

EFFECTS OF TEMPERATURE AND MOISTURE CONTENT ON THE STORABILITY OF HARDWOOD SEEDS¹

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Abstract—Experimental results have been inconclusive about low temperature storage of recalcitrant seeds from temperate zone trees. Experiments were conducted on four species of oak - chinkapin (*Quercus muehlenbergii* Engelm.), water (*Quercus nigra* L.), Shumard (*Quercus shumardii* Buckl.), and northern red (*Quercus rubra* L.). Storage temperatures were -1.5 °C and 3 °C, and lengths of storage were 1, 2, and 3 years. Seeds, stored both hydrated and dried, had moisture contents ranging from 23 to 45 percent. Chinkapin acorns did not survive past 1 year in storage, and few northern red acorns were viable after 3 years. Both water oak and Shumard acorns survived at high and low moisture contents; however, Shumard acorns lost 2/3 of their viability by year 3 with best survival rates at -1.5 °C, while water oak survival was over 75 percent after three years storage at 3 °C. Presprouting occurred in all species. Additional investigations have begun on white oak (*Quercus alba* L.), swamp chestnut oak (*Quercus michauxii* L.), and red buckeye (*Aesculus pavia* L.). Differences are known to exist in the degree of recalcitrance in seeds, and these studies will determine if some recalcitrant seeds are more amenable to storage than others.

INTRODUCTION

Low temperature storage of hardwood tree seeds has been studied for the last 30 years. During this period, it has been determined that seeds can be divided into at least two storage classes — orthodox and recalcitrant (Roberts 1973). Orthodox seeds can be dried to a moisture content (MC) less than 12 percent and stored for long periods of time at low or sub-freezing temperatures; recalcitrant seeds are sensitive to moisture loss, making storage for any useful period extremely difficult. Some north American genera containing species with recalcitrant seeds are *Castanea* (Pritchard and Manger 1990) and some *Acer*, *Aesculus*, and *Quercus* (Bonner 1990).

The physiological basis of recalcitrant behavior is not fully understood. Several hypotheses have been proposed suggesting that seed deterioration during storage may be due to (1) deleterious changes in lipid composition (Flood and Sinclair 1981, Pierce and Abdel Samad 1980), (2) physical disruption of the seed membranes (Seewaldt and others 1981, Simon 1974), or (3) an increasingly aberrant metabolism during hydrated storage (Pammenter and others 1994) and as water is lost (Berjak and Pammenter 1997).

Acorns of the red oaks and of *Quercus robur* have reportedly been stored at -1 °C or -2 °C for periods up to 5 years in Europe (Suszka and Tylkowski 1980, 1982). Experiments here have been less successful, suggesting a varying degree of dormancy between European and United States species. We are reporting the results from a 3-year storage study of chinkapin (*Quercus muehlenbergii* Engelm.), water (*Quercus nigra* L.), Shumard (*Quercus shumardii* Buckl.), and northern red oak (*Quercus rubra* L.) acorns; and preliminary results of a storage experiment on species with seeds even more sensitive to desiccation, namely red buckeye (*Aesculus pavia* L.), white oak (*Quercus alba* L.), and swamp chestnut oak (*Quercus michauxii* L.).

PROCEDURES

Shumard, water, and chinkapin oak acorns were collected locally in Oktibbeha and Winston Counties, Mississippi. The

northern red oak acorns were from Georgia, the swamp chestnut oak from Texas, and the white oak from North Carolina. All seeds were cleaned by floatation, soaked overnight, and then stored at 3-4 °C until the start of the experiment. Original MC's for each drying regime were determined by drying 4 to 5 samples of acorns at 105 °C for 16 to 17 hours. In preparation for germination tests, acorns were cut in half, and the seed coat peeled from the half containing the embryo. Buckeye seeds were germinated intact. Germinations were conducted on moist Kimpak at an alternating temperature regime of 20 °C for 16 hours in the dark and 30 °C for 8 hours with light. The red oaks received 60 days of moist stratification prior to testing. Since sprouting in storage can be a common problem, counts were made at the start of each germination test of the number of seeds in a sample which had sprouted during storage and stratification. Experiments were conducted as follows:

Experiment 1—High and low moisture levels for Shumard, water, chinkapin, and northern red oak acorns were imposed by either soaking in tap water for 16 hours or by drying on a lab bench for 16 hours. Lots of 100 to 150 acorns were stored in 4-mil polyethylene bags either in a refrigerator set at 3 °C or in a modified chest freezer set at -1.5 °C. Temperature in the latter fluctuated from -1 to -3 °C. Original percent germination was determined for all species and was tested again as follows: 1, 2, and 3 years for water and northern red oak; 2 and 3 years for Shumard oak; and 1 and 2 years for chinkapin oak. Seeds were germinated as six replications per sampling period.

Experiment 2—This experiment was conducted on tree species with highly recalcitrant seeds. Two separate lots of swamp chestnut oak acorns were received from Texas; the first lot was stored fresh or after drying on the lab bench for 2 days. Buckeye and the second lot of swamp chestnut oak acorns were stored either fresh or after drying for 3 or 6 days on the lab bench; the large size of these seeds and limited amounts received restricted quantity stored to 25 per bag. White oak acorns were stored 50 per bag at the fresh MC only. Seeds were stored at either 4 °C in a Lab-Line Ambi-

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Hi-Low Chamber or at -2 °C in a modified chest freezer. Original percent germination was determined, and all species were tested again at 75 and 90 days. Seeds were germinated as two replications per sampling period. Seeds dried prior to storage were rehydrated overnight in tap water prior to germination testing. Tests at 120 days and 6 months are planned.

RESULTS

Experiment 1—High MC's ranged from 33 percent (Shumard) to 46 percent (northern red) and lows from 23 percent (water oak) to 35 percent (northern red); original viability averaged over 90 percent for all species (table 1). Chinkapin oak did not survive for more than 1 year in storage; by this time, sprouting was prevalent, especially in the high temperature treatment (3 °C), and germination had been reduced by at least 30 percent for all treatments (fig. 1). Storage at the low temperature treatment, -1.5 °C, yielded the best results; MC at this temperature did not have a significant effect on storability. Northern red oak also did not store well beyond 1 year. Storage at -1.5 °C kept germination high and sprouting at a minimum (fig. 1); however, unlike chinkapin oak, the acorns stored at -1.5 °C and high MC yielded significantly better germination results than those dried prior to storage. By the second year, however (fig. 2), germination had dropped below 35 percent, even in the best storage treatment (-1.5 °C/high MC); and by year 3, survival in all treatments was minimal (fig. 3). The best 2-year storage treatment for Shumard oak was also -1.5 °C/high MC (fig. 2). However, like chinkapin oak, germination had fallen well over 30 percent from the original value, and by year 3 (fig. 3), viability had dropped to less than 30 percent for all treatments. Water oak was unique in that storage at -1.5 °C was not superior to that at 3 °C; and, unlike any of the other species, one treatment, 3 °C/high MC, had excellent survival after 3 years (figs. 1-3).

Experiment 2—MC's of fresh seeds vs. those dried for 2 to 6 days varied by as little as 4.5 percent or as much as 17.5 percent within a species (table 2); original viability of treated seeds averaged 80 percent or more. *Quercus michauxii* acorns did not store well at 4 °C, but, through 90 days have survived at rates above 50 percent when stored at -2 °C (fig. 4). In contrast, red buckeye seeds (fresh and day 3

treatments) had excellent survival at both 4 °C and -2 °C (fig. 5); seeds dried for 6 days, however, had low viability. Sprouting in both these species is negligible. White oak acorns stored at -2 °C lost over 60 percent viability after 90 days, and sprouting averaged 6.3 percent. Those stored at 4 °C have a survival rate considerably higher, 68.2 percent after 90 days; but sprouting at this temperature has been extremely high, averaging 33 percent after 75 days and 73 percent after 90 days, thus negating any storage advantage offered by this treatment.

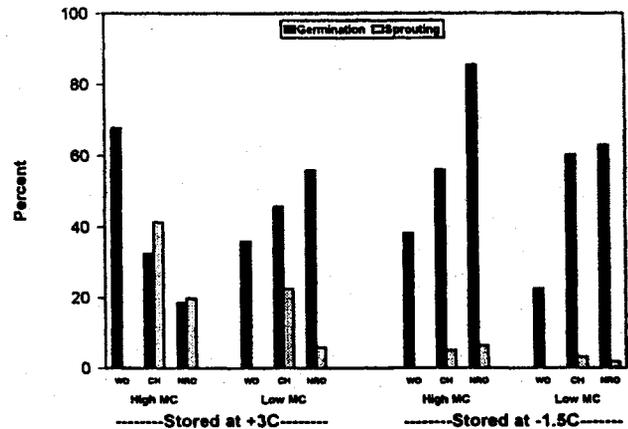


Figure 1—Germination and sprouting percentages of high and low moisture content water oak (WO), chinkapin oak (CH), and northern red oak (NRO) acorns stored for 1 year at 3 °C and -1.5 °C. Moisture contents are presented in table 1.

Table 1—Original average moisture contents and germination of acorns at the start of storage experiment 1

Species	Moisture content		Initial germination
	High	Low	
----- Percent -----			
Northern red oak	45.5	35.0	99.0
Chinkapin oak	39.7	30.7	91.3
Shumard oak	32.8	25.0	99.4
Water oak	29.1	23.2	96.3

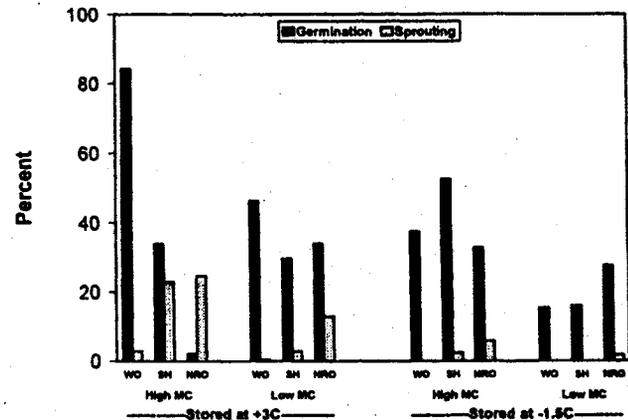


Figure 2—Germination and sprouting percentages of high moisture and low moisture content water oak (WO), Shumard oak (SH), and northern red oak (NRO) acorns stored for 2 years at 3 °C and -1.5 °C. Moisture contents are presented in table 1.

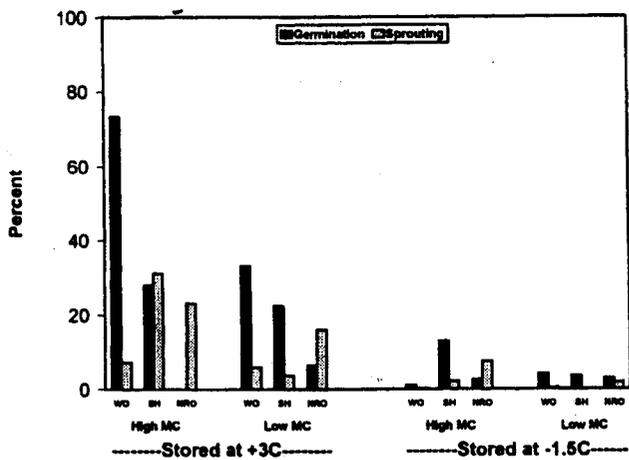


Figure 3—Germination and sprouting percentages of high moisture and low moisture content water oak (WO), Shumard oak (SH), and northern red oak (NRO) acorns stored for 3 years at 3 °C and -1.5 °C. Moisture contents are presented in table 1.

Table 2—Original average moisture contents and germination of acorns at the start of storage experiment 2

Species	Days drying	Initial germination	Initial moisture content
		----- Percent -----	
White oak	0	82.0	45.1
	3	90.0	54.4
	6	80.0	44.0
Swamp chestnut 1	0	85.0	51.1
	2	80.0	46.6
Swamp chestnut 2	0	100	48.1
	3	100	45.9
	6	95.0	42.6

DISCUSSION

No one temperature/MC combination was best for storage of all oak species. In experiment 1, chinkapin acorn viability was highest and sprouting lowest when stored at the combination of -1.5 °C/low MC. The low storage temperature was also best for acorns of northern red oak and for 2-year storage of Shumard oak. However, unlike chinkapin, the acorns of these species stored at high MC had a higher rate of survival than those dried prior to storage; and after 3 years of storage, Shumard acorns stored at 3 °C had a higher rate of survival than those stored at -1.5 °C. Viability for all three species dropped significantly from the original viability count after only 1 to 2 years in storage. Water oak, unlike the other three oaks, retained a high viability after 3

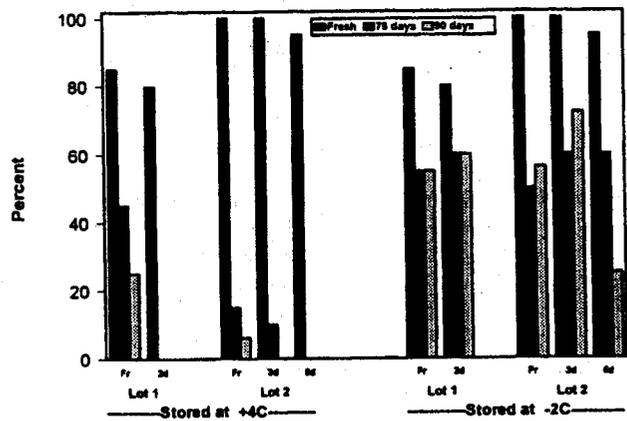


Figure 4—Germination of two lots of swamp chestnut oak stored at 4 °C and -2 °C for 0 (fresh), 75, and 90 days. The acorns were stored at fresh (Fr) moisture content or after drying for 2 days (2d), 3 days (3d), or 6 days (6d). Moisture contents are presented in table 2.

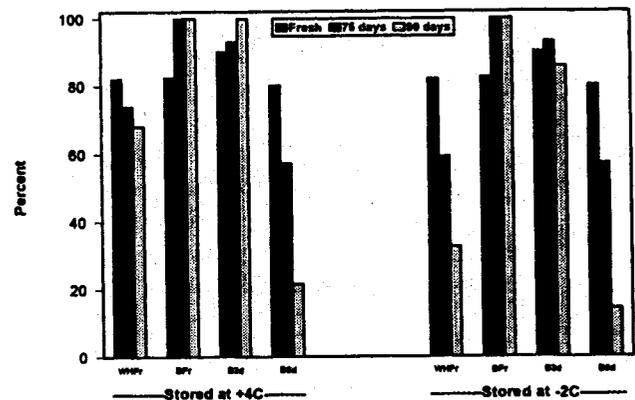


Figure 5—Germination of white oak (WHFr) and red buckeye stored at 4 °C and -2 °C for 0 (fresh), 75, and 90 days. Buckeye seeds were stored at fresh (Bfr) moisture content or after drying for periods of 3 days (B3d) or 6 days (B6d). Moisture contents are presented in table 2.

years of storage and stored best at the 3 °C/high MC combination. This supports the idea that the most dormant red oaks store best. It should be noted that water oak had less sprouting than the other species (figs. 1-3). Sprouting apparently does little harm over a short storage period, such as 1 year, but over longer periods it may hasten seed deterioration. Emerging radicles permit greater gas exchange between the embryo and the storage atmosphere, and the faster metabolism may be harmful. Primary roots from early sprouters soon die if storage is prolonged, and this dead tissue may promote the growth of damaging microorganisms.

The highly recalcitrant oak species in experiment 2 also differ in their storage preferences; to date, swamp chestnut oak acorns have good viability when stored at the -2 °C/high MC treatment; but white oak exhibited reduced viability when stored at -2 °C and, while viability is greater for white oak

acorns kept at 4 °C, they sprout prolifically at this storage temperature. This species specificity for storage treatment further complicates the problem of extending storage of the recalcitrant-seeded oaks.

Red buckeye, unlike the oak species, has retained its viability at both 4 °C and -2 °C and at both the high and 3-day-drying MC. The drying regime can be harmful, though, as evidenced by the poor germination of the seeds dried for 6 days. Interestingly, these 6-day seeds have not rotted or shown other signs of deterioration; when cut open after the test, they are counted as 'good but ungerminated', suggesting that the drying regime may have an adverse effect on embryo hydration and elongation.

In summary, the storage of acorns beyond 3 years is not advised at this time; as is evident, some oaks do not store well beyond 1 year. It is also apparent that the best storage treatment for a species can change with the length of storage and that the best storage treatment is species specific. Other genera will be added to the experiment in the future, and the biochemistry and moisture dynamics of extended storage will be examined.

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