds in lot 2 appeared to be intermediate in their development.

The data suggest that, had the study continued for several more years, seedlot 3 would have kept in storage significantly longer than lot 2, and lot 2 would have kept longer than lot 1. The relative strength of each seedlot, or the differences in their keeping quality, can be assessed by comparing the patterns of the shaded area between seedlots in tables 1 and 2.

Reporting on the maturation of sugar maple seed, Carl and Snow (*1972*) found that considerable variation exists among trees. They reported that germination potential develops rapidly, requiring as little as 2 weeks to go from 0 to 95 percent, and that near maximum potential is reached about 4 to 5 weeks in advance of seedfall. Their findings and the results from our study suggest that, although the seeds may be structurally complete and have high germination percentages, they may not be completely tree ripened.

Barnett and McLemore (*1970*) reported that longleaf pine seeds collected from a given tree 1 year may store well, while seeds collected from the same tree in another year may store poorly. They speculated that, if the seeds have not reached some critical stage of maturity, they will fail rapidly in storage.

To insure a high germination potential and to insure good retention of viability during storage, we recommend that sugar maple seeds not be collected until the samaras have lost their bright green color.

A comparison of the data in tables 1 and 2 suggests that seed in sealed containers retained their viability better than those in open containers. This may be due in part to a reduction of the oxygen supply in the sealed containers, which would favor retention of viability (*Crocker and Barton 1957*).

In this study, however, we attributed losses in germination capacity of the open stored seed largely to the high initial moisture content (around 22 percent) when the study began and the high relative humidities present in the storage facilities. In those storage units that permitted the adjustment of the seed moisture content downward, storage life of the samples was significantly lengthened. For example, seedlot 3 in open containers had an initial moisture content of 23 percent. When stored at 7°C, it was gradually reduced to about 10 percent, and at the end of 4½ years was still 50 percent viable. In contrast, seedlot 3, held at 25 percent moisture content in sealed containers at 7°C, failed to germinate after 2½ years.

We conclude that results equally as good can be achieved with either sealed or open containers, provided a low temperature and a low seed moisture content are maintained. As a practical extension of this study, we have practiced storing sugar maple seeds, which have been dried to 10 percent moisture content or less, in lots of 10,000 or more in closed plastic containers in ordinary kitchen freezers with excellent results.

SUMMARY AND CONCLUSIONS

Sugar maple seeds collected in northern Vermont were successfully stored for 4½ years—the duration of this study. We found the conditions necessary for long-term storage to be a combination of a low temperature and a low seed moisture content. When the study was completed, germination capacity remained at about prestorage levels for those seed stored with 17 percent moisture content at −10°C, and with 10 percent moisture content at 7, 2, and −10°C.

On the basis of the trends indicated by our data, we believe that the seeds could have been stored for a considerably longer period than that covered by this study. The most favorable conditions for continued storage appeared to be with 10 percent moisture content and at −10°C.

LITERATURE CITED

Barnett, J. P., and B. F. McLemore.
1970. STORING SOUTHERN PINE SEEDS. J. Forest. 68: 24-27.

Carl, C. M., Jr., and H. W. Yawney.
1966. FOUR STRATIFICATION MEDIA EQUALLY EFFECTIVE IN CONDITIONING SUGAR MAPLE SEED FOR GERMINATION. Tree Planters' Notes 77:24-28.

Carl, C. M., Jr., and A. G. Snow, Jr.
1972. MATURATION OF SUGAR MAPLE SEED. USDA Forest Serv. Rcs. Pap. NE-217. 8 p., illus.

Crocker, W., and L. V. Barton.
1957. PHYSIOLOGY OF SEEDS. Chronica Botanica Co., Waltham, Mass. 267 p.

Harlow, W. M., and E. S. Harrar.
1958. TEXTBOOK OF DENDROLOGY COVERING THE IMPORTANT FOREST TREES OF THE UNITED STATES AND CANADA. McGraw-Hill Book Co., Inc., New York. Ed. 4, 561 p.

Stanley, R. G., and W. L. Butler.
1961. LIFE PROCESSES OF THE LIVING SEED. U. S. Dep. Agr. Yearb. 1961:88-94.

U. S. Forest Service.
1948. WOODY-PLANT SEED MANUAL. U. S. Dep. Agr. Misc. Pub. 654. 416 p.

Yawney, H. W.
1968. ARTIFICIAL REGENERATION OF SUGAR MAPLE. Mich. Tech. Univ. Sugar Maple Conf. Proc.: 65-74. Houghton, Mich.

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