ALTERNATIVE METHODS FOR EXTRACTING SOUTHERN PINE SEEDS

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Abstract.--The mechanics of cone and seed drying and alternative drying techniques are reviewed. Preliminary tests of freeze-drying techniques for extracting southern pine cones and drying seeds indicate that freeze-drying can lower seed moisture contents to less than 2 percent without apparent seed injury. The effects of lower moisture content on seed storability are still under evaluation.

Additional keywords: Pinus, seed storage, viability, cone drying, freeze-drying.

Because high kiln temperatures may injure seed, and because the energy required for kiln drying is becoming more expensive, alternative methods of cone opening and seed drying must be found.

MECHANICS OF DRYING CONES AND SEEDS

Pine cones become lignified and hard upon maturity. The hygroscopic scales that enclose the seeds shrink and swell, causing the cone to open. Thus seed dispersal is made possible by cone drying. The rate of drying is proportional to the moisture deficit in the surrounding air, and is influenced greatly by temperature and air movement.

Heat is the primary means of reducing humidity. Heating air raises its saturation point and allows it to absorb moisture more readily. But drying operations require some air movement around the cones. Without air movement, cones or seeds become surrounded by saturated vapor that obstructs heat transfer and limits evaporation. Constant heat and air movement rapidly dry cones and seeds.

BENEFITS OF LOW SEED MOISTURE

One of the main factors influencing seed longevity is seed moisture content. At temperatures at which seeds are normally stored, higher seed moisture causes more rapid decreases in germination capacity (Figure 1). Southern pine seeds should be dried to a moisture content of 10 percent or less before storing (Barnett and McLemore 1970).

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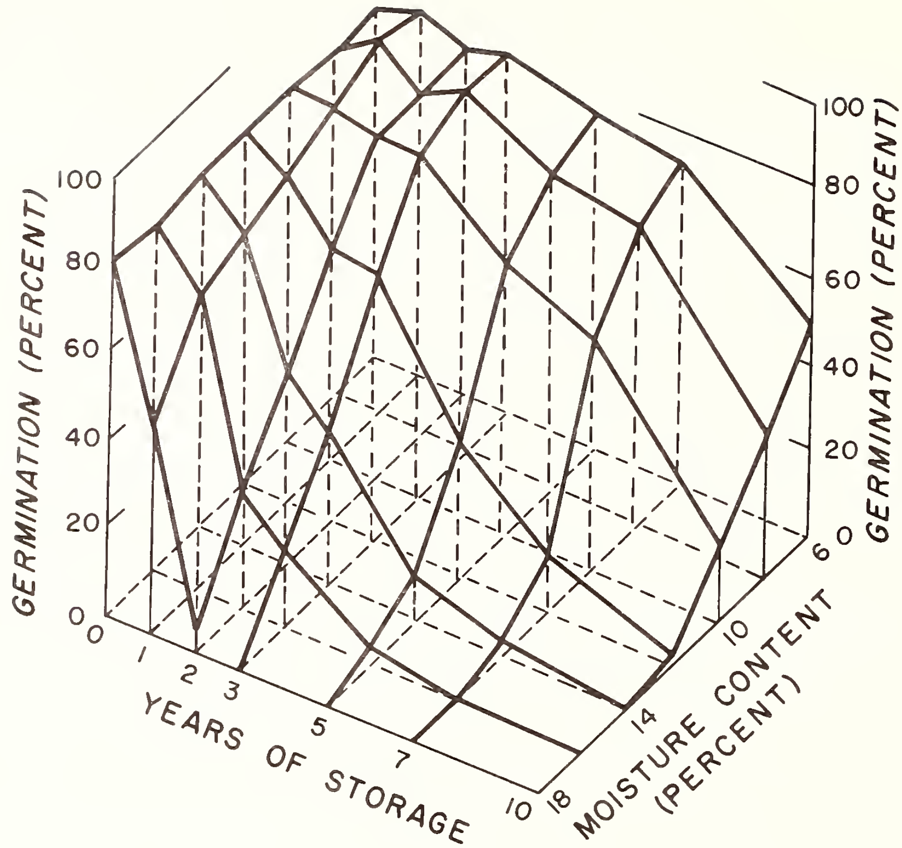

Figure 1.--Germination of longleaf pine seeds as influenced by moisture contents and years of storage at 34° F.

Problems of maintaining seed viability increase with seed moisture content:

Seed moisture above 8-9% -- insects become active and reproduce
Seed moisture above 12-14% --fungi grow on and in seed
Seed moisture above 18-20% -- heating may occur
Seed moisture above 40-60% -- germination occurs (Harrington 1972).

When the seed moisture content is between 5 and 14 percent, each 1-percent increase in seed moisture content halves the life of the seed (Harrington 1959).

Pine seeds are not usually dried below a moisture content of 6 to 8 percent. It is difficult to obtain lower moisture levels with conventional kiln drying techniques. Drying to 1- to 2-percent moisture should maximize the period of viability, but the heat required to dry seeds that much may damage the seeds. Roberts (1972) suggests that decreasing moisture content below 5 or 6 percent may not increase seed storability.

METHODS OF DRYING

Drying is very slow under natural conditions because cones must equilibrate with the relative humidity of the atmosphere around them. Artificial drying is the only way to extract the large quantities of seeds now required in reforestation.

Heated Air

Kiln drying brings about complete cone opening in as short a time as is now possible. Heated air is moved around the cones and seeds. Total drying time depends on initial moisture content, final moisture content desired, rate of airflow, and the temperature of the drying air. Most seeds dry rapidly at first, but dry more slowly as they approach the desired moisture content.

Generally, drying temperatures should not exceed 90° to 110° F. for the southern pines. Higher than conventional drying temperatures can injure seed in the 15- to 30-percent moisture range. Increases in the time that seed remain in the kiln also reduce germination (Rietz 1941).

Solar Drying

Drying in the sun has often been used to open cones in hot, dry regions such as the South or Southwest, where cones are spread on large sheets of canvas. Glass-covered boxes or beds have been used for solar drying in Northern Europe for generations (Baldwin 1942). A solar-heated kiln has recently been designed for use in the South by the Tennessee Valley Authority, but it is limited to small-scale, temporary operations where investment in more complicated equipment is not justified (Barnett and Scanlon 1978).

Dehumidified Air

The use of dehumidified air is a safe method of drying seeds to a low moisture content. Air may be dehumidified by dessicants such as silica gel, calcium chloride, activated alumina, or anhydrous calcium sulfate. Equipment for chemical dehumidification is now commercially available.

Air may also be dehumidified by refrigerating it below its dewpoint, where moisture is condensed. Dehumidified air can then be heated to further increase its moisture-absorbing capacity.

Infrared Drying

Infrared heat has been used to dry seeds (particularly of farm crops) but I know of no application of this technique to cone drying. Radiant heat rays from infrared lamps pass through the air without warming it and are absorbed by the seed. Seeds are heated rapidly, moving the internal moisture to the surface where it evaporates. This is a particularly fast method, since seeds can be dried in a thin layer on a converyor system (Rosberg *et al*.1960).

Vacuum drying

Vacuum drying is especially well adapted to drying seeds to a very low moisture content. Vacuum drying is similar to drying with dehumidified air. In recent years, refrigeration has been combined with vacuum drying in what is termed freeze-drying. Refrigeration is used to condense moisture from the air and lower its vapor pressure. (The term freeze-drying is a misnomer. The material being dried is not necessarily frozen, and can remain at ambient temperatures.) Early results of tests indicate that freeze-drying can improve vegetable seed storability. Moisture content can be lowered to levels that heretofore could not be reached with heat drying without injuring seeds (Woodstock 1975, Woodstock et al. 1976). Freeze-drying has also been tried successfully with spruce seeds (Suber et al. 1973).

Evaluations of freeze-drying southern pine seeds are being conducted because freeze-drying offers the opportunity to improve seed storability by lowering moisture contents well below the minimum of 6 to 8 percent achieved in kilns. The effectiveness of freeze-drying in opening cones is also being tested, since it requires little heat.

PRELIMINARY RESULTS OF FREEZE-DRYING TESTS

Seed

Freeze-drying effectively reduces the moisture content of southern pine seeds to unusually low levels. Early tests resulted in the following moisture contents after 24 hours of freeze-drying (FD):

Species	Moisture content		Germination	
	Initially	After FD	Initially	After FD
	Percent			
Longleaf pine	5.4	0.7	83.4	81.0
Slash pine	12.8	1.8	89.4	91.2

Drying to less than 2 percent seed moisture content had no adverse effect on germination of unstratified seeds that were tested immediately after treatment. The effects of freeze-drying to improve storability by reducing seed moisture contents below levels usually attained by conventional drying methods is still under evaluation. In this and the subsequent evaluations, the seeds remain at ambient temperatures during freeze-drying.

Stratified and unstratified loblolly and slash seeds with widely differing moisture contents were tested, since Woodstock (1975) found that initial moisture contents affected response to freeze-drying. Seed moisture content, germination, and Czabator's (1962) germination values (GV) were determined after oven drying (100° F) and freeze-drying for 24 and 48 hours. Neither method of drying affected germination of unstratified seeds adversely, even though moisture contents were reduced from 6 to 1.2 and 0.7 percent for slash and loblolly pine seeds, respectively (Table 1).

Table 1.--Comparison of oven and freeze-drying methods on seed moisture contents and germination[a]

Species	Drying Method	Drying Length	Unstratified Moisture content	Unstratified Germ.	Unstratified Germ. value	Stratified Moisture content	Stratified Germ.	Stratified Germ. value
		Hours	Percent	Percent		Percent	Percent	
Slash	Control	--	6.0	81a	20.7a	43.5	67b	17.2c
	Oven	24	5.0	81a	23.4a	17.9	75a	20.8a
		48	4.0	79a	19.9a	7.6	76a	18.9b
	Freeze-dry	24	1.7	79a	21.1a	11.4	48c	6.3d
		48	1.2	82a	20.2a	7.1	47c	5.3d
Loblolly	Control	--	6.2	90a	19.7a	37.4	90a	36.5a
	Oven	24	5.0	93a	20.4a	12.5	94a	26.8b
		48	3.5	92a	21.6a	4.8	95a	23.6c
	Freeze-dry	24	1.2	92a	19.0a	10.8	79b	16.0d
		48	.7	89a	16.4a	5.4	67c	10.4e

[a] Species means within columns followed by the same letter are not significantly different at the 0.05 level.

Germination of stratified slash and loblolly pine seeds with initial moisture contents of 44 and 37 percent were not adversely affected by oven drying for 48 hours. However, freeze-drying of these moist seeds significantly reduced both rate and completeness of germination. This adverse effect occurred even though the rate of moisture loss was not markedly different between oven and freeze-drying. It is apparent, then, that freeze-drying should not be used to lower seed moisture contents when the initial moisture level is high.

Cones

Shortleaf pine cones were collected and seed were extracted by freeze-drying and conventional kiln techniques. Seed yields per cone averaged 14 for kiln and 16 for freeze-drying extraction (Table 2). Seeds from both treatments were then dried by kiln, oven, and freeze-drying methods. Although the combination of cone and seed freeze-drying resulted in somewhat lower germination and germination values, the differences were not of practical importance. Seed samples are now in storage to evaluate any effects on storability.

These results confirm that dehumidification extraction techniques can produce seed yields as good as conventional kilning without reducing initial seed quality. Further evaluation of such techniques to extract and dry seed to lower than usual moisture levels is yet to be carried out. Reduction in seed vigor may be a more important consequence of drying-related injury than drop in total germination. But there are no good methods to test vigor and testing germination after storage is still the best way to measure these effects.

Table 2.--Evaluation of effect of alternative methods of shortleaf cone opening and seed drying on seed yield and viability

Method cone opening	Method of seed drying	Seed yield	Seed germination	Germination value
		Seed/cone	Percent	
Kiln	Kiln	---[a]	95	26.3
	Oven	---	94	26.3
	Freeze-dry	---	93	24.3
	Avg.	14	94	25.6
Freeze-dry	Kiln	---	93	24.1
	Oven	---	93	24.1
	Freeze-dry	---	88	19.8
	Avg.	16	92	22.6

[a] Seed drying methods had no effect on seed yield. Although statistical analyses (ANOV $_{.05}$) indicated that freeze-drying resulted in higher seed yields and in lower speed and completeness of germination, these differences are of little practical importance.

APPLICATIONS

Results from these preliminary tests indicate that alternative drying methods can be used to extract seed from pine cones as effectively as conventional kilning. They also show that seed moisture contents can be reduced to levels much lower than those now reached. The lowering of seed moisture offers the possibility of increasing seed longevity, particularly with small lots of unusually high value (such as special genetic material).

The tests do show that freeze-drying seeds with high moisture contents injures the seed. Stratified seed could perhaps be dried to a lower moisture content conventionally, and then freeze-dried to reduce the moisture content further.

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