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Season for Direct Seeding Slash Pine in the Middle and Upper Coastal Plains of Georgia

Abstract. — Repellent-treated seed of slash pine (*Pinus elliottii* Engelm. var. *elliottii*) were sown at eight monthly dates from November to June for 5 years in Dooly County, Georgia. Observations of seedlings indicated that germination, survival, and first-year establishment were superior on plots planted in November through April. Slow germination in November and likelihood of droughtiness in May, however, detract from November and April as suitable months for direct seeding. The optimum for seeding was mid-February through March. This season allows for germination and early seedling development when soil moisture is adequate and daily high temperatures are between 70 and 90 degrees Fahrenheit.

Slash pine (*Pinus elliottii* Engelm. var. *elliottii*) trees cast their seed about October, and germination under natural conditions may occur any time from November into the following April.[1] With artificial seeding, man can improve on nature by selecting the time of year when weather conditions are best for germination and seedling development, and when losses of seed and seedlings to destructive forces will be minimal. In their "Guides," Mann and Derr state: "The most difficult question in direct-seeding slash pine is the optimum time for sowing."[2] The time of year best suited for direct seeding slash pine varies across the South, and to some extent varies from year to year at any given location.

The purpose of this study was to determine the best time for seeding slash pine on old-field, loamy sand sites in the middle and upper coastal plains of Georgia. Although the kind and degree of seed destruction are important factors to the success of seeding, they were not included as variables; to have done so would have required much more plot space over a broader territory than was available for this experiment.

[1]U. S. Forest Service. Silvics of forest trees of the United States, p. 459. Agr. Handbook 271. 1965.

[2]Mann, W. F., Jr., and Derr, H. J. Guides for direct-seeding slash pine. South. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SO-12, 27 pp. 1964.

TREATMENTS AND METHODS

Treatments consisted of seeding on eight dates at 4-week intervals from November to June. To account for year-to-year variation, treatments were replicated for 5 consecutive years, beginning with the 1960-61 season. Average sowing dates were November 16, December 15, January 14, February 9, March 9, April 6, May 3, and June 1. Each yearly installation of treatments was arranged in a randomized complete-block design with four replications. Plots were 10 by 10 feet and each contained 25 seed spots spaced 2 by 2 feet. Four repellent-treated seed were sown at each spot (fig. 1).

The study was located on an abandoned agricultural field of Lynchburg loamy sand. Yearly installations were alternated between two areas within the field to permit observations to the end of the second growing season for each installation. The areas were separated by 200 feet of untouched soil and were without obvious site differences. One month prior to the first sowing date in each year, the area for that year was harrowed and dragged smooth. As each set of four treatment plots was due for seeding, it was cleared of weeds and raked smooth. Although seldom necessary, plots were watered before seeding if soil moisture was excessively low. This circumvented the problem of annual variation in rainfall pattern, and seedings could be made at regular intervals.

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U.S. Department of Agriculture–Forest Service

Figure 1. — View of field installation for 1 year. Wooden stakes are at plot corners. Protective hardware cloth cones cover each of 25 seed spots on which four seed were sown.

Plots were hand-weeded once or twice during the first growing season, depending on degree of overtopping growth.

Plots were sown with unstratified, repellent-treated seed from three seed lots for which laboratory tests indicated a germinative capacity of about 85 percent. A single lot was used each year. Seed were pressed into the soil, but were not covered. Since this study began, general recommendations are that slash seed should be damp-cold stratified to hasten germination,[2,3] and they should be covered with about ¼ inch of soil.[4] Repellent treatment was standard throughout the study: 15 percent (by weight of seed) sublimed synthetic anthraquinone and 1 percent endrin,* a latex sticker, and a light outer coating of aluminum flakes. A cone of ¼-inch hardware cloth was placed over each seed spot as added protection. Cones were removed when most seedlings for that particular sowing were about 5 inches tall.

[3]International Paper Company. Row seeding. Southlands Exp. Forest Tech. Bull. 4, 51 pp. 1964.

[4]Jones, Earle P., Jr. A test of direct seeding depths for slash and longleaf pine. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-5, 2 pp. 1963.

*Anthraquinone is considered a nonirritating compound, but endrin is highly toxic. As with any repellent or pesticide, both should be handled with caution to protect personnel and environment. After recent re-evaluation, Forest Service recommendation for use of endrin on coniferous tree seed is set at 0.5 percent active endrin.

Four seed were planted at each spot to improve the chances of having one live seedling for height measurement at the end of the second growing season. Where more than one seedling became established at a spot, all but the dominant one were removed at the end of the first year. The remaining seedlings were kept until the end of the second growing season and constituted the sample for second-year survival and total height measurements.

DATA COLLECTION AND ANALYSIS

The basic unit of observation was the "seed spot" at which four seed had been sown. A spot was counted as germinated or established at the time of inspection if it had at least one germinant or established seedling. In this discussion, a "germinant seedling" is one—standing upright, and with primary or secondary needles—in the juvenile stages of development, from germination to establishment. An "established seedling" is a normal, healthy seedling at the end of the first growing season, or beyond.

Progress of germination and seedling development were recorded in periodic inspections of treatment plots. Over the first 3 years of study, inspections were made at weekly intervals from sowing until germination virtually ceased and at monthly intervals thereafter until the end of the first growing season. In the last 2 years, only monthly inspections were made from sowing

until the end of the first growing season. Seedling heights were recorded at the last observation of the first growing season and again at the end of the second growing season.

Germination and seedling establishment were expressed as a percentage of the 25 seed spots sown on each plot. For survival, the number of established seedlings at the end of the first growing season was stated as a percentage of the number of germinated seed spots. These data were transformed to the arcsin $\sqrt{\text{percent}}$ for statistical analysis. Differences among seeding dates and among years were subjected to block analysis of variance, and seeding date means were further tested by Duncan's Multiple Range Test. Regression techniques were used to test the effect of date of seeding on second-year seedling height. Data were analyzed during the second growing season of the fifth annual replicate; thus first-year germination, survival, and establishment analyses were for five replications, but second-year survival and height analyses represented four replications. Table 1 shows components of variation and expected mean squares in all analyses of variance.

Table 1. — Components of variation and expected mean squares tested by analysis of variance

Effect	Level	Source	d.f.	Expected mean squares
Random	5	Years (Y)	4	$\sigma^2 + 8\sigma^2_{B(Y)} + 32\sigma^2_Y$
Random	4	Blocks within years (B(Y)) Error a	15	$\sigma^2 + 8\sigma^2_{B(Y)}$
Fixed	8	Seeding date (T)	7	$\sigma^2 + 5\sigma^2_{T \times Y} + 20\sigma^2_T$
		T x Y	28	$\sigma^2 + 5\sigma^2_{T \times Y}$
		Error b	105	σ^2
Total			159	

RESULTS AND DISCUSSION

Germination

Germination, based on the seed spot, was at an acceptable level for all months except May and June. The 5-year average values below (by sowing dates) show the percentage[5] of seed spots on which at least one seed germinated sometime during the first growing season:[6]

	Mar.	Nov.	Dec.	Feb.	Jan.	Apr.	May	June
	97.4	94.5	94.3	93.4	86.6	86.5	52.7	26.5
.05								

Watering before some seedings probably had very little effect on these 5-year averages, although it may have improved germination for a treatment in 1 or 2 years. There was no pattern of the waterings to suggest that any treatment was regularly watered.

Speed of germination has an important effect on seeding success. The longer seed lay dormant in the field, the greater the risk of their loss to birds and rodents because exposure causes repellent coating to deteriorate and lose some of its effectiveness. The length of time between sowing and attainment of an acceptable level of germination was greatest for the fall months. The average number of days required for 75 percent of the seed spots in a plot to germinate (a standard set arbitrarily), and the proportion of plots to reach this level of germination, are outlined below:

Seeding month	Number of days for 75 percent of seed spots to germinate	Percentage of plots that reached 75 percent germination
November	117	85
December	88	85
January	53	65
February	41	80
March	33	100
April	28	80
May	20	35
June	—	0

On this basis, March is the optimum seeding month—all the plots attained 75 percent germination in an average of 33 days. In contrast, 85 percent of the November plots

[5]Decoded from arcsin $\sqrt{\text{percent}}$ transformation after analysis.

[6]Arrays are in order of value. Values not underlined by a common line are significantly different at the level of probability indicated to the left.

reached this level in 117 days. None of the June plots reached the 75-percent level, and records show that for 3 years out of 5 none of the May plots reached it. Fall and winter seedings did not reach 75 percent germination until mid-March, some 2 to 4 months after sowing. March seedings, on the other hand, were 75 percent germinated within 5 weeks after sowing. This emphasizes the fact that most seed will not germinate until moisture and temperature conditions are adequate.

Seedling Establishment

Survival at germinated seed spots at the end of the first growing season was best for early seeding dates which allowed time for germinant seedlings to mature enough to withstand air temperatures above 90° F. Evapotranspiration is high during the summer, and roots and leaves must be adequately developed to control water loss from seedlings. Five-year average survival percentages among the eight seeding dates follow:[6]

	Mar.	Feb.	Dec.	Jan.	Nov.	Apr.	May	June
	85.9	81.6	78.9	78.5	73.6	72.5	42.9	40.1
.05								

Among the six seeding dates from November through April, survival from the end of the first to the end of the second growing season was not significantly affected by date of seeding, although survival did vary significantly among years.

The eight seeding dates were evaluated by comparing the number of spots that resulted in at least one live seedling at the end of the first growing season with the number of spots seeded. This represents the net effect of germination and survival. The percentages shown below are 5-year averages:[6]

	Mar.	Dec.	Feb.	Nov.	Jan.	Apr.	May	June
	76.0	68.4	65.9	64.8	55.7	53.9	22.8	10.9
.01								

The progress toward seedling establishment for each seeding date is plotted for 5 years in figure 2. Untransformed treatment means are represented in the graph, and for this reason the end-of-season values do not match exactly with the array above (which was decoded from the arcsin $\sqrt{\text{percent}}$ transformation used in the analysis).

May and June are obviously not desirable seeding dates. Of the 20 treatment plots for each sowing date during the 5 years of study, May had no seedling establishment on 8 plots, and June had none on 10 plots. April had the only other zero recorded for seedling establishment. Although the 5-year averages show April sowings did fairly well, these plots were never sown later than the ninth of the month. Because May is often a low-rainfall month, sowing later in April would probably not do as well as the early-April sowings in this study.

"Tree percent" is an expression often used in judging direct seeding results. It expresses the number of individual seedlings established as a percentage of the number of seed sown. Although not a part of the study analysis, tree percent was calculated from the data because a specified quantity of seed (100) had been sown on each plot (four seed at each of 25 spots) and establishment observations included a count of individual seedlings. The 5-year tree percent averages follow the same pattern as the seedling establishment data at the end of the first growing season—there is little variation in establishment from November through April, but May and June are perceptibly lower (fig. 3). Since tree percent represents survival (at the end of the first growing season in this case), an approximate measure of mortality can be added, and the total very nearly represents all germination[7] during the first growing season.

Dominant Seedling Height

The dominant seedling at each spot was selected at the end of the first growing season, and other seedlings were removed. The dominant seedlings were remeasured for total height at the end of the second growing season. The sample was biased to the extent that it was restricted to the best seedling at each spot; to have used a random selection or an average height for each spot would have included some seedlings whose height growth had been suppressed by the dominant ones.

May and June were poor seeding months by every criterion used for evaluation of first growing season results. For this reason, and in order to minimize the imbalance in the number of observations due to different levels of survival among treatments, May and June were eliminated from analyses of second-year heights. For the six remaining dates, average heights of dominants per plot at the end of the second growing season were weighted by the number of observations and

[7]Although records showed the number of germinant seedlings at each spot, total germination could not be exactly ascertained because individual seed were not identified. For example, the tally may have shown that only two seed germinated at a given seed spot, when, in fact, all four had germinated but only two were alive at any one time.

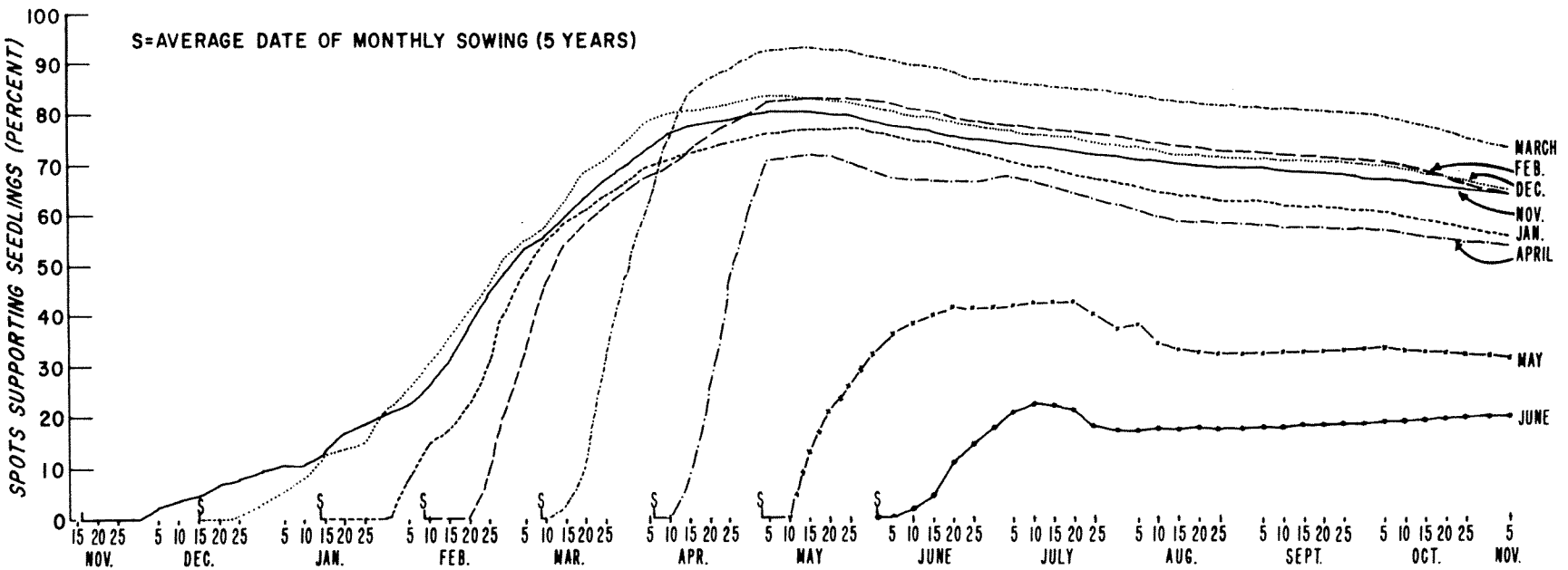

Figure 2. — Spots with at least one live seedling, as a percentage of the number of spots sown. Plotted values are 5-year averages of untransformed treatment means.

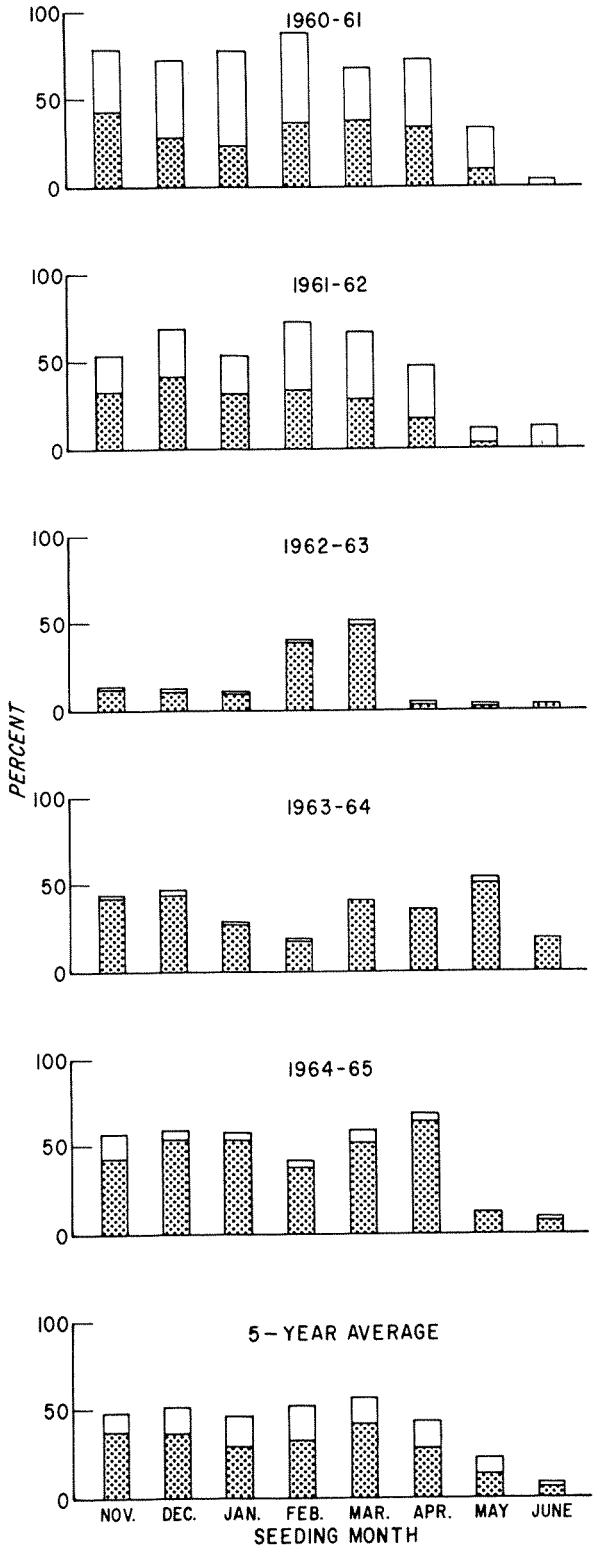

Figure 3. — Tree percent (shaded bar) at the end of the first growing season is based on the number of seed sown rather than the number of seed spots. An approximate measure of mortality is added (white bar), and the whole bar represents all germination.

analyzed by regression methods. Year of seeding had no significant effect on seedling height. Although there was a significant difference in height, among the six seeding months, it principally resulted from the lower response in April; the other means represented a homogeneous set. Four-year plot averages (inches) follow:[6]

	Nov.	Dec.	Mar.	Feb.	Jan.	Apr.
	15.52	15.42	15.15	14.57	13.67	10.56
.05						

Although statistically significant, the difference of 5 inches between the extremes at this young age would probably not really influence the ultimate height growth of trees from seed sown at different months from November through April.

Weather Factors

Over the 5 years of study, germination was best when daily high temperatures were between 70° and 90° F., provided moisture was adequate. This was generally indicated for each year by the changes in numbers of germinant seedlings in response to changes in weather. For example, in the 1962-63 and 1964-65 study years, daily high temperatures were frequently above 70° throughout the winter, and seed sown in November and December germinated earlier than usual.

Early germination followed by severe freezing resulted in heavy losses in the November and December 1962 seedings. In both cases, 30 percent of the spots had germinant seedlings by 7 weeks after seeding. But November plots suffered from a 25° F. low on January 2, and both November and December plots sustained a freeze from an 8° low on January 24 which was preceded by heavy rains. Damage was not caused by frost heaving; instead, the tissue froze, as evidenced by a shriveled and blue-black appearance of the dead seedlings. In the 5 years of observations, these were the only setbacks in the progress toward seedling establishment during cold weather. In other years, cold weather only delayed the start of germination or slowed it after it had begun.

Very hot weather also appeared to have a limiting effect on germination and the number of germinant seedlings. In all 5 years, summer air temperatures above 90° were coupled with a leveling off or decline in the number of germinant seedlings. However, evidence does not clearly indicate whether high air temperature or low soil moisture is the more limiting factor for germination and seedling survival. In 1961 and 1962 there was a marked decline in the number of germinant

seedlings for all sowing dates immediately after daily temperatures began to rise above 90°; but part of the mortality could also be ascribed to the low rainfall in those years. Daily high temperatures were usually above 90° when May and June plots were germinating, and peak germination values for these sowing dates were generally very low. One exception was in 1964, a year of abundant rainfall. Despite daily highs above 90°, May had established seedlings on 94 percent of its spots (the best for any sowing date that year) and June averaged 59 percent seedling establishment (the highest attained in June during the 5 years of study). Obviously, ample moisture sustained germination and survival during the high temperature period.

Annual rainfall during years of this study was 44 inches in 1960, 40 in 1961, 37 in 1962, 50 in 1963, 72 in 1964, and 54 inches in 1965; the 6-year mean was 49 inches. May had the lowest rainfall of the spring months, averaging 2.19 inches for the 5 seeding years. The 18-year (1948-65) mean annual precipitation was 47.45 inches. Rainfall and air temperature observations were recorded at the George Walton Experimental Forest weather station, 2 miles from the study site.

CONCLUSIONS

From this study in which unstratified slash pine seed were direct seeded at 4-week intervals from November to June, the following conclusions should be applicable in the middle and upper coastal plains of Georgia:

1. Although November seedings did very well in the protected field plots in this study, such early dates should be avoided where birds and rodents are likely to be a nuisance. The longer seed lay dormant in the field, the greater the risk of loss to these agents. Stratification will hasten germination, but tender germinant seedlings from early seedings may freeze.

2. Seeding should be timed so the germinative process will commence, preferably with minimum delay, when daily high air temperatures are above 70° F. and be completed before temperatures reach 90° F.

3. Temperatures in May and June are usually too high for survival of newly germinated and succulent pine seedlings.

4. Direct seeding in the latter half of April is risky because May is often a low-rainfall month in the middle and upper coastal plain areas of Georgia.

5. For most years seeding from December to mid-April will be successful, but mid-February through March should be considered the optimum season for direct seeding slash pine.

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