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Speed of Germination Affects Diameter at Lifting of Nursery-Grown Loblolly Pine Seedlings

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ABSTRACT. Speed of germination affects seedling quantity and quality. This study investigated the effect of germination speed on loblolly pine (Pinus taeda) *seedling diameter at lifting. Studies were installed at three forest nurseries in Alabama to test the effects of stratification treatments on speed of germination and of seedling emergence date on final seedling diameter. Results varied with the length of stratification employed. However, in all cases, seedlings which emerged earliest (first 40%) attained significantly larger diameters than seedlings from seeds which germinated later.*[1]

More than 33 million seedlings were lost to early heavy rains in southern forest nurseries in 1980 (Boyer and South 1984). The more rapidly seeds germinate and roots become firmly established, the less likelihood of seedlings being washed away. Accelerating the germination process also shortens the period when emerging seedlings are most susceptible to certain diseases (Pein 1953). Another possible benefit of faster germination, often ignored, is larger seedlings at lifting. An increase in seedling size can often result in an increase in volume production at time of harvest (South et al. 1984).

Stratification increases the rate of germination and results in greater uniformity of the seedling crop. Late-germinating seeds seldom become plantable seedlings.

Species which exhibit internal seed dormancy generally respond well to stratification. More than 50 years ago, Barton (1928) showed that stratification of loblolly pine seeds for 3 to 4 months at 5° C increased the speed of germination over that of seeds which had undergone 1 month of stratification. Overemphasis on completeness of germination has resulted in a lack of information on the optimum duration of stratification (McLemore and Czabator 1961).

It is important to realize that stratification will not improve germination for every species, provenance, or family. Some seed lots may even respond negatively to stratification or to a long period of stratification. Donald (1968) has shown this to be the case for slash pine (*Pinus elliottii*) where adverse effects of stratification are more common than for loblolly pine. It is best to have individual seed lots tested for stratification requirements.

The objectives of the studies presented here were two-fold: (1) to determine whether stratification and pregermination treatments increased seedling diameter; and (2) to determine whether seedlings which emerge earliest have the largest diameters at the end of the growing season.

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MATERIALS AND METHODS

Studies were established at three nurseries in Alabama in 1983 to determine the effects of seed stratification and pregermination treatments as well as speed of seedling emergence on final seedling diameter. Different seed lots were used at each nursery. Hammermill seeds were from a 1981 bulk orchard collection and of medium size, with 13,600 seeds per pound. Kimberly-Clark employed wild seeds from a 1979 collection, which was not sized and contained 17,000 seeds per pound. MacMillan-Bloedel also used wild seed (Livingston Parish) containing 20,300 seeds per pound. At two nurseries (Kimberly-Clark and MacMillan-Bloedel), treatments consisted of: (a) double stratification (37 to 45 days of stratification followed by drying, storage until the next year, and 30 to 35 more days of stratification), vs. (b) normal operational stratification for 35 to 38 days. For each treatment, there were three replications and six subplots within each replication. At the third nursery (Hammermill), treatments consisted of: (a) 122 days of stratification plus a pregermination treatment (three days in a 24° C, lighted, aerated water bath) designed to give prompt germination; (b) 122 days of stratification alone; and (c) 60 days of stratification. For each treatment, there were seven replications and two subplots within each replication.

Barnett (1982) developed a method of germinating seeds to the point where the radicles had emerged in order to prepare the seeds for "fluid drilling." However, for traditional operational sowing, emerged radicles would be undesirable, because of the increased danger of such radicles breaking off prematurely. Therefore, Barnett's procedures were followed for the pregermination treatment except that seeds were removed from the water bath before any radicles had emerged.

Order of seedling emergence was denoted with colored plastic rings. The first 20% to emerge were marked with an orange ring, the next 20% with a blue ring, and so on, while the final 20% to emerge received no ring at all. As rings came off some seedlings, there was uncertainty about whether they truly belonged in the no-ring group. Therefore, trees having no ring were deleted from the data.

Each plot was monitored for speed of germination, and curves were drawn to show germination percent vs. days after sowing (Figures 1, 2, and 3). At the Hammermill Nursery, seeds were sown with a precision sower (Summit Equipment Ltd., Rotorua, New Zealand), and the number of seed spots per given area was known. Therefore, germination percent for that study is a reflection of the percentage of seed sown. At the other two nurseries, the total number of seed sown in a given area was not known. Therefore, at those two nurseries, percent emergence refers to the percent of the total number which eventually emerged for a given plot.

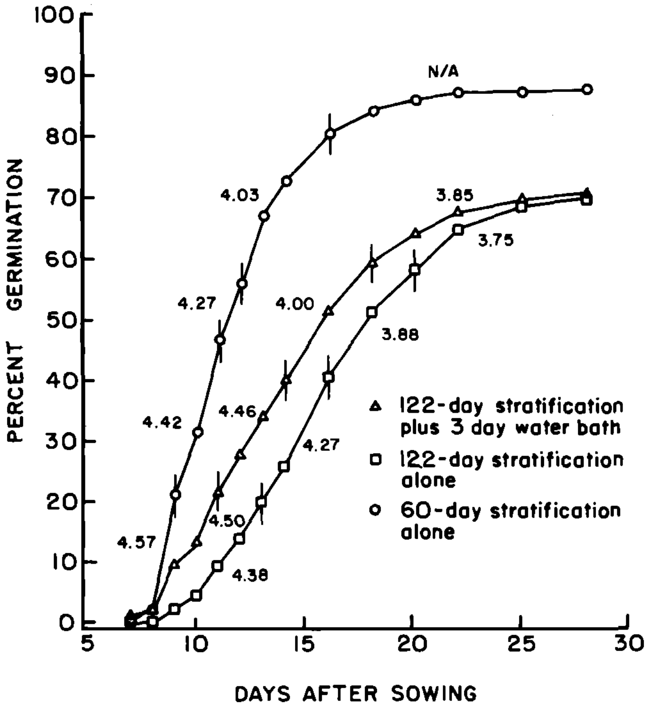

Figure 1. Effect of germination timing on final seedling diameter at Hammermill Nursery. Numbers between hash-marks represent diameters of seedlings germinating in that period for that treatment (N/A = data not available).

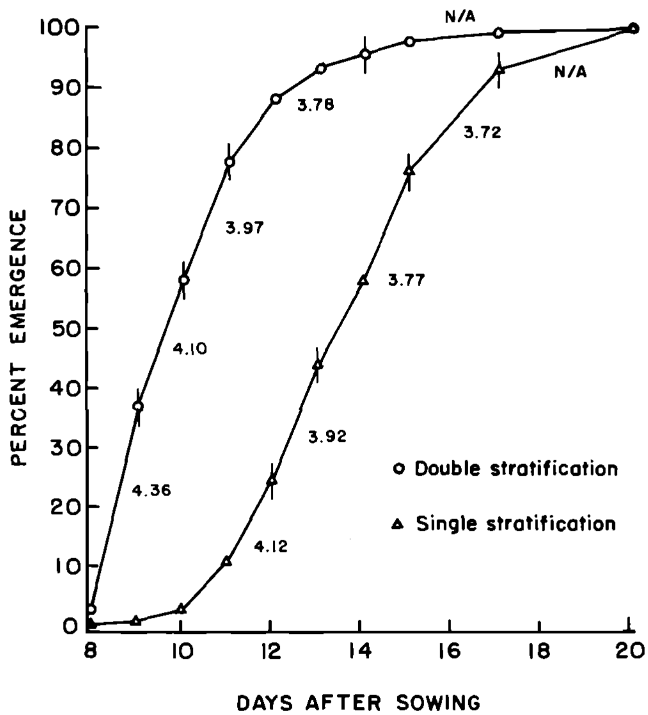

Figure 2. Effect of germination timing on final seedling diameter at Kimberly-Clark Nursery. Numbers between hash-marks represent diameters of seedlings germinating in that period for that treatment (N/A = data not available).

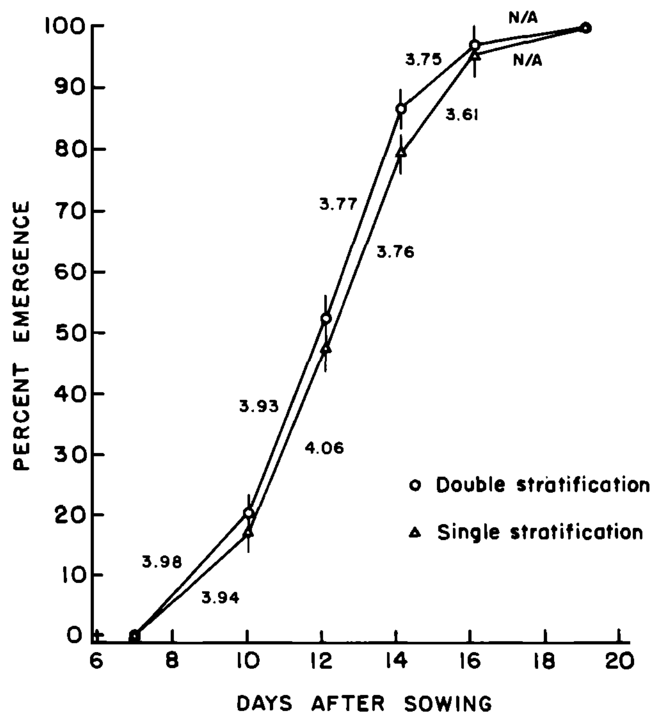

Figure 3. Effect of germination timing on final seedling diameter at MacMillan-Bloedel Nursery. Numbers between hash-marks represent diameters of seedlings germinating in that period for that treatment (N/A = data not available).

At the end of the growing season, 0.37-squaremeter samples were hand-lifted from each plot. Each seedling was measured for groundline diameter and its treatment and ring color were recorded. Analyses of variance were used to test for differences among treatments and color groups at each nursery.

RESULTS AND DISCUSSION

At the Kimberly-Clark Nursery, double stratification significantly increased seedling diameter, apparently through increased speed of germination (Table 1). At the MacMillan-Bloedel Nursery, there was no difference in speed of germination between the stratification treatments, with both emerging rapidly. Thus, double stratification at the MacMillan-Bloedel Nursery had no beneficial effect on increasing seedling diameter (Table 1). At the Hammermill Nursery, seed was kept in stratification longer than planned. The study originally called for 30 days vs. 90 days of stratification plus the pregermination treatment. It is not known why the extra-long stratification had a deleterious effect on germination. Treatment C (60-day stratification) gave the best and fastest germination, and thus the largest seedling diameters (Table 1). The water bath treatment increased speed of emergence over 122-day stratification alone. In all cases, when a treatment increased speed of germination, seedling diameter was increased as well. The varying response to stratification treatments at the different nurseries may be partially explained by the different stratification lengths, conditions during germination, and genetic differences (since different seed sources were used).

Order of seedling emergence had a significant effect on seedling diameter at all three nurseries (Table 2). In all three studies, the first 40% to emerge developed significantly larger diameters than trees which emerged in the second 40%. Figures 1, 2, and 3 demonstrate the effect of germination timing on final seedling diameter.

The data for each nursery were used to calculate regressions predicting seedling diameter from emergence date, seedbed density, and number of seedlings previously emerged on the plot at time of emergence (Table 3). Each ring-color group in each subplot was used as a point in the regression. For each nursery, the best multiple regression is shown as well as the simple linear model using only date of emergence as the independent variable. All three independent variables were negatively correlated with seedling diameter. That is, the later the emergence date, the higher the total seedbed density, and the more seedlings already emerged, the smaller the diameter of a newly-emerging seedling.

Data comparing morphology of seedlings based on emergence timing are scarce. One study was conducted by Venator (1973), who demonstrated that height of *Pinus caribaea* seedlings was dependent on

Table 1. Days to reach 50% germination and average seedling diameters for seed treatments at three nurseries.

Treatment	MacMillan-Bloedel Days to 50%	MacMillan-Bloedel Diameter (mm)	Kimberly-Clark Days to 50%	Kimberly-Clark Diameter (mm)	Hammermill Days to 50%	Hammermill Diameter (mm)
Double stratification	12.0 a[1]	3.86 a	10.0 b	4.07 a	—	—
Single stratification	13.3 a	3.84 a	14.0 a	3.88 b	—	—
Long strat. + areation	—	—	—	—	16.9 b	4.20 a
Long strat. alone	—	—	—	—	19.1 a	4.07 b
Operational strat.	—	—	—	—	11.7 c	4.32 a

[1] Means followed by the same letter are not significantly different at the 0.05 level of probability as compared by Duncan's Multiple Range Test.

Table 2. Effect of order of emergence on average diameter at three nurseries.

Order of emergence[1]	*MacMillan-Bloedel* Diameter (mm)	*Kimberly-Clark* Diameter (mm)	*Hammermill* Diameter (mm)
1	3.96 a[2]	4.24 a	4.48 a
2	3.99 a	4.01 b	4.38 a
3	3.77 b	3.87 c	4.05 b
4	3.68 b	3.75 c	3.88 c

[1] 1 = first 20%, etc.; data not available for fifth 20%.
[2] Means followed by the same letter are not significantly different at the 0.05 level of probability as compared by Duncan's Multiple Range Test.

the date of germination. Early-germinating seedlings were 60% taller than seedlings which germinated 10 days later. Mexal (1980) conducted studies at two loblolly pine nurseries and reported that rate of emergence significantly affected seedling height, diameter, and shoot fresh weight. At the Fort Towson Nursery in Oklahoma, a 9-day delay in seedling emergence resulted in a reduction in shoot fresh weight of 50%. Mean heights and diameters were reduced by 15 to 30% when compared to seedlings that emerged 9 days earlier. Mexal's data indicate a 1.7 to 3.3% decrease in seedling diameter for each day emergence is delayed. In our studies, each day's delay in seedling emergence reduced seedling diameter by 0.05–0.07 millimeter. This equates to a 1.2 to 1.7% decrease in diameter for each day emergence is delayed.

Obviously, the date of seedling emergence is directly related to the date of sowing. A study in Georgia demonstrates that total biomass production in loblolly pine seedbeds decreases when the sowing date is delayed (Mexal 1984). When the sowing of seeds was delayed from 15 April to 29 April, the resulting seedlings were 17% lower in fresh weight. This equates to more than a 1% decrease in fresh weight for each day sowing is delayed.

Barnett and McLemore (1984) reported that seed stratification increases seedling size in the nursery, solely by increasing speed of germination. Our results strongly support their findings.

Wakeley (1954) stated that stratified southern pine seeds cannot be successfully dried and stored. However, Donald (1968) and Barnett and McLemore (1970) subsequently reported to the contrary, as long as the seed is dried to 10% moisture content or lower. Others have since reported that stratified seeds can be dried to a low moisture content and stored for 9 to 12 months without significantly reducing seed viability (Barnett 1972, Belcher 1982, Danielson and Tanaka 1978). Barnett (1972) reported that the benefits of stratification were lost upon drying, but Danielson and Tanaka (1978) stated that the effect of stratification was not lost when seed was air-dried and stored at 2 C for up to 9 months. Our data confirm that drying and restratification do not reduce seed germination and may be beneficial for certain seed sources. At Kimberly-Clark Nursery, the effect of the original stratification apparently was not lost as the double-stratified seed germinated much more quickly than single-stratified seeds. Subsequent tests at the MacMillan-Bloedel Nursery have also shown double stratification increases speed of germination. However, more experiments should be conducted to determine if the benefits of double stratification are derived from interrupting stratification with a drying cycle or simply from the prolonged stratification time.

CONCLUSIONS

These tests demonstrate that increasing speed of emergence increases loblolly pine seedling diameter at lifting. This could be economically important, since several studies have shown that seedlings with larger diameter at planting can produce a greater volume at harvest. Our tests also demonstrate that seedlings which are the first to emerge in the nursery bed

Table 3. Models predicting seedling diameter at three nurseries.

Model[1]	R-Square[2]	# Observations	Coefficient of variation
MacMillan-Bloedel			
Diameter = 11.6 − 0.0504 (A) − 0.00989 (B)	0.27	96	7.1
53 Diameter = 10.4 − 0.0504 (A)	0.13	96	7.7
Kimberly-Clark			
Diameter = 9.26 − 0.0347 (A) − 0.00246 (C) − 0.00413 (B)	0.39	139	5.9
56 Diameter = 13.3 − 0.0712 (A)	0.28	139	6.4
Hammermill			
Diameter = 8.71 − 0.0291 (A) − 0.00703 (C)	0.34	168	9.2
Diameter = 12.3 − 0.0546 (A)	0.28	168	9.6

[1] A = Date of emergence (days after 1 January).
B = Final seedbed density (number per linear 30.5 cm of bed).
C = Number previously emerged in plot (linear 30.5 cm of bed).
[2] All equations are significant at the 0.001 level.

become the largest seedlings. Optimum stratification lengths (for increasing germination speed) should be determined for various southern pine seed sources and should be operationally employed whenever feasible. □

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Growth and Yield of Planted Loblolly and Shortleaf Pines in a North Mississippi Creek Bottom

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ABSTRACT. Unthinned loblolly pine (Pinus taeda *L.*) *planted near Abbeville, Mississippi in a creek bottom with a site index of 122 had a yield of 6,925 cubic feet per acre at age 26. Shortleaf pine* (Pinus echinata *Mill.*) *planted beside the loblolly pine had a site index of 108 and a yield of 4,120 cubic feet per acre.*

Abandoned creek bottom fields, too small or wet for mechanized farming, are frequently planted with pine. A study established near Abbeville, in north Mississippi, to assess the impact of tipmoth damage on the growth and yield of loblolly and shortleaf pine (Williston and Barras 1977) offers some insight into the productive potential of such sites.

METHODS

In March 1959, four ⅛-acre plots each of loblolly and shortleaf pine were planted in the Bagley Creek bottom on the Holly Springs National Forest in a field formerly cultivated but then occupied by a scattering of redcedar, sweetgum, and shortleaf pine. Seed source of the loblolly pine was the Strong River District, Bienville National Forest; that of the shortleaf pine, the Holly Springs National Forest. Two plots of each species were treated with insecticides annually during the first 6 years to prevent tipmoth attack; two were left untreated. Treatment had only a minor impact on stand development.

Each plot was planted with 81 trees at a 7 × 9-ft spacing. The central 25 trees were examined annually for 6 years to determine height growth and tipmoth infestation. After the eleventh, fourteenth, and sixteenth growing seasons (from seed), tree dbh and height were measured. Some form class measurements were also taken. In March 1984 the dbh of all trees, now 26 years from seed, and the heights and