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Emergence timing affects root-collar diameter and mortality in loblolly pine seedbeds

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Application. To increase the average root-collar diameter: pretreat seeds to increase speed of germination.
To improve the uniformity of nursery-grown loblolly pine seedlings: pretreat seeds to increase uniformity of germination.

Abstract. Eight half-sib families of loblolly pine (*Pinus taeda* L.) were sown in a nursery. Total germination, speed and uniformity of germination, root-collar diameters, mortality, and percent cull were recorded by family. Families which germinated quickest attained the greatest average diameters at the end of the growing season. Low variability in date of emergence led to correspondingly low variability in seedling diameter. When data for all families were combined, seedlings which emerged earliest experienced the lowest mortality, had the largest diameters, and produced the fewest culls.

Introduction

Increasing the germination speed of loblolly pine (*Pinus taeda* L.) through seed stratification and pregermination treatments increases average seedling diameter (Boyer et al. 1985). It has also been shown that the earliest loblolly pine seedlings to emerge in a stand become larger than those emerging later (Boyer et al. 1985, Mexal 1980). Seedlings emerging late are at a competitive disadvantage and contribute heavily to the cull population (Mexal 1980).

Forest nursery managers are sowing increasing amounts of improved half-sib seeds, and several are sowing families separately. These families often have different germination characteristics, which could lead to differences in seedling characteristics. An objective of this study was to determine if differences in root-collar diameter, mortality, and percent cull among families could be related to differences in the speed and uniformity of germination.

Materials and methods

Seeds from eight half-sib loblolly pine families were sown separately in replicated plots (four replications) at the Jake Stauffer Alabama Forestry Commission Nursery near Opelika, Alabama. All families were selections from within Alabama. All seeds were stratified for 30 days and sown by hand April 16-17, 1984, on operationally prepared 1.2 m wide nursery beds in 0.6 m long plots. Seeds were placed 2 cm apart in rows 15 cm apart for a sowing density of 322 seeds per square meter.

Germination was checked daily from 12 days after sowing until 20 days, and again on days 22, 24, and 30, and the day of emergence for each seed was recorded. In late November, 1984, the root-collar diameter of the subsequent seedling in each position was recorded to the nearest 0.01 mm. From the number of seeds sown, the number germinated, and the number of seedlings measured, percent germination and percent mortality were calculated. From the diameter measurements, a percent cull (trees with diameter less than 3.2 mm) was calculated for each plot.

Using family means, correlation coefficients were calculated for average diameter, coefficent of variation (CV) for diameter, percent mortality, and percent cull with average days to germination and CV for germination time.

Analyses of variance were performed on average diameter, CV for diameter average days to germination, CV for germination time, percent mortality, and percent cull using plot means to test for differences among families.

Prior to further analyses, the emergence period was divided into six time classes: a) 12-14 days after sowing; b) 15-16 days; c) 17-18 days; d) 19-20 days; e) 21-24 days; and f) 25-30 days. Within a replication, data for families were combined for these classes and analyses of variance were performed for average diameter, percent mortality, and percent cull using class means within a replication to test for differences among the emergence periods.

Results and Discussion

Significant differences among families were observed in the percentage of seed that germinated, but no differences in seedling mortality were detected (Table 1). An average of 88 percent of the seeds that were sown resulted in a live tree at the end of the experiment. Families with the greatest speed of germination (earliest average germination day) achieved the greatest diameters. Mean germination date accounted for 77 percent of the variation in mean diameter for a family ($P > r = 0.004$). The following linear regression equation describes the relationship between mean root-collar diameter (Y, mm) and mean germination date (X, days after sowing): $Y = 4.97 - 0.0803\ X$. This

Tabel 1. Family means for germination percent and mortality (as a percent of germinants).

Family	Germination	Mortality
	-%-	-%-
408	98.7 a[1]	1.6
456	97.7 ab	2.0
37	94.3 abc	7.1
187	93.9 abc	3.2
138	90.6 bcd	3.0
73	88.7 cd	4.0
447	84.9 de	3.1
454	79.6 e	3.5

[1]Means followed by the same letter (within a column) are not significantly different at the 5 percent level of probability as compared by Duncan's Multiple Range Test. Where no letters follow the means, analysis of variance showed no significant differences among families at the 5 percent level.

equates to about a 2 percent decrease in mean diameter for each day the mean germination date is delayed after the earliest family to emerge. Furthermore, families with the lowest variation (CV) in date of seedling emergence also had the lowest variation in diameter (Fig. 1). This is further illustrated in Fig. 2 which shows distributions of germination time and diameter for individual seedlings of two families. Seeds from family 73 varied widely in date of emergence and showed a broad bell-shaped curve for seedling diameter. Initial seedling emergence for family 447 began at approximately the same time as family 73; however, the germination rate was significantly greater for family 447, resulting in a lower CV for date of emergence. Average seedling diameter

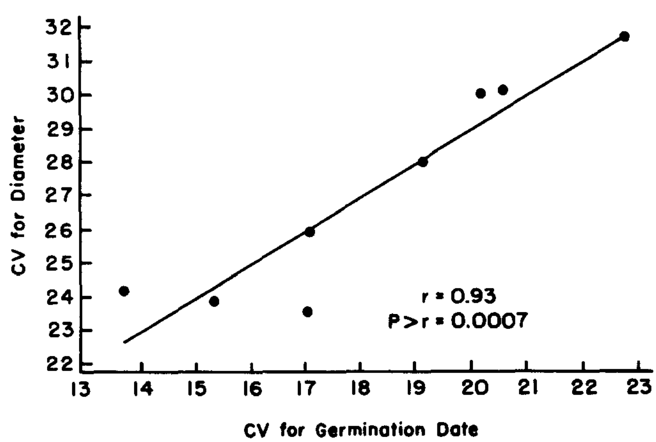

Fig. 1. Correlation between coefficient of variation (CV) for root-collar diameter and CV for germination date for eight half-sib families

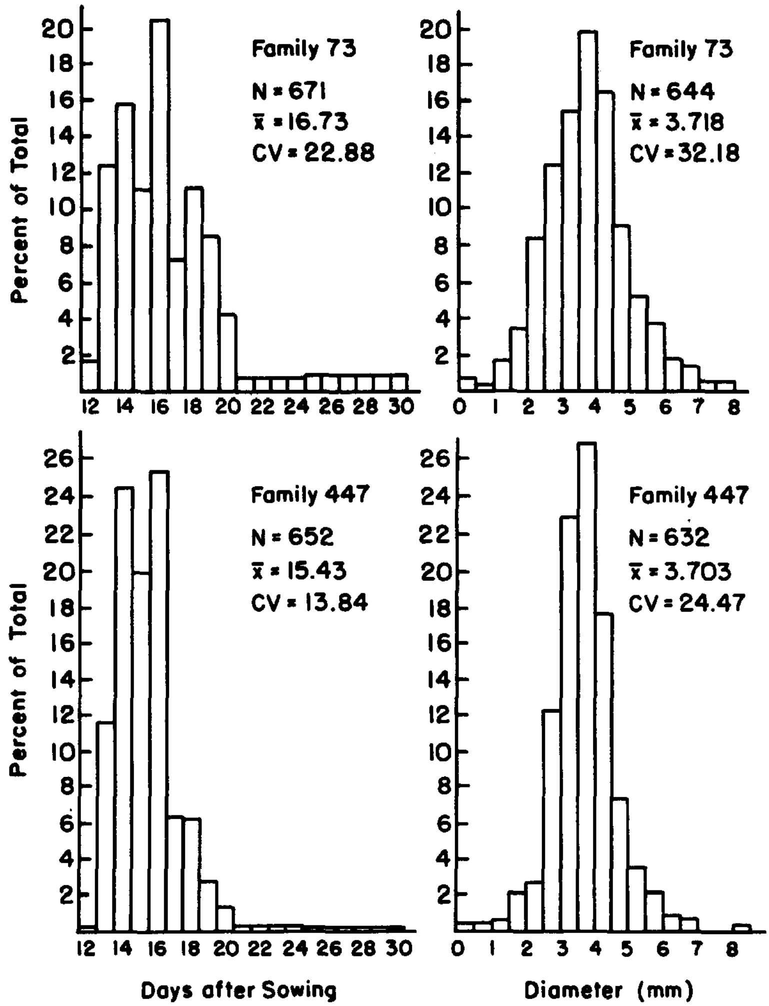

Fig. 2. Distributions of germination date and root-collar diameter for two half-sib families

for family 447 was nearly the same as that of family 73, but family 447 had a much more compact distribution, resulting in lower CV for diameter and fewer culls on the low end of the distribution. Cull percent was positively correlated with the mean germination date ($r = 0.86$, $P > r = 0.006$).

Considering the data for all families, seedlings which emerged earliest experienced the lowest mortality, achieved the largest diameters, and produced the fewest culls (Table 2). This demonstrates that the earliest seedlings to emerge have an advantage over the late emergers.

Boyer et al. (1985) showed that order or rank of seedling emergence had a significant effect on seedling diameter at three Alabama forest nurseries. In their study, the earliest trees to emerge developed the largest diameters.

Table 2. Percent mortality, average root-collar diameter, and percent cull by emergence time. Data for all families are combined.

Days After Sowing	Mortality	Diameter	Cull
	-%-	-mm-	-%-
12-14	2.4 b[1]	4.0 a	22 d
15-16	2.0 b	3.7 b	29 cd
17-18	4.1 b	3.5 b	36 c
19-20	4.0 b	3.3 c	47 b
21-24	5.4 b	2.9 d	59 a
25-30	9.6 a	2.5 f	65 a

[1]Means followed by the same letter (within a column) are not significantly different at the 5 percent level of probability as compared by Ducan's Multiple Range Test.

Barnett and McLemore (1984) stated that the last seeds to germinate are probably the weakest or most dormant in the lot. Mexal (1980) also showed that seedlings which emerge early in a population are larger at the end of the growing season than later emerging seedlings. He also reported that the cull percent rises with a delay in emergence. While our findings confirm that timing of emergence can significantly affect the average size of the seedling crop, they go further in showing that uniformity of emergence time, or shortening of the emergence period, can reduce variability in the seedling crop.

A longer stratification period in our study would likely have reduced the differences among families caused by differing germination characteristics. In general, increasing the length of stratification of loblolly pine seeds improves nursery performance because it is the most consistently effective method of increasing the speed and uniformity of germination (Barnett 1986). This is especially important in the early spring when soil temperatures are low and days are short (Barnett and McLemore 1984, McLemore 1969). Stratification of loblolly pine seed for 60 to 90 days has been recommended and is completely feasible for most seed lots of loblolly pine (Barnett 1986, Barton 1928, MacKinney and McQuilkin 1938, McLemore and Czabator 1961). However, germination of a relatively small proportion of seed lots may be reduced with as little as 15 days of stratification (McLemore and Czabator 1961).

Conclusions

The results of this experiment demonstrate that improving the speed and uniformity of emergence improves the average diameter and uniformity of the seedling crop. The economic benefits of increasing germination speed and uniformity are derived from a reduction in cull percent and an increase in seedling quality. Nursery managers who wish to produce more uniform seedling crops with larger root-collar diameters should strive to stratify and sow their seeds in a manner to achieve quick, uniform emergence. Therefore, the optimal stratification length (for increasing germination speed) should be determined for each seed lot.

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