EFFECTS OF SEED EXTRACTION ON THE QUALITY OF SOUTHERN PINE SEEDS

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Abstract.--Cone-drying tests with six pine species indicated that cones should be precured to moisture levels of 35 to 50 percent before application of heat. Precuring to 25 percent moisture may damage seed quality in some species. Proper precuring can also reduce, up to two-thirds, the amount of water loss required from cones for complete opening, as well as minimize damage to seeds from excessive drying temperatures.

Additional keywords: Pinus, germination, cone kilns, moisture content.

Extraction of seeds from cones of the southern pines by application of artificial heat in some type of kiln has long been an accepted practice in southern tree seed operations. And judging from the millions of acres of successful pine plantation in the South today, the practice has been satisfactory. Nothing stays the same, however, and changes in cone collection and seed management operations have occurred that demand a reexamination of pine seed extraction.

For one thing, everyone is much more cognizant of seed quality. Nurserymen demand not only high germination, but also rapid germination with uniform seedling emergence. When seeds are stored, high vigor is desired so that performance will not decline as the same lots are utilized in future years.

Another development is the predominance of seed orchard collections. Orchard cones tend to show up at the extractory greener than cones picked from logging slash. The latter cones usually have time to dry a little before collection, while the orchard cones come right from the tree. Orchard seeds are expensive to produce and thus are expensive to buy; therefore, seed managers are very reluctant to lose any of the inherent quality to poor processing.

Another item is the cost of kiln operation. When fuel prices rapidly increased, many questions were asked about fuel costs at the extractory. A survey by Belcher and Lowman (1982) highlighted these concerns.

PRESENT PRACTICES

Wakeley (1954) established 0.89 as the specific gravity (SG) desired for picking cones of southern pines, although those picked within the range of 0.89 to 1.0 could be matured in a "precuring" period before extraction. He also recommended maximum kiln temperatures of 115 F for longleaf cones and

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120°F for loblolly, slash, and sliortleaf cones. These recommendations were based on the kiln experiments of Rietz (1939) and experience of southern extractories in the 1940's and 1950's.

McLemore (1975), however, reported that many cones with SG's in the 0.80's and almost all in the 0.90's were likely to caseharden in modern extractories unless they were precured. He found that careful precuring for 3 to 5 weeks was beneficial and could expand the cone collection period by raising the minimum SG to 0.92 for loblolly, 0.95 for slash, and 0.90 for longleaf. Barnett (1976) confirmed the feasibility of this for loblolly and slash, but not for longleaf. He found that premature collection of longleaf cones damaged seed quality, and seed yield was usually reduced for all three species. In actual practice, collection of immature cones (SG in 0.90's) is common, although the primary reasons are time and labor constraints during cone-collection season.

The desirable SG for cone collection of Virginia pine has been reported to be 1.0 (Fenton and Sucoff 1965). A maximum range in SG for eastern white pine cones of 0.92 - 0.97 was suggested by Jones et. al. (1967). In recent trials, however, SG was determined not to be a good index of cone maturity in white pine; cone moisture content was much better.

The crucial factor, of course, is cone moisture content, not SC. SG is the rapid estimate that is commonly used to determine moisture content. Belcher and Lowman (1982) reported that cone moisture contents should he in the 35 to 50 percent range when cones go into the kiln and that drying to 10 percent moisture is the goal for complete seed extraction.

Not only has a precuring period before drying proved beneficial in many cases, it has proved necessary in any good cone year. Kilns cannot keep up with the volume of cones coming in, and some sort of storage is required. Both burlap bags and 20-bushel wire-bound wooden crates have been popular. Problems exist with both storage methods, and studies to compare them have been inconclusive (Barnett 1979b). Comparisons of cone storage under sheds vs. storage in the open in the same study have also reached no clear-cut conclusion.

A review of literature and discussions with some current extractory operators convinced the author that some parts of the seed extraction process needed further evaluation. Preliminary cone-drying trials were run in 1982 and 1983 on six pine species, with the emphasis on the effects of seed quality. This paper summarizes the 1983 study.

MATERIAL AND METHODS

A single collection of apparently mature cones was made of each species, and the cones were precured for varying periods before oven drying for extraction.

The following species and sources were used in this study:

2/ J. Barnett, personal communication.

Loblolly pine (Pinus taeda) Oktibbeha Co., MS

Slash pine (P. elliottii) Oktibbeha Co., MS (trees planted at the Forestry Sciences Laboratory)

Shortleaf pine (P. echinata) Oktibbeha Co., MS

*Virginia pine (P. virginiana) -- Clay Co., AL

*Longleaf pine (P. palustris) -- central AL

*Eastern white pine (P. strobus) -- western North Carolina

For every species, cones were collected from at least five trees and mixed as a single lot.

The cones were spread in one layer on trays having wire mesh bottoms. One sample was drawn for immediate drying and extraction, and subsequent samples were taken after varying periods of air-drying on the trays. The trays were indoors, where exhaust fans were running during most daylight hours. This arrangement dried the cones much faster than typical precuring of bags, boxes, or piles of cones.

As each cone sample was drawn, SG was determined by water immersion (Barnett 1979a) on 10 cones, and cone moisture content was measured on another 10 cones. These latter cones were cut into 4 to 6 pieces with a Sandia cone cutter and dried at 105°C for 24 hours. All cone moisture contents were expressed as a percentage of fresh weight.

Thirty cones were randomly chosen at each sampling time pre ssed extrastionn. For aLl excegt white pine, drying temperatures were 35°, 43 , and 49°C (95 , 110 , and 120 F). White pine was dried at 35 , 40 , and 45 C. Two drying rates were simulated by placing cones in either foil trays (rapid-dry) or cloth bags (slow-dry). The cloth bags slowed drying by impeding air movement around the cones. There were 5 cones in each temperature/drying-rate combination (30 cones total). All drying was done in forced-draft ovens.

All cones were weighed individually to the nearest 0.1g at the start of oven-drying and thereafter at 1 to 2 day intervals until constant weights were generally reached. At the conclusion of the drying period, seeds were extracted by sharply striking each cone on its tip 5 times on a hard surface. Seeds retained by the cone were extracted by peeling all scales from the cone axis by hand. Seeds were dewinged by hand, counted, and stored at 2 C until germination tests were run.

Germination was tested in cabinet germinators according to testing rules of the Association of Official Seed Analysts (A.O.S.A. 1978). Because many cones had only a few seeds extracted or retained, the seeds from all five cones

*Collected under contract by Tree Improvement Services, Inc., Dadeville, AL.

in each drying treatment were combined for one germination sample. This step provided a 100-seed sample in all but a few cases. In no case were more than 100 seeds placed ina germination sample. Loblolly, shortleaf, Virginia, and eastern white seeds were stratified for 28 days at 2 C before germination. Slash and longleaf seeds received no stratification. Germination was counted 3 times a week, and percentages were based on filled seeds only. Germination rate was expressed as Peak Value (PV), that component of Czabator's Germination Value that expresses speed of germination (Czabator 1962).

RESULTS

In the interest of brevity, only data from loblolly, longleaf and eastern white pine tests are given in detail.

Loblolly, shortleaf, and Virginia pines -- Loblolly cones averaged 0.82 SG and 55.0 percent moisture at the start of drying. Samples were taken after 1, 3, 6, and 7 days of drying had dropped SG to 0.63 and moisture to 23.6 percent (Table 1). To reach the 10 percent moisture goal, 26.4 pounds of water had to be removed from a bushel of cones having a moisture content of 55 percent as opposed to only 3.6 pounds from a bushel of cones having a moisture content of 23.6 percent.

Table 1. Condition of loblolly pine cones at the start of oven-drying schedules and amount of moisture removal required per bushel of cones to reach 10 percent.

Precure period	Specific gravity	Moisture content	Moisture removal required to reach 10% level
days	g/cc	pct	lb/bu*
0	0.82 ± .01	55.0 ± 0.6	26.4
1	.81 ± .02	50.7 ± 0.8	20.2
3	.74 ± .02	45.2 ± 1.9	12.5
6	.74 ± .01	39.3 ± 2.7	9.8
7	.63 ± .04	23.6 ± 2.0	3.6

* Assume 300 cones/bu.

Extraction efficiencies were about equal for all samples, averaging 70 to 80 percent. Initial extraction yielded a much higher proportion of filled seeds than did the fraction retained in the cones and extracted by hand. In slow-drying treatments, the difference was 83 to 60 percent; in rapid-drying treatments the difference was 76 to 64 percent.

The germination data suggested no differences in performance of slow vs. rapid drying or of extracted vs. retained seeds, so the data were grouped by sample period and drying temperature (Table 2). Total germination and rate germination *were* low in cones from the original sample that was dried at 49 °C (67 percent germination and only 2.6 PV), but this difference disappeared with increased precuring. Seed quality was best after 3 days of precuring (initial cone moisture of 45.2 percent, Table 1), but then it decreased with additional precuring. This condition also occurred with Virginia pine, and it may be very significant.

Table 2. Germination of loblolly pine seeds extracted under different drying conditions.

Drying temperature	Precure period (days)				
	0	1	3	6	7
	Germination capacity				
°C	pct				
35	94	94	96	81	81
43	85	92	93	83	74
49	67	81	94	93	88
	PV				
35	4.4	4.5	4.7	3.3	3.2
43	4.2	4.6	4.2	3.7	3.3
49	2.6	3.6	4.2	4.0	3.4

Results with shortleaf were similar to those with loblolly, except that shortleaf was more tolerant to different drying conditions. Unlike loblolly, shortleaf seed quality was not affected by drying temperature or precuring period. In all but one case, rapid-drying yielded equal or higher seed quality than did slow-drying.

Virginia pine cones were very mature when delivered (SG, 0.83; cone moisture, 45 percent), and con(opening and seed extraction were easy. Moisture loss during drying and seed-quality patterns were very similar to those of loblolly, except that seed quality of Virginia pine seemed to be damaged more by longer precuring than was that of loblolly.

Longleaf and slash pines -- Longleaf cones were in good shape when delivered, with a mean SG of 0.82 and a mean moisture content of 52.9 percent (Table 3). Only 6 days of predrying brought these values down to 0.76 and 33.6 percent. Even though there was a great difference in cone size between longleaf and the other species, the patterns of moisture loss were quite similar. Calculations of requirements for total water removal show that predrying for 6 days reduce the amount to about one-third of that for cones without predrying: 18.5 vs. 6.7 pounds of water per bushel.

Table 3. Condition of longleaf pine cones at the start of oven-drying schedules and amount of moisture removal required per bushel of cones to reach 10 percent.

Precure period	Specific gravity	Moisture content	Moisture removal required to reach 10% level
days	g/cc	pct	lb/bu*
0	0.82 ± .01	52.9 ± 0.3	18.5
1	.84 ± .01	52.2 ± 0.8	20.7
4	.79 ± .02	41.6 ± 2.1	14.4
5	.78 ± .01	39.3 ± 1.7	9.2
6	.76 ± .02	33.6 ± 0.8	6.7

* Assume 100 cones/bu.

Extraction efficiencies were extremely good for longleaf pine, better, in fact, than for any other species in the study. Apparently, there was a slight advantage to rapid-drying over slow-drying, except in the first sample, which received no predrying.

Unlike some other species, there was no difference in the percentage of filled seeds between extracted and retained seeds. And like loblolly, there was no difference in seed quality between these fractions.

There was a considerable difference in seed quality in relation to sample times (Table 4). Seed quality was low at 0 to 1 day and rose considerably for samples on days 4, 5, and 6. Drying at 49°C was definitely detrimental to seed quality when cone moisture content was high. Longleaf cones opened well when moist, but seed quality suffered.

Table 4. Germination of longleaf pine seeds extracted under different drying conditions.

Drying temperature	Precure period (days)				
	0	1	4	5	6
°C	Germination capacity (pct)				
35	75	74	80	90	90
43	71	75	87	92	91
49	39	56	83	92	86
	PV				
35	3.8	3.7	4.7	4.7	5.0
43	2.8	4.3	4.6	4.5	5.1
49	2.3	2.4	4.0	4.1	3.8

Slash pine cones were too green when picked (SG 0.95; cone moisture, 56 percent), and the first three samples casehardened completely. With another 6 days of precuring, however, mean SG was 0.83, and most cones opened. Extracted seeds were somewhat better than those retained in the cones. The highest drying temperature (49 C) severely damaged the quality of seeds from the greener cones. With longer precuring, this effect diminished.

Eastern white pine -- As one might expect, moisture loss from white pine cones was different from that of the other species in this study. Initial cone moisture content at delivery was 64.0 percent (no SG's were measured) (Table 5). Extraction efficiency was a low 10 percent, and it increased to only 18 percent after 3.7 days of predrying. The next sample, after 6 days of predrying, yielded cones of 47.7 percent moisture and a mean extraction efficiency of 47 percent across all drying temperatures.

Table 5. Condition of eastern white pine cones at start of oven-drying, extraction efficiency. and amount of moisture removal required per bushel of cones to reach 10 percent.

Precure period	Initial cone moisture content	Moisture removal required to reach 10% level	Extraction efficiency			
			35°C	40°C	45°C	Mean
days	pct	lb/bu*	pct			
0	64.0 ± 0.3	35.9	13	17	0	10
1.7	60.0 ± 0.7	33.8	30	5	11	15
3.7	55.5 ± 1.4	22.0	14	22	19	18
6.0	47.7 ± 1.4	15.7	48	60	32	47
7.7	42.6 ± 2.7	11.8	27	45	35	36

* Assume 460 cones/bu.

The patterns of moisture loss were also different for white pine. Many cones were open and releasing seed long before cone moisture dropped to 10 percent. There was one similarity to the other species -- the ratio of water removal requirements for the first and last sample. This value was again about 3 to 1; 35.9 pounds per bushel had to be removed with no predrying, but only 11.8 pounds after 7.7 days of predrying (Table 5).

Germination tests were run on pooled samples of both drying rates. Seed quality was low initially but increased as predrying increased (Table 6). Extracted seeds were of much higher quality than those retained in the cones, but there was no difference between these fractions in the percentage of filled seeds. There was also a clear decrease in seed quality as drying temperature was increased in early samples; 35 C was definitely better than the other temperatures. Later samples yielded seeds that exhibited equal seed quality for all three temperatures.

Table 6. Germination of eastern white pine seeds extracted under different drying conditions.

Drying temperature	Precure period (days)				
	0	1.7	3.7	6.0	7.7
	Germination capacity				
°C	pct				
35	58	68	62	74	80
40	51	72	51	65	61
45	1	20	58	70	68
	PV				
35	2.8	3.4	2.6	3.6	3.6
40	2.4	3.0	2.4	2.8	3.0
45	0.1	0.9	2.8	2.8	3.2

DISCUSSION

It should be emphasized that this was a preliminary study designed not to give final answers but to point out potential trouble spots in seed extraction that need detailed research.

It was also not the intent of this study to test SG as a maturity index in pine cones. All collections were intended to be fully mature cones. The slash and shortleaf cones were a little immature, a condition that impeded the opening of slash cones but not that of shortleaf cones. In terms of optimum SG to initiate oven-drying, the best in this study were loblolly, 0.74; slash, 0.64 - 0.72; shortleaf, 0.84 - 0.86; Virginia, 0.63 - 0.83; and longleaf, 0.76 - 0.78.

The data suggest, however, that cone moisture content is really a better index. This finding agrees with the results of Helium and Barker (1980) and Helium (1982) with lodgepole pine -- cone moisture content is the most important factor for pine seed extraction. Belcher and Lowman (1982) reported that cone moisture content should be 35 to 50 percent when cones go into the kiln. If extraction efficiency alone is considered, the current data suggest that shortleaf and longleaf cones can start drying at moisture levels above 50 percent. If seed quality is considered, however, then much lower cone moisture levels should be used for longleaf, 34 - 40 percent. The quality of shortleaf seed from cones dried with moisture levels at 50 to 53 percent was good.

In terms of drying time required to reach the 10-percent moisture goal in cones (Belcher and Lowman 1982) and the amount of water removal required, it would seem that the lowest cone moisture levels would be best. However, the last samples of loblolly and Virginia pines, which had cone moisture contents of 23 to 25 percent, yielded seeds of reduced quality. Helium and Barker (1980) reported that extraction was better at 20-percent cone moisture than at 7 percent for lodgepole pine. These study results suggest that seed quality may be damaged at the lower moisture levels. Further research should be conducted to confirm these results. If drying at lower moisture levels does damage seed quality, then precuring cones under a roof may be less desirable than precuring them outdoors in the weather. The cone moisture characteristics of white pine are obviously different, and the 10 percent goal does not apply.

Examination of seed-quality data suggests that the lowest temperature ($35^{\circ}C$) was best for extraction of the sensitive seeds of longleaf and eastern white pines. The highest temperature (49C) was damaging to seed quality when cone moisture was high (above 50 percent). As cone moisture decreased in precuring, damage at the higher temperatures ceased. This relationship has long been recognized in seed extraction.

Initial extraction yielded higher percentages of filled seeds than the fraction retained in the cones of loblolly, shortleaf, and Virginia; the other species appeared about equal. These results agree with a previous study by Karrfalt (1979). The extracted seeds seemed to be of higher quality in all but loblolly and longleaf.

CONCLUSIONS

Even though these are preliminary results, some general conclusions can be suggested:

(1) Cones should be precured to moisture contents of 35 to 50 percent before going into heated kilns or ovens. Precuring to as low as 25 percent may damage seed quality.

(2) Extraction efficiency can be good over a wide range of drying conditions, but quality suffers in some of these, such as drying at 49 °C with cone moisture above 50 percent. Extraction methods should be judged on seed quality as well as extraction efficiency or seed yield.

(3) The absolute amount of water to be removed from cones can be reduced up to two-thirds by proper precuring. This difference could be significant in seed extraction costs.

(4) Longleaf and eastern white pine seeds are very sensitive to drying conditions and can be easily damaged. Special care should be taken during extraction of these species.

(5) In years of "typical" cone crops, the volume of cones delivered to extractories dictates some period of cone storage or precuring before heating in the kilns. Since this precuring period is also used to adjust cones to the proper moisture level for drying (35 to 50 percent), it becomes the most crucial phase of the extraction operation in terms of seed quality and unanswered questions.

Additional research is underway to identify the type of precuring that will bring cones to the proper moisture level without damaging seed quality.

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