Cone Storage and Seed Quality in Eastern White Pine (*Pinus strobus* L.)

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*To achieve maximum seed extraction and germination from stored, immature cones of eastern white pine (*Pinus strobus *L.) the cones should be stored for about 1 week, or until cone moisture drops below 50 percent. Indoor and outdoor storage in burlap bags yielded similar results.* Tree Planters' Notes 37(4):3-6; 1986.

Deciding when to collect and how to handle the cones of eastern white pine (*Pinus strobus* L.) has been a problem for many seed managers. Cone color can be used as a maturity index, and if demand for seed is low, it is possible to delay the collection until cones are a "straw yellow" color (6). The increasing demand for white pine seed in the last 15 years, however, negates the use of cone color, because delaying collection until this color change occurs does not allow enough time to collect large quantities of cones before most of the seeds are disseminated. The best alternative is to use cone moisture content, estimated by specific gravity, as a maturity index. One study in Michigan showed that seeds were mature when cone specific gravities were in the 0.92 to 0.97 range (5). However, cones picked with this much moisture must be handled carefully to avoid severe molding and case-hardening.

Preliminary tests at our laboratory in 1983 showed that green cones from North Carolina averaged 64 percent moisture 1 day after picking and were hard to open in ovens; germination was also poor (3). Storing cones for up to 8 days before ovendrying improved cone opening and seed quality considerably. This test had used indoor storage only; a larger test was installed in 1984 to include outdoor cone storage.

Materials and Methods

Immature cones were collected from 5 to 10 trees in western North Carolina on August 11 and 12, 1984, by a contractor and delivered to the Forestry Sciences Laboratory at Starkville, MI, the following day. The cones were mixed, and two 5-cone samples were immediately taken to determine initial cone moisture content.

The remaining cones were placed in small burlap bags for storage under the following conditions:

(1) outdoors without protection,
(2) outdoors with overhead cover, but exposed to blowing rains, and
(3) inside small, unheated sheds or buildings with complete protection.

There were four replications of each storage condition. Cones stored outdoors (condition 1) were sprayed with hoses every other day to stimulate occasional rainfall when natural rainfall did not occur.

After 2, 5, 8, and 12 days of storage, 20-cone samples were removed from each bag. Five cones were used for determination of specific gravity and cone moisture and five cones were dried at each of three extraction temperatures (30, 35, and 40 °C) in forced-draft ovens.

The cones were dried in trays for 48 hours, then hit against a table top to remove the easily extracted seeds. The cones were then carefully torn apart by hand to recover all other seeds. The number of easily extracted seeds was expressed as a percentage of the total seeds for a measure of extraction efficiency.

The seeds were dewinged by hand, and germination was tested under standard conditions (1) following 56 days of stratification at 3 °C. The percentage of germination was based on filled seeds only. Analyses of variance were carried out using arcsine transformations of extraction efficiency and percent normal germination, and germination rate was expressed by peak value (4). Differences among means were tested by Duncan's new multiple range test. All tests of significance were made at the 95 per-

cent level of confidence.

The specific gravity of cones was measured by water displacement (2). Moisture contents were determined by weight loss of cones dried for 24 hours at 105 °C and were expressed as a percentage of fresh weight. Each of these cones was cut into three or four pieces with a cone cutter for the determinations.

Results and Discussions

Cone Moisture. The initial cone moisture content averaged 62.2 percent. The cones still had their green, vegetative color, and they did not open when placed in the drying ovens. The initial specific gravity of the cones was not measured, but it can be estimated as about 0.90 based on the relationship of specific gravity and cone moisture that was established with measurements taken during the storage test (fig. 1). The strong correlation between the two (r = 0.9819) illustrates how well moisture content can be estimated by specific gravity in eastern white pine cones.

During the storage period, cone moisture loss was about equal under all conditions for storage periods of 2 and 5 days (table 1). Rain on the seventh day kept outdoor cones high in moisture, but they lost moisture rapidly after that time. At 12 days, cones stored indoors had the highest moisture, 26.0 percent,

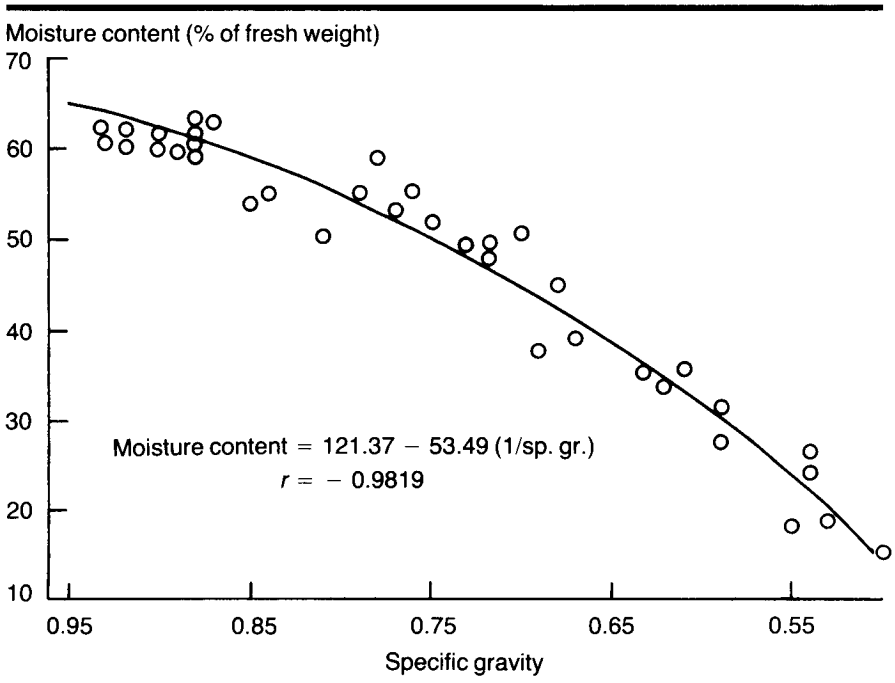

Figure 1—*The relationship of specific gravity to moisture content in cones of eastern white pine.*

Table 1—*Moisture content of cones stored for 2 to 12 days under three conditions (all percentages are based on fresh weight)*

Storage condition	Average moisture content (%)				
	0 days	2 days	5 days	8 days	12 days
Outdoors	62.2	61.2	52.2	48.1	17.6
Outdoors, covered	62.2	60.5	49.7	38.5	12.3
Indoors	62.2	61.0	55.4	36.7	26.0

while cones from the outdoor conditions had moisture levels of 17.6 and 12.3 percent.

Extraction Efficiency. Neither storage condition nor drying temperature had any significant effect on extraction efficiency (table 2); however, length of the storage period was very important. Extraction removed an average of only 13 percent of the total seeds after 2 days of storage and was best at 8 days (69 percent). The best extraction efficiency was

Table 2—*Extraction efficiency for cones of white pine stored for 2 to 12 days under different conditions and dried at three temperatures*[1]

Temperature (°C)	Extraction efficiency (%)				
	2 days	5 days	8 days	12 days	Mean
Outdoor storage					
30	18	41	35	61	38
35	35	61	86	56	60
40	26	41	87	63	55
Mean	26	48	71	60	51
Outdoor storage, covered					
30	1	34	72	62	38
35	7	55	76	44	44
40	11	65	72	41	46
Mean	6	51	73	49	43
Indoor storage					
30	12	60	59	69	49
35	18	56	66	64	51
40	5	63	65	66	47
Mean	11	60	63	66	49
Means[1]	13a	53b	69c	58b	

[1]Means followed by the same letter do not differ significantly ($P > 0.05$).

obtained after 8 days of storage (table 2), when cone moisture contents had fallen below 50 percent (table 1). Similar results had been obtained in the 1983 test (3).

Cones allowed to dry to below 20 percent moisture while in storage did not open as well when heat was applied and had extraction efficiencies of only 60 and 49 percent, similar to values obtained in the 1983 test.

Germination. As with extraction efficiency, percentage total germination was not affected by the storage conditions but was significantly affected by the length of storage (table 3). Seed from cones stored only 2 days before extraction had significantly lower total germination than seed from cones stored for longer periods. The highest mean total germination was 75 percent after 8 days of storage, but it was not significantly better than the values for 5 to 12 days of storage.

Extraction temperature also had a significant effect. Seed from cones dried at 30 °C averaged only 56 percent of percentage total germination, whereas seed extracted at 35 °C averaged 77 percent. Germination of seed extracted at 40 °C was only 65 percent, significantly lower than the 77 percent at 35 °C.

Germination expressed as peak value (PV), the maximum cumulative percentage germination divided by the number of days from sowing (4), followed the pattern of percentage total germination. Seed from cones stored only 2 days germinated at significantly lower rates than did seed from cones stored longer (table 3). The best extraction temperature was 35 °C; there was no difference between 30 and 40 °C. There was a significant interaction between storage period and extraction temperature; at 30 °C, the quality of extracted seed increased as the storage period increased from 2 to 8 days.

One remaining question is whether or not cone storage will affect the long-term storage potential of seed. Seed from this study are now in a storage test to provide the answer.

Conclusions

The data clearly show that immature white pine cones should be stored for about 1 week before heat is applied to the cones for seed extraction to obtain the best yields and seed quality. In this test, the best extraction rate was obtained after 8 days of storage, although seed quality was just as good from cones stored 5 to 12 days. Both indoor and outdoor storage were equally successful. Cone moisture content appears to be the key factor,

Table 3—*Germination of seeds extracted from cones of white pine stored for 2 to 12 days under different conditions and dried at three temperatures*

Temperature (°C)	2 days	5 days	8 days	12 days	Mean
Total germination (%)					
Outdoor storage					
30	30	55	51	67	51
35	70	85	86	79	80
40	64	52	67	74	72
Mean	54	65	69	73	66
Outdoor storage, covered					
30	12	54	76	62	50
35	71	66	92	73	76
40	42	81	75	57	64
Mean	40	68	82	64	64
Indoor storage					
30	52	74	66	78	68
35	74	79	77	62	73
40	59	75	74	50	65
Mean	62	76	73	64	69
Means[1]	52a	70b	75b	67b	
Peak Value					
Outdoor storage					
30	1.3	2.2	2.0	2.6	2.0
35	2.8	3.4	3.6	3.0	3.2
40	2.8	2.0	2.5	2.9	2.6
Mean	2.3	2.5	2.7	2.9	2.6
Outdoor storage, covered					
30	0.6	2.0	2.8	2.5	2.0
35	2.7	2.4	4.0	2.8	3.0
40	1.6	3.0	2.9	2.1	2.4
Mean	1.6	2.5	3.2	2.5	2.4
Indoor storage					
30	2.2	2.7	2.4	2.8	2.6
35	3.2	2.9	3.1	2.4	2.9
40	2.2	3.0	2.6	1.9	2.4
Mean	2.5	2.9	2.7	2.4	2.6
Means[1]	2.2a	2.6b	2.9b	2.6b	

[1]Means followed by the same letter do not differ significantly ($P > 0.05$).

however. Extraction should not be started until cone moisture drops below 50 percent. If drying conditions during storage are slower than in the current test, this may take longer than 8 days.

The best extraction temperature was 35 °C, and higher temperatures should be used only with great care.

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