Sizing Slash Pine Seeds as a Nursery Procedure

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Three slash pine seedlots were each graded by diameter and weight into 10 seed classes. These classes were evaluated in laboratory tests, nursery seedbeds, and 5-year-old plantations. Lightweight seeds had lower laboratory germination percentages than heavier seeds, while small seeds had lower survival rates in the nursery and produced shorter seedlings than larger seeds. Differences in seedling heights at 5 years were significant only between plantations.

Sizing seeds was a common nursery practice until it was suggested that it may eliminate some genotypes (9, 16). Actually, no genotypes are lost unless one or more seed sizes are discarded. In fact, sizing may preserve slower germinating genotypes (18). Further, Righter (13) showed that there was no relationship between seed weight and inherent vigor. He therefore suggested that selection for genetic improvement through seed sizing was of no benefit within a progeny seedlot.

The real benefits of seed sizing are more uniform germination in the nursery and more uniform seedling density in the seedbed. Both of these qualities are very important in the forest nursery to increase the seedling-to-seed ratio. There are two basic means of grading seeds (screens and gravity), but few comparisons have been made and very little research is available to guide nursery personnel.

The objective of this study was to investigate the effect of sizing seed orchard and wild-collected slash pine seeds by diameter and by density on laboratory tests and on nursery and field performance.

Materials and Methods

Two seed orchard (Pensacola and Georgia) and one wild collection of slash pine seeds from St. Regis seed stores were commercially separated into four physical sizes by screens. Each of the three smaller sizes was then separated on a gravity separator into three density grades. This provided a total of 10 classes per lot (fig. 1).

A sample was drawn from each of the 10 classes in each lot and sent to the National Tree Seed Laboratory for examination. The seed laboratory evaluated the percentage of filled seeds by radiography and the average number of seeds per pound and then tested four 100-seed samples from each lot for germination. The seeds were germinated at 22° C with 8 hours of fluorescent light daily. Counts were made weekly for 4 weeks.

Another sample of each size class was sown in the St. Regis Nursery at Lee, Fla., in April 1973. Each treatment was sown on a 3-foot length of nurserybed. Treatments were randomly assigned and replicated three times. Nursery germination was last measured on May 30 and appeared to be virtually complete. The number of seedlings per square foot and their height were measured on July 11 and November 20. At lifting time (January), 10 seedlings were randomly selected and lifted from the

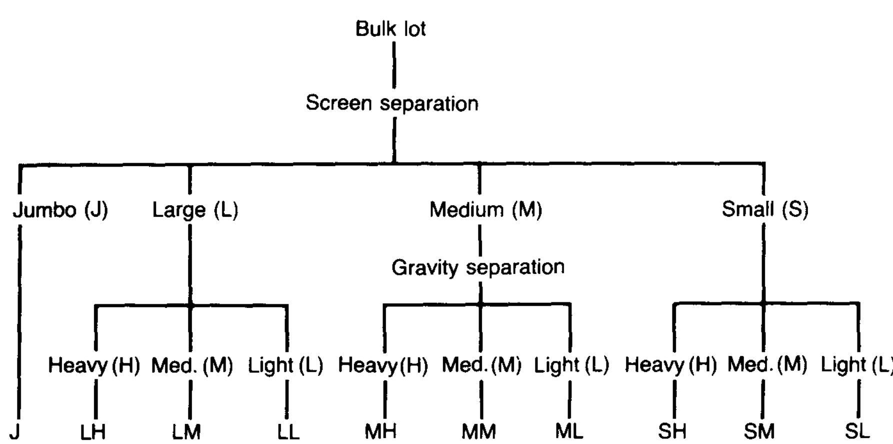

Figure 1—*Diagram of seed classes derived from each seedlot.*

center of each plot. These seedlings were transported in polyethylene bags to the National Tree Seed Laboratory for evaluation. The remaining seedlings were outplanted in 10-tree row plots replicated four times. The seedlings were machine-planted on a 7- by 12-foot spacing in Madison County, Fla.

The seedlings transported to the seed laboratory were weighed upon arrival, and the tops were cut off at the root collar. The tops were measured for length and both tops and roots were weighed and ovendried at 105° C for 24 hours. The stem diameter was measured at the root collar with a caliper. Finally, the dry weight of the top and roots was recorded.

The entire experiment was repeated a second year, and the seedlings were outplanted in Escambia County, Fla. The field design was modified slightly by using block plots of 50 seedlings at an 8- by 10-foot spacing replicated three times. Analysis of variance was conducted on all data. Duncan's multiple range test was used to determine differences between treatment means.

Table 1—*Average measurements made on slash pine seed grades in a laboratory evaluation*

Grade	Seeds per pound	Germination of filled seeds	Days to 90% of total germination
		%	
Screens			
Jumbo	9,373a[1]	87.5a	12.5a
Large	10,278b	84.8b	12.2a
Medium	13,182c	87.8a	13.0a
Small	17,737d	89.4a	13.1a
Gravity			
Heavy	13,022a	91.8a	12.7a
Medium	13,513b	89.7a	12.6a
Light	14,662c	79.6b	12.9a

[1] Means followed by the same letter are not significantly different at $p = 0.01$. The multiple range tests were used within each method of sizing and not in their combination.

Results and Discussion

Laboratory tests. Both screens and gravity separations gave significantly different seed sizes (table 1). Seeds per pound varied continuously from the largest diameter class, at 9,630 seeds per pound, up to the lightest seeds in the smallest diameter class, at 18,870 seeds per pound.

Germination percentage was significantly less for the lightest seeds in each diameter class. Within the light-seed category, the germination percentage decreased as the diameter class increased (fig. 2). This result was attributed to the number of partially filled seeds (as seen in the radiograph).

Larger seeds reportedly have more stored energy. Also, seed vigor is related to seed density (10). Therefore, larger seeds are expected to germinate first and get a faster start than smaller seeds (2, 3, 5, 7). However, large seeds have been surpassed by medium-sized seeds (4, 8); and in some cases, no relationship was found between seed size and germination (1, 6, 12, 19). These differences may have several explanations: (1) Not recording germination often enough to fully identify the rate of germination, (2) the reduction in variability with improved seed stock, and (3) variations within a given seedlot, with storage.

We noted, in this study, that 7-day intervals were too long to examine germination rate accurately. In the first year of the study, 63 to 68 percent of the seeds germinated in 7 days. In the second year, germination was only 15 to 18 percent in 7 days, but nearly 100 percent in 14 days. Also, the greater variability of wild-collected seeds produced slower germination. Apparently, each seedlot must be analyzed on its own merits to obtain accurate germination rates.

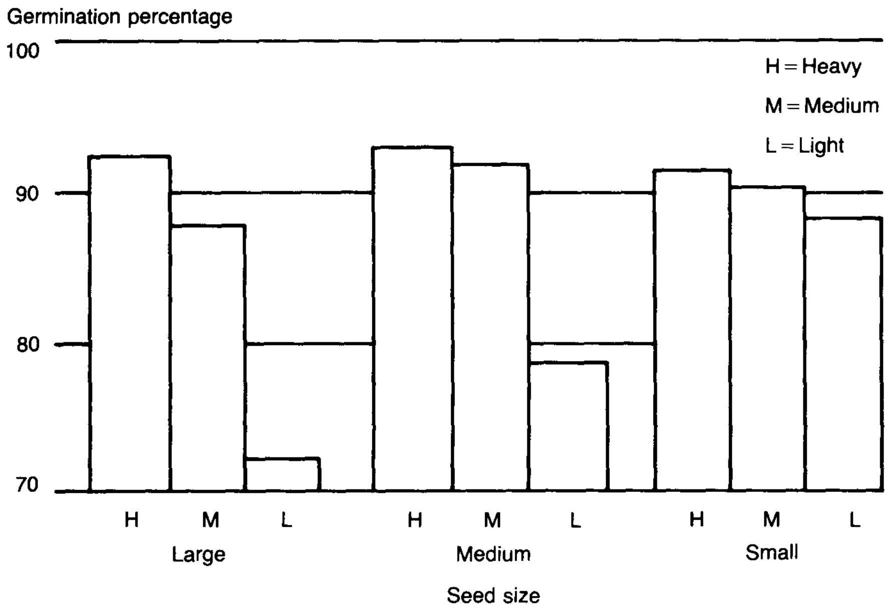

Figure 2—*Germination of filled seed within grading classes.*

Nursery data. The differences between laboratory and field germination were inversely related to seed diameter (table 2). Small seeds survived poorly in the field. Much of their loss may be attributed to slower germination and possibly weaker seeds. No relationship was noted with seed weight. Sowing rates could therefore be adjusted to give desired seedling densities among lots with varying seed sizes.

Height differences between seedlings from various seed sizes became more distinct with time (table 3). Differences in seed density did not affect seedling height, while differences in seed diameter produced three significantly different seedling heights. Overall, seedlings developed an array of heights, uniformly decreasing from a high of 12.5 inches with jumbo seeds to 9.6 inches with small, light seeds.

Seedling data. Initial seed diameter significantly affected all seedling measurements, while seed weight had no significant effect (table 4). Seedling height was correlated to seed size ($r^2 = 0.84$): the jumbo seeds produced seedlings 19 percent taller than those developed from small seeds, while the large seeds produced seedlings with a larger root collar diameter and heavier seedling weight.

Table 2—*Comparison of laboratory germination and nursery survival*

Treatment	Laboratory prediction	Actual field count	Difference
	------- % -------		
Screens			
Jumbo	86	80	6
Large	82	70	12
Medium	85	70	15
Small	88	64	24
Gravity			
Heavy	90	74	16
Medium	87	70	17
Light	75	60	15
Source			
Georgia seed orchard	92	81	11
Florida seed orchard	86	78	8
Wild collection	73	70	3

Table 3—*Seedling height in the nursery*

Grade	Month May	July	November
		In	
Screens			
Jumbo	2.63a[1]	6.30a	12.47a
Large	2.56a	5.94b	11.64b
Med.	2.29b	5.58c	10.91c
Small	2.10c	5.12d	10.13c
Gravity			
Heavy	2.34a	5.64a	11.13a
Med.	2.33a	5.60a	10.91a
Light	2.26a	5.40b	10.64a

[1]Means with the same letter, within the grade and month, are not significantly different at $p = 0.01$.

Stem diameters and mean seedling weights were correlated with seed size for wild-collected seeds ($r^2 = 0.64$), but no relationship existed for orchard seedlots. The reason for this is not clear, but a possibility is that sizing of wild collections may result in a sorting of genetic parents, especially if the seeds were collected from relatively few parent trees.

The generally larger size of improved seeds is because of increased storage material resulting from cultural treatments in seed orchards. Seedlings derived from large seeds produced 25 percent more dry matter than those from small seeds, and they also produced 10 percent greater stem diameters.

Plantation data. Significant differences occurred in all measurements between locations. The seedlings in the second planting (Escambia County) were shorter (table 5), were smaller in diameter, had better survival, and exhibited less rust infection (table 6). However, there were no significant differences among the seed classes in the combined data related to either seedling height or rust infection rates.

These results do not agree with reports by Sluder (17) and Robinson and Van Buijtenen (14), which showed seed size had a significant effect on tree height and volume at age 15 in loblolly pine. In Sluder's study, only one bulk lot of unimproved seeds was used, and planting was done at only one location. If the bulk lot was composed of seeds of relatively few parent trees, separating the lot into size classes could result in genetic differences among the size classes. This is because seeds from a given parent tree are fairly uniform in size, and are closely related (at least as half-sibs, with many full-sibs likely). Therefore, the comparison of seed size classes could really be a comparison of different families, and substantial family variation in slash pine is well known. Planting at only one location would enhance this ge-

Table 4—*Data summary (nursery seedlings)*

Measurement	Laboratory evaluations: Seedling height	Root collar diameter	Top:root ratio	Root dry weight	Top dry weight	Weight of 10 seedlings
	----------- *In* -----------			------------------- *Oz* -------------------		
Screens						
Jumbo	9.76a[1]	0.206b	3.95a	0.039ab	0.153a	6.33a
Large	9.68a	.211a	3.95a	.040a	1.157a	6.52a
Medium	8.86b	.203b	3.99a	.035bc	.140b	5.79b
Small	8.23c	.191c	3.92a	.032c	.126c	5.26c
Gravity						
Heavy	9.09a	.201a	3.88a	.036a	.139a	5.76a
Medium	8.94a	.199a	4.11a	.034a	.140a	5.77a
Light	8.78a	.204a	3.92a	.037a	.145a	6.04a
Source						
Georgia seed orchard	9.21a	.203a	4.16a	.034a	.141ab	5.90ab
Florida seed orchard	8.78b	.198b	3.91a	.034a	.134b	5.56b
Wild collection	8.78b	.204a	3.99a	.037a	.148a	6.11a

[1]Within screens, gravity, and source, data having the same letters are not significantly different at $p = 0.01$.

Table 5—*Mean seedling height in the plantation at 5 years from seeds of different diameters, weights, and sources*

	Seed diameter				Seed weight			Seed source		
Location	Jumbo	Large	Medium	Small	Heavy	Medium	Light	Florida seed orchard	Georgia seed orchard	Wild
						Ft				
Madison Co.	15.4b[1]	15.4b	16.4a	16.8a	16.6a	16.0a	16.1a	16.3b	16.8a	15.5c
Escambia Co.	14.6a	15.1a	14.7a	14.5a	14.8a	14.7a	14.8a	15.1a	14.6a	14.6a
Combined data	15.0a	15.2a	15.6a	15.6a	15.7a	15.4a	15.4a	15.7a	15.7a	15.6a

[1] Means with the same letter, within each location, are not significantly different at $p = 0.01$.

Table 6—*Percentage of rust infection in plantation at 5 years from seeds of differnent diameters, weights, and sources*

	Seed diameter				Seed weight			Seed source		
Location	Jumbo	Large	Medium	Small	Heavy	Medium	Light	Florida seed orchard	Georgia seed orchard	Wild
						%				
Madison Co.	38.7a[1]	33.3a	36.9a	37.1a	38.6a	33.4a	35.3a	41.0a	34.7b	31.6c
Escambia Co.	6.7a	11.0a	9.2a	10.0a	11.2a	10.0a	9.0a	11.1a	11.9a	7.2a
Combined data	22.7a	22.2a	23.0a	23.6a	24.9a	21.7a	22.2a	26.0a	23.3ab	19.4b

[1] Means with the same letters, within each location, are not significantly different at $p = 0.01$.

netic effect if there was a significant family by location interaction. Sluder recognized these limitations in the loblolly pine study. Since our slash pine study involved three bulk lots and two planting locations, these confounding factors are not likely to have an effect.

In the study of east Texas loblolly by Robinson and Van Buijtenen, the separation by seed weight may have really been a separation of natural shortleaf loblolly pine hybrids from loblolly pine. Since natural interspecific hybridization is not common in slash pine, it is not likely that seed weight differences were caused by hybridization.

These findings of our study support Langdon's results (11) that seedlings from a given seed size had only a slight influence on field survival; and those of Shoulders (15), which showed that height differences developed in the nursery from sized seeds were soon eliminated in plantations.

Conclusion

Seed sizing is a useful tool in the forest nursery. These data show that large seeds will produce large seedlings and that, by separating the seeds into classes, a more uniform seedbed density may be obtained. The uniformity in density is derived through more uniform germination of the sized seeds. After outplanting, however, the range of variation is expected to be large and the distribution approximately normal, since seed weight is not correlated with inherent vigor (13).

Literature Cited

1. Ackerman, R. F.; Gorman, J. R. Effect of seed weight on the size of lodgepole pine and white spruce container planting stock. Pulp Paper Mas. Con. 70(C): 167-169; 1969.
2. Andersson, E. Cone and seed studies in Norway spruce. No. 23. Stockholm, Sweden: University of Sweden, Stnd. For. Suec. Skosshossk; 1965. 214 p.
3. Bjorkbom, J. C.; Morquis, D. A.; Cunningham, F. E. The variability of paper birch seed production, dispersal; and germination. Res. Pap. NE-41. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1965. 8 p.
4. Caballero, D. B.; Chacon, J. T. Effects of seed size and of three types of substratum on the germination and early development of *Pinus pseudostrobus* var. Oaxacana. Mexico City: Bol. Tec. Insti. Noc. Invest. For. Mexico; 1967. 35 p.
5. Canido, J. F. The effect of seed size and environment on the germination of Eucalyptus citriodora seed. Revista Cares, Vicosa 17(91): 77-85; 1970.
6. Cevedo, A. Germination tests of *Pinus elliottii* at different depths. Rev. For. Agent. 10(3): 104-105; 1966.
7. Choi, S. K.; Kim, K. C. Studies on the characteristics of selected plus-trees. II. The difference in seed germination capacity between plus-tree clones. Res. Rep. Inst. For. genet. Korea No. 7: 8190; 1969.
8. Cozzo, D. The relationship between seed size and plant height in Eucalyptus viminalis. Rev. For. Argent. 7(4): 101105; 1963.
9. Hellum, A. K. 1976. Grading seed by weight in white spruce. Tree Plant. Notes. 27(1): 16-17, 23-24; 1976.
10. Heydecker, W. Vigour. Chapter 8. In: Roberts, E. H., ed. Viability of seeds. Syracuse, NY: University Press; 1972.
11. Langdon, G. O. Cone and seed size of south Florida slash pine and their effects on seedling size and survival. J. For. 56: 122-127; 1958.
12. Larson, M. M. Initial root development of ponderosa pine seedlings as related to germination date and size of seed. For. Sci. 9(4): 456-460; 1963.
13. Righter, F. I. Pinus: The relationship of seed size and seedling size to inherent vigor. J. For. 43: 131-137; 1945.
14. Robinson, J. F.; Van Buijtenen, J. P. Correlation of seed weight and nursery bed traits with 5-, 10-, and 15-year volumes in a loblolly pine progeny test. For. Sci. 25(4): 591-596; 1979.
15. Shoulders, E. Effect of seed size on germination, growth, and survival of slash pine. J. For. 59: 363-365; 1961.
16. Silen, R.; Osterhaus, C. Reduction of genetic base by sizing of bulk Douglas-fir seed lots. Tree Plant. Notes. 30(1): 24-30; 1979.
17. Sluder, E. R. The effects of seed and seedling size on survival and growth of loblolly pine. Tree Plant. Notes. 30: 25-28; 1979.
18. Wasser, R. G. Tree Improvement Research. In. Proceedings 1979 southern nursery conference. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southeastern Area; 1978: 1525.
19. Zaborovskij, E. P. Analysis of cones and seeds of a single Scots pine tree. Lesn. Z. Arhansel'sk 9(6): 162-163; 1966.