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Seed and Seedling Size Grading of Slash Pine Has Little Effect on Long-Term Growth of Trees

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Seeds from approximately 25 slash pine (Pinus elliottii Engelm. var. elliottii) trees were bulked, separated into three size classes, and planted in the nursery. Seedlings from each size class were graded into small, medium, and large size classes, and the resulting nine treatment combinations were planted in a randomized-block field design. Seed size had no significant effect on heights at outplanting (1 year from seed) or at three measurement ages (3, 10, and 15 years from outplanting) but did significantly affect survival and thus volume per plot at age 15. Seedling size affected heights at age 3 but the effect did not persist to ages 10 and 15 years. The only evidence of interaction between seed size and seedling size was for height and survival at age 3 years. Genetic identity in the study materials was not retained and may have masked the effects of seed and seedling size. Size grading of seeds or seedlings to control variation in long-term growth seems unnecessary for slash pine. Tree Planters' Notes 42(3) :23-27;1991.

Nursery managers separate seeds of coniferous species into size classes for more uniform sowing density, better synchrony in germination, and better control of seedling size. Also, seedlings may be separated into two or more size classes before field planting for easier handling and to reduce variation in survival and growth of the trees. However, it is not always clear whether grading seeds or seedlings according to size meets the desired objectives. Environmental conditions vary among planting sites. Seedlings best suited for one site may do poorly on a different site. Seedling traits other than size also may affect performance.

Separating seeds into size or weight classes is easy to do, but factors other than inherent growth potential of the embryo may affect seed size, such as seed maturity (Campbell and Sorenson 1984), cone size (Righter 1945), and mother tree (Brown and Goddard 1959). Consequently, though seedling size often is positively correlated with seed size, the association usually does not persist for more than a few years after seedlings are planted in the field (Belcher et al. 1984, Brown and Goddard 1959, Dorman 1976, Righter 1945). However, the correlation between seed size and tree height (Sluder 1979) or volume per acre (Robinson and van Buijtenen 1979) may persist for up to 15 years.

Seedlings usually are graded on height and/or root collar diameter. The relationship between morphological grade and subsequent field performance of seedlings has been more consistent than that between seed grade and performance. Large seedlings generally survive and grow better than do small seedlings (Burns and Brendemuehl 1971, Dorman 1976, Mexal and Landis 1990, Sluder 1979, South et al. 1985, Wakeley 1954, 1969). The physiological state of the seedlings also affects survival and growth, causing erratic response to morphological grading (Mexal and Landis 1990, Wakeley 1954). Also, though they generally grow better than short ones, tall seedlings may have low survival rates on some sites (Thompson 1985). Variation in inherent growth potential may be expressed later than the seedling stage, decreasing the long-term effects of seedling morphological grade (Righter 1945).

Although long-term correlations between tree height or volume per acre and seedling grade have been reported from several studies (Dorman 1976, Robinson and van Buijtnenen 1979, Sluder 1979, South et al. 1985, Wakeley 1969), few studies have investigated long-term effects of seed size on tree growth. The objective of this study was to determine the effects of seed and seedling size on slash pine survival and growth up to 15 years of age.

Methods

Seeds for this study were collected in 1952 from approximately 25 slash pine trees in plantations on Callaway Foundation land near Pine Mountain, GA. The single-tree seed lots were combined, then the bulk lot was separated into small, medium, and large size classes before planting in the nursery at Callaway in 1953. Seed size was not replicated in the nursery. After 1 growing season, seedlings from each seed size class were lifted and graded into small, medium, and large seedling size classes. No size specifications other than the words "small," "medium," and "large" were recorded for seeds or seedlings. The resulting treatments constituted a factorial combination of 3 seed sizes x 3 seedling sizes. Seedlings from the 9 treatments were outplanted in early 1954 in 4 randomized-block replications of 25-tree square plots of each treatment at a spacing of 10 by 10 feet on an old-field site on Callaway Foundation land. Included in each replication was a 25-tree plot of each of 3 ungraded control lots2 half-sib progenies grown in the same nursery as the study seedlings and a lot of seedlings procured from a commercial nursery.

Data recorded were heights at outplanting and at plantation ages 3, 10, and 15 years; survival at ages 3, 10, and 15; and diameter at breast height (dbh) and infection by southern fusiform rust at age 15. Heights were measured to the nearest 0.1 foot at the two younger ages and to the nearest 0.5 foot at ages 10 and 15. The data were subjected to factorial analyses that tested for significance of the mean effects of the two factors and their interactions as well as for their linear and quadratic effects and interactions. Bonferroni's multiple comparison method was used to separate outplanting mean heights of seed and seedling grades.

To determine whether seed and seedling grading affected height variation within treatment at age 15 years, within-plot coefficients of variation in height were calculated for each of the 9 factorial treatment combinations and the 3 ungraded control lots. Coefficients of variation for treatments were compared statistically with those for controls.

Table 1—*Mean initial seedling heights for the 9 treatment combinations of small, medium, and large seed and seedling sizes, at the time of planting*

Seed	Initial height (ft)			
size	Small	Medium	Large	Mean
Small	0.72	0.86	0.92	0.83 a
Medium	0.73	0.87	0.99	0.86 a
Large	0.75	0.82	0.89	0.82 a
Mean	0.73 a	0.85 ab	0.94 b	0.84

Within a factor, means not followed by a common letter differ significantly at the 0.05 level (Bonferroni's multiple comparison method).

Table 2—*Analysis of variance of mean seedling heights at ages 1, 3, 10, and 15 years of trees from 3 seed sizes and 3 seedling sizes*[1]

		F values			
Source	df	1 yr	3 yr	10 yr	15 yr
Replication (R)	3	1.74	2.81	3.97	13.48**
Seed size (A)	2	2.36	0.24	0.87	0.09
Linear (A_1)	1	0.31	0.40	1.60	0.07
Quadratic (A_q)	1	4.41	0.08	0.14	0.11
Seedling size (B)	2	24.10**	4.98	0.93	1.21
Linear (B_1)	1	47.95**	2.38	0.35	2.14
Quadratic (B_q)	1	0.26	7.59*	1.50	0.29
A × B	4	0.84	2.80	1.97	1.31
$A_1 \times B_1$	1	0.77	1.44	0.03	3.45
$A_1 \times B_q$	1	0.39	1.51	1.83	1.25
$A_q \times B_1$	1	2.19	0.11	3.17	0.01
$A_q \times B_q$	1	0.01	8.13*	2.88	0.53
R × A	6	0.41	4.15*	1.78	1.38
R × B	6	0.95	1.72	5.13**	4.07

[1]Age 1 from seed, ages 3, 10, and 15 from outplanting.
*Significant at the 0.05 level.
**Significant at the 0.01 level.

Results

Seed size. Mean heights after outplanting of seedlings from the 3 seed sizes did not differ significantly (tables 1 and 2). Neither did seed size have any independent effect on tree height at plantation ages 3, 10, or 15 years (table 2, figure 1). It did, however, affect survival and thus volume per plot at age 15, with trees from medium-sized seeds tending to do poorest in both traits (figures 2 and 3). Neither dbh nor fusiform rust infection rates of the trees at age 15 were affected by seed size.

Seedling size. Mean outplanting heights for the 3 seedling sizes differed highly significantly (0.01 level), as expected (tables 1 and 2). The seedling size effect on tree height was still significant (0.05 level) at age 3 but not at ages 10 or 15 (table 2, figure 1). At ages 3 and 10 years, trees from medium-sized seedlings tended to be tallest, but by age 15 they were about intermediate in height to those from small and large seedlings (figure 1). There were no significant effects of seedling size on dbh or rust infection rate at age 15.

Interaction. Interaction between seed size and seedling size was confined to a significant (0.05 level) quadratic x quadratic interaction for height at age 3 (table 2). At that age, medium seedlings were tallest for the small and large seed sizes but were intermediate in height for the medium seed size (figure 1).

Variation within treatment. None of the mean within-plot coefficients of variation in height at age 15 for the 9 treatment combinations was significantly different from the CV for the commercial control. The coefficient of variation for the control was 10.79% and the coefficients for the 9 treatments ranged from 7.37 to 11.70% (mean 9.14%). One of the 2 half-sib progenies was significantly less variable in height than the commercial control; it had a coefficient of 5.94%.

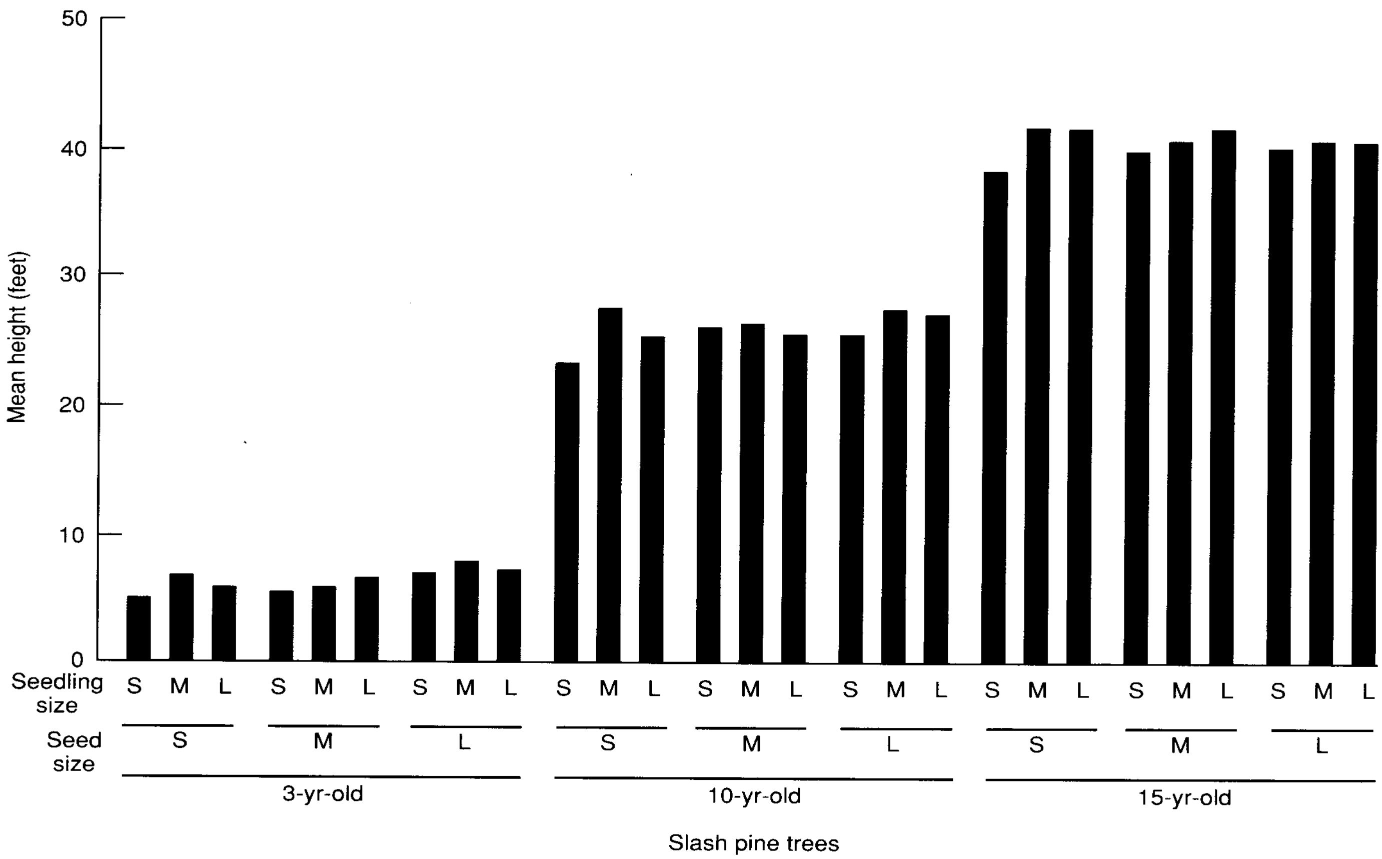

Figure 1—*Mean heights at ages 3, 10, and 15 years of slash pines from seeds separated into small, medium, and large classes and the seedlings from each size in turn graded into small, medium, and large size classes.*

Discussion

The performance of a tree, or a plot or stand of trees, is determined by genetic and environmental factors. Both kinds of factors may change over time. Genetic controls during the juvenile stage may differ from those of more mature stages. The competitive environment changes with tree size. Studies on the effects of nursery practices, some of which may have genetic implications (Campbell and Sorensen 1984), on tree growth and variation therefore need to be long term to allow time for these changes to occur and to interact. This study has been carried for 15 years, providing a good test of the long-term effects of seed and seedling size grading. Information is especially lacking for seed size.

Grading seeds and seedlings into size classes is advantageous to nursery and forest managers if it produces gains in uniformity of sowing density, germination rate, size of planting stock, or performance of planted trees. This study, as have many others, indicates that seed and seedling grading is not likely to produce undesirable results, so the cost of grading needs to be weighed only against expected advantages. Grading seeds should be easy to justify because it is a low-cost process. Grading seedlings, however, is expensive and, other than the benefits of discarding cull seedlings, probably won't produce significant gains in performance of planted trees.

The seed and seedling grading done in this study did not separate the trees into groups of uniform height growth. Even if grading does tend to separate seeds by maternal parent (Brown and Goddard 1959), each of the grades will contain seeds from a number of parents. Also, seed grading should have

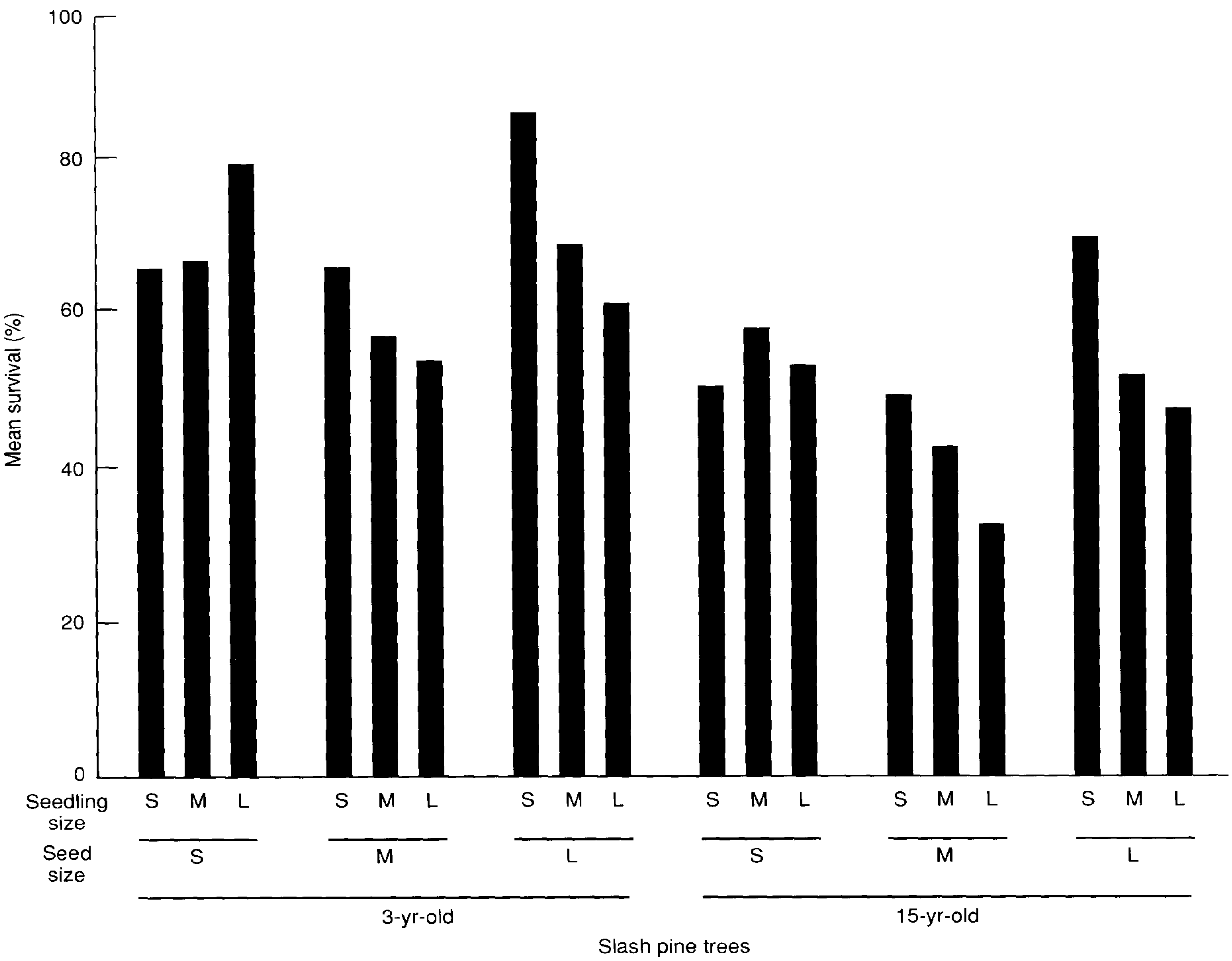

Figure 2—*Mean survival at ages 3 and 15 years of small, medium or large slash pine seedlings from small, medium, or large seeds.*

little or no effect on the paternal parent mix in each grade. Therefore, grading seeds from a bulk lot originating from a large number of parents should have little effect on variability of height growth within grades.

Even though height growth variation within seed or seedling grades may remain as high as that within ungraded lots, it is possible that genetic differences among grades in mean performance may occur in some traits. That did not occur for long-term height growth in this study, but it did for long-term survival as shown by a lower survival rate of trees from medium-sized seeds. There is no obvious reason why seed size per se should cause this difference. A more logical explanation is that seed size grading did tend to separate the seeds by mother tree and that at least one tree with predominantly medium-sized seeds produced seedlings that survived poorly after outplanting.

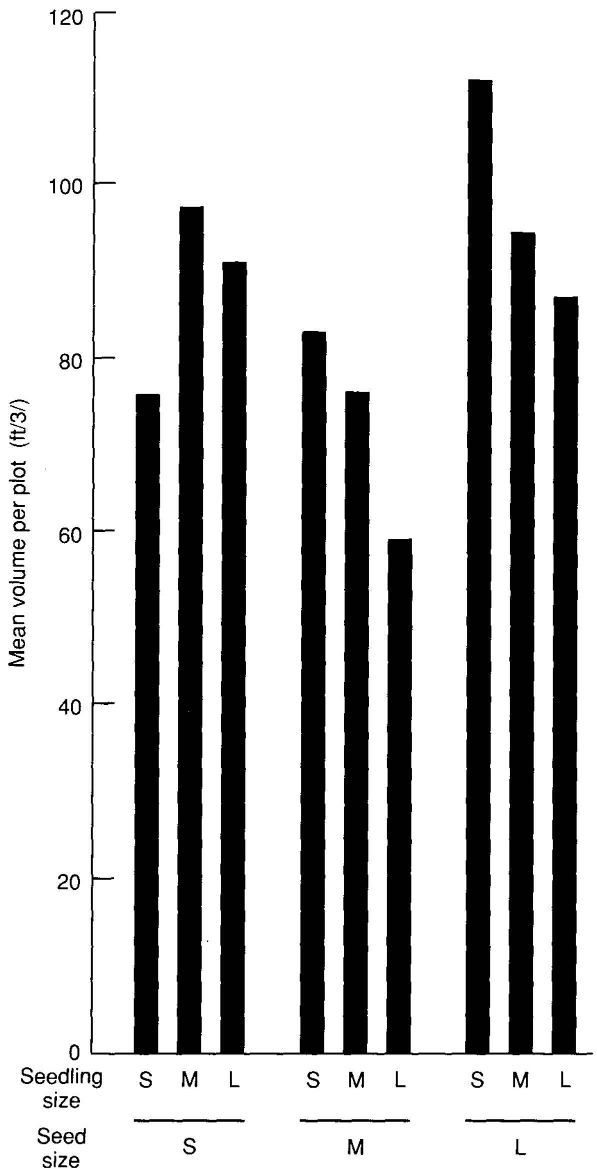

Figure 3—*Mean volume per plot at age 15 years of slash pine trees planted as small, medium, or large seedlings from small, medium, or large seeds.*

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