Growth and Survival of Slash Pine Seedlings in a Florida Nursery

Robert A. Haack

Research entomologist, USDA Forest Service, North Central Forest Experiment Station, East Lansing, MI

*Growth and development of slash pine (*Pinus elliottii *Engelm.) seedlings were monitored. About 11.5% of the seedlings died: 10.8% due to disease, 0.4% due to insects, 0.2% due to weather, and 0.1 % due to mechanical factors. The cull rate at lifting was influenced by the frequency of top pruning (once versus twice) and seedling density.* Tree Planters' Notes 39(2):30-36; 1987.

Knowledge of normal seedling growth and survival enables nursery managers to promptly identify abnormalities in their nursery stock (15). Growth and survival studies of slash pine (*Pinus elliottii* Engelm. var. *elliottii*) nursery stock have been reported from Georgia (11) and Louisiana (10) but not Florida. Slash pine is the principal forest tree in Florida, with over 5 million acres of plantations under intensive management (12).

To obtain desirable seedling densities at lifting, nursery managers adjust their sowing rates according to results of laboratory germination tests as well as the expected losses between germination and lifting (usually 10 to 30%) based on years of experience (15). The objectives of this study were a) to monitor growth and development of slash pine seedlings and b) to determine the cause, impact, and seasonality of seedling losses in a northcentral Florida nursery.

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Methods

This study was conducted at the Andrews Nursery (Florida Division of Forestry) in Chiefland, FL, during 1982. This nursery is typical of other Florida nurseries on sandy sites. Some of the 1982 management practices relevant to this study were: 1) spring soil fumigation with MC-33 (67% methyl bromide and 33% chloropicrin) at 350 pounds per acre; 2) pre-sowing fertilization with 15-0-15 (N-P-K) at 300 pounds per acre followed by two top-dressing applications of ammonium nitrate and 22-22-11 (Su-K-Mg), each at 150 pounds per acre; 3) repeated applications of ferbam for control of fusiform rust; 4) overhead irrigation when needed; 5) herbicide applications of oxyfluorfen (Goal) at 4-week intervals from time of sowing through August; and 6) two top prunings, one in late August and one in late September.

Slash pine seeds from four seedlots were planted between 29 April and 3 May in eight seedbeds; hence, 1 May will be used as the average planting date. Four beds were mulched with hydromulch and the other four with pine straw.

Seedlings were sampled biweekly from May through mid-June and then monthly through October. To monitor seedling growth, 10 seedlings were randomly selected and removed from each of the eight seedbeds (but not from sample plots) on each sampling date. Seedlings were removed from the two outermost drills on either side of the bed, put into labeled bags, and refrigerated until examined. Top height, stem diameter at ground line, and root length were recorded for each seedling. Observations were made on timing of seed coat loss, primary and secondary needle appearance, branching, bark and terminal bud formation, lateral root development, and root colonization by mycorrhizal fungi.

Seedling survival was monitored in 40 plots (1 foot long by 4 feet wide) positioned across seedbeds and randomly located throughout the eight beds (five plots per bed). The plots were established immediately after sowing so that all seeds could be located. To enable individual seedling recognition, eight maps were made per plot, one corresponding to each of the eight seed drills per bed. The maps

were drawn on 12-inch wooden garden labels, showing the location of each seed and eventual seedling. Dates of germination and mortality (if it occurred) were recorded for each seedling on the 320 maps. The probable cause of seedling death was determined on the basis of field and laboratory observations and tests.

The effects of top pruning on seedling cull rate were studied in the four beds with hydromulch. On 15 August, each seedling less than 15 cm tall was so designated on the appropriate map. All 20 plots in these four beds were top pruned in late August, and 10 of these were again top pruned in late September.

On 6 November, 27 weeks after sowing, all seedlings from each of three drills per plot were removed from the 20 plots. The drills were randomly selected within each plot; however, one drill was always an outside drill, while the other two were selected among the inner six drills. Seedlings from each drill were placed between two strips of masking tape in the same order that they had been growing. Similar measurements to those mentioned above as well as whether top pruning had occurred were recorded for each seedling.

Results and Discussion

Seedling Growth. Development of seedlings in the four seedlots was similar and thus the data were pooled. Within 2 weeks of sowing, over 70% of the seeds had germinated and taken root (table 1). Germination was nearly complete within 4 weeks of sowing. Similarly, Huberman (10) found that most seeds of southern pines germinated between 12 and 20 days after sowing.

Once a seedling was established, root growth occurred more rapidly than top growth (fig. 1). Rapid elongation of the primary root continued through mid-July, but elongation virtually stopped thereafter. Lateral roots were not present on any seedling collected 2 weeks after sowing, but they were found on nearly all (98%) seedlings within 4 weeks. Huberman (10) reported a similar pattern of root growth for slash pine seedlings. In other studies (15), root length was found to be influenced by soil texture and soil moisture. Hence, the long tap roots observed in this study may, in part, reflect the sandy soils at Andrews Nursery. Mycorrhizae were first observed on a few seedlings collected in July, while nearly all seedlings were well-colonized by September (table 1).

Seedling top growth followed a sigmoidal curve (fig. 1). Top growth was slow during the first 6 weeks after sowing, consisting mostly of elongation of the stem (epicotyl) and cotyledons, and emergence and elongation of the primary needles. Seed coats were still attached to most (82%) seedlings 2 weeks after sowing; however, within 4 weeks most seed coats were shed (table 1).

Table 1—*Seasonal occurrence of various growth characteristics of slash pine seedlings (80 per sampling date) planted 1 May and tested 2 to 10 weeks later*

Seedling growth characteristic	Percent of seedlings						
	2 wks (15 May)	4 wks (30 May)	6 wks (13 June)	11 wks (17 July)	15 wks (15 Aug.)	20 wks (18 Sept.)	24 wks (16 Oct.)
Germination	71	98	99	100	—	—	—
Mycorrhizae	0	0	0	23	59	92	100
Seed coat attached	82	13	8	2	1	1	1
Cotyledons expanded	18	97	99	100	—	—	—
Primary needles	0	94	98	99	100	—	—
Secondary needles	0	0	0	95	99	100	—
Woody stems	0	0	59	98	99	99	99
Branches	0	0	0	55	45	60	44
Terminal bud	0	0	0	0	0	0	15

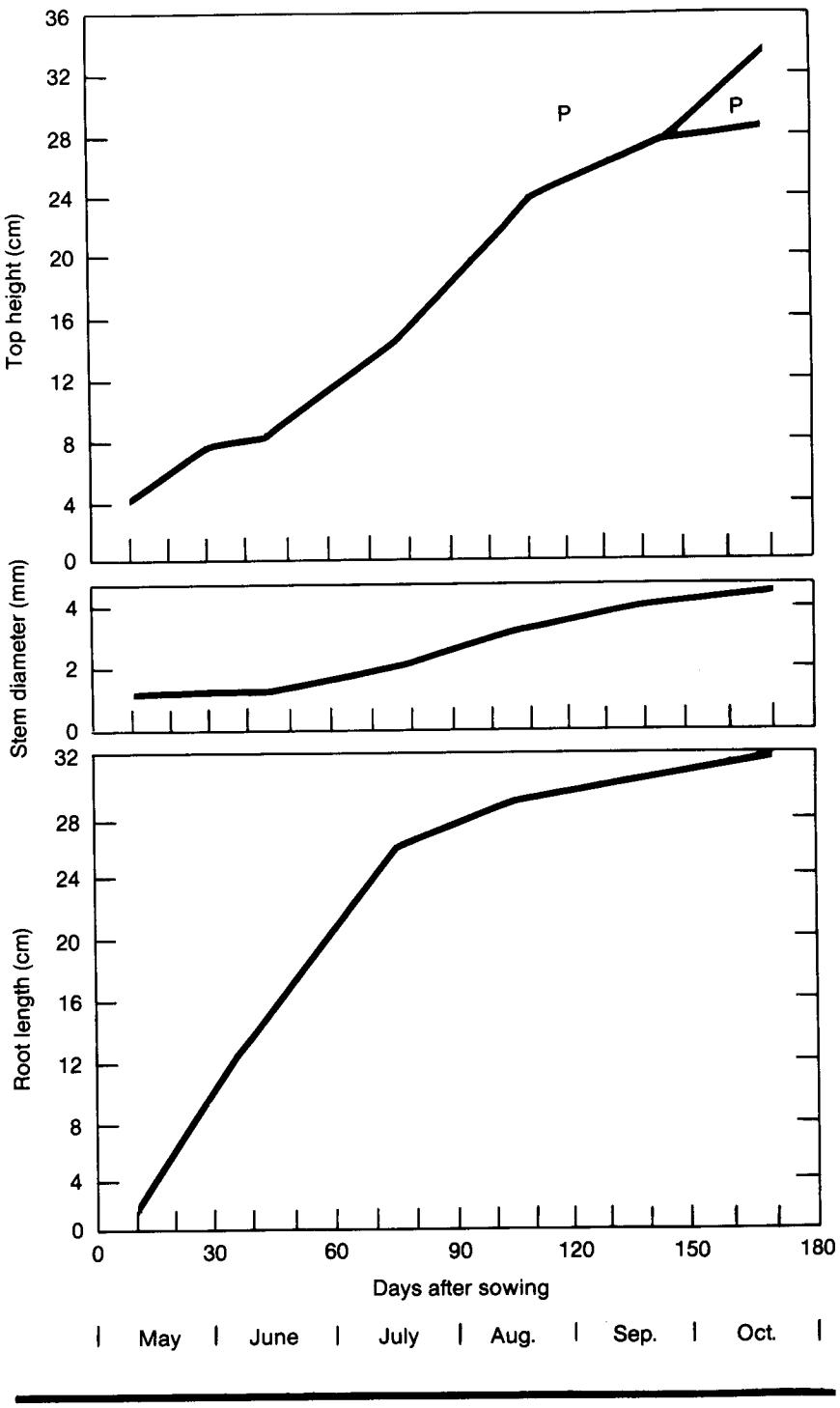

Figure 1—*Cumulative top, stem, and root growth of slash pine seedlings sown on 1 May. P = top pruning of all (August) or half (September) of the sample plots.*

Cotelydons were expanded (free of the seed coat) on 18% of the seedlings within 2 weeks of sowing and on nearly every seedling within 4 weeks (table 1). Primary needles appeared on almost every seedling within 4 weeks of sowing; secondary needles (needles in fascicles) appeared on most seedlings within 11 weeks of sowing (table 1).

Stem diameter increased very little during the first 6 weeks after sowing, but thereafter it increased rapidly (fig. 1). The lower stems of some seedlings changed from green and soft to reddish and woody within 6 weeks of sowing (table 1). Branches were first observed on seedlings collected in July, with about half the seedlings possessing branches on each sampling date thereafter (table 1).

Terminal buds were first present on seedlings collected in October (table 1). Of the 12 seedlings with terminal buds, 3 had been top pruned and the other 9 had not. The effects of top pruning on seedling height are shown in figure 1. In most respects, the patterns of early seedling growth recorded here were similar to those reported by Huberman and Rowan (10, 11). However, seedling growth after initial establishment appeared much faster in this study, probably reflecting the warmer temperatures of Florida.

Seedling Survival. Of the 6,865 seeds sown in the 40 plots, 77% successfully germinated and rooted (table 2). Average laboratory germination for these seedlots was 88%. Although not quantified, some of the 1,553 seeds classified as dead (table 2) could have died from pre-emergence damping off, failure to root, or other causes. Of the 5,312 seedlings that successfully rooted, 11.5% died by the last sampling date-i.e., 24 weeks after sowing (table 2); seedlings were lifted in late November. Such losses are similar to those (11 to 12%) reported recently by other southern nurseries (4). Six factors were identified as causing seedling mortality (table 2): two are diseases (post-emergence damping off and pitch canker), two are insects (cutworms and pine webworm), one is weather (rain-induced erosion), and one is mechanical (tire damage).

Of the seedlings that died, over 90% apparently succumbed to damping off (table 2); however, sun scald may have killed some. Losses to damping off occurred early in the growing season, with mortality appearing earlier (but not more severely) in beds mulched with hydromulch as compared with pine straw. In hydromulch plots, 71% of the 258 damped-off seedlings died prior to 30 May (4 weeks after sowing). In contrast, 78% of the 293 damped-off seedlings died after that date in plots with pine straw. Damping-off organisms may develop differently under these two mulches due to possible variations in microenvironments.

Identifiable losses to pitch canker occurred late in the growing season (table 2), or at least that is when diseased seedlings became evident-i.e., foliage turned from green to red. This fungal disease has been recognized only recently as a threat to nursery stock (1). Infected seedlings often occurred in groups, with each seedling having a resin-soaked stem canker near the ground line.

Insects were far less damaging than diseases when comparing total seedling losses-i.e., 3

Table 2—*Survival and mortality of slash pine seedlings*

Sampling date (wks after sowing)	Seeds or seedlings			Seeds or seedlings killed						
	Alive									
	Total	No./ft²	Dead	Seed death[1]	Damping off	Pitch canker	Cutworm	Webworm	Erosion by rain	Mechanical
Survival (No.)										
1 May (0)	6,865	43	0	0	0	0	0	0	0	0
15 May (2)	5,290	33	1,575	1,553	21	0	1	0	0	0
30 May (4)	5,058	32	1,807	0	224	0	8	0	0	0
13 June (6)	4,796	30	2,069	0	250	0	0	0	8	4
17 July (11)	4,739	30	2,126	0	56	0	0	0	1	0
15 Aug. (15)	4,722	30	2,143	0	0	7	0	9	0	1
18 Sep. (20)	4,703	29	2,162	0	0	17	0	2	0	0
16 Oct. (24)	4,702	29	2,193	0	0	1	0	0	0	0
Total				1,553	551	25	9	11	9	5
Mortality (%)										
Of all 6865 seeds				22.6	8.0	0.4	0.1	0.2	0.1	0.1
Of all 5312 seedlings					10.4	0.5	0.2	0.2	0.2	0.1
Of the 610 dead seedlings					90.3	4.0	1.5	1.8	1.5	0.9

[1]All seeds were considered viable at time of sowing.

versus 94%. Similar loss patterns have been reported (8). Early in the growing season, cutworms were responsible for the insect-related mortality (table 2). Cutworms, which feed mostly at night, are caterpillars of moths in the family Noctuidae. All cutworm-damaged seedlings were in the cotyledon stage. Characteristic damage is a seedling bitten through the stem near the ground line. Some cutworms were found just under the soil in close proximity to damaged seedlings during the daytime. Although losses were small in this study, cutworms are potentially very destructive (15).

Pine webworms were found defoliating seedlings late in the growing season (table 2). Pine webworms are larvae of moths in the family Pyralidae. Early larval stages mine needles when small, but later larval stages feed externally and form communal "frass nests" within the foliage. This insect can complete three generations per year in north Florida (9). The larvae observed in this study were probably members of the second generation, the offspring of moths that recently had completed development on pines in nearby stands.

Some seedling losses resulted from weather and mechanical factors (table 2). Twice, heavy rains eroded soil from around seedlings (in the outermost drills only), exposing roots to desiccation. Similarly, on two occasions during regular nursery operations, a tractor tire hit and dislodged soil from the side of the bed. This resulted in roots of a few seedlings being exposed to the sun, which eventually resulted in their death.

Two weeks after sowing, at which time 98% of the seeds had germinated, the initial seedling density was 33 seedlings per square foot (43 seeds per square foot sown) (table 2). Although the density desired at lifting was 27 seedlings, 29 seedlings per square foot occurred. This density is close to the range (25 to 28) recommended for slash pine (5).

Effects of Top Pruning. Seedlings are top-pruned to improve the shoot-to-root ratio, produce seedlings of more uniform height, reduce the number of cull seedlings, and improve field survival (7). In this study, the effects of top pruning once (392 seedlings) versus twice (427 seedlings) on seedling cull rate were determined using Wakeley's (15) slash pine standards for minimum height (15 cm), maximum height (33 cm), and minimum stem diameter (3.2 mm).

Between 15 August and 6 November, the number of seedlings under 15 cm in height decreased from 4.8 to 1.5% in once-pruned plots (69% reduction), and from 4.7 to 0.2% in twice-pruned plots (96% reduction). These data indicate that more seedlings were released from competition when top pruning occurs twice rather than once.

Seedlings much over 33 cm tall are often culled because they are not easily handled during mechanical planting and they tend to be easily wind whipped and die of desiccation after outplanting (15, 17). In this study, none of the twice-pruned seedlings was more than 33 cm tall. However, 77% of the once-pruned seedlings were oversized. These data suggest that slash pine seedlings will usually require two top prunings under Florida conditions.

Seedling stem diameters 27 weeks after sowing (2 to 3 weeks prior to lifting) ranged from 0.8 to 8.2 mm. Average stem diameter was larger for seedlings from outside drills (4.6 mm, N = 268) than from interior drills (4.1 mm, N = 551). Hence, the stemdiameter values presented in figure 2 may be slightly overestimated because seedlings in only the outer drills were selected. Using Wakeley's 3.2 mm as the minimum acceptable stem diameter for slash pine seedlings, cull rates were similar (17% between once-pruned and twice-pruned plots).

Cull rate, based on minimum stem diameter, was affected by

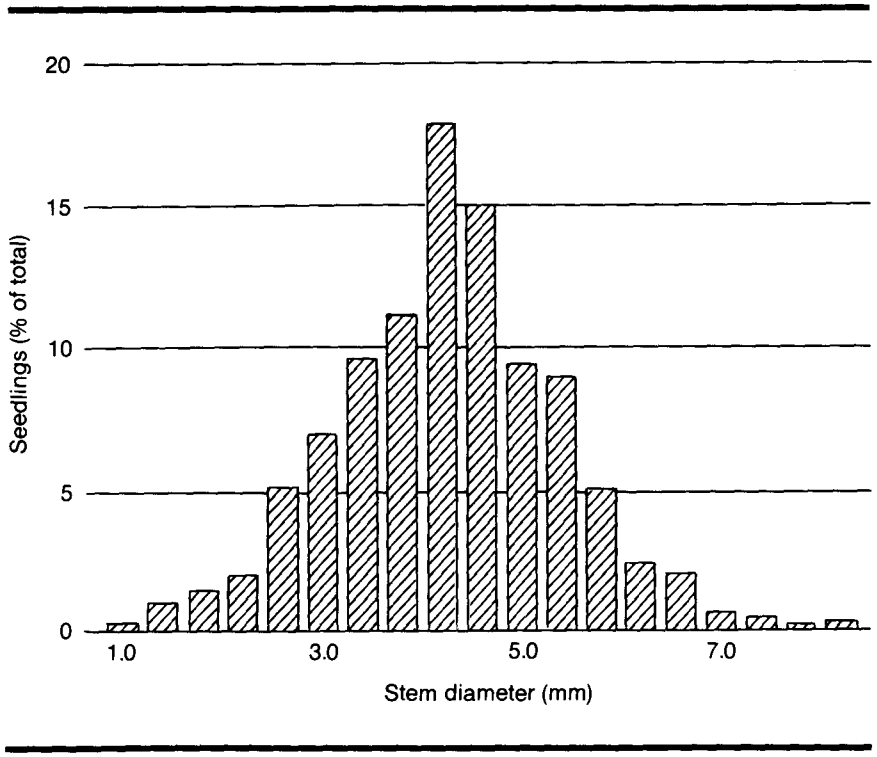

Figure 2—*Distribution of slash pine seedlings by 4-mm stem diameter classes when lifted in November, 27 weeks after sowing.*

seedling density—i.e., the number of seedlings per 1-foot drill. In this study, cull rate was positively correlated (r^2 = 0.6) with seedling density. The highest number of culls was 14 when 29 seedlings grew in a single 1-foot drill. There were usually 1 to 2 culls when 12 to 14 seedlings were growing per 1-foot drill.

Hence, besides selecting the proper initial sowing rate, spacing the seed evenly within the drills is also very important in regulating seedling quality, and thus their grade. In other studies, high seedling densities resulted in more low-grade (cull) seedlings (6, 13). This is an important consideration for southern pines because several studies have reported that seedling grade was directly related to eventual field performance (3, 6, 14, 16) .

Several nursery practices at the Andrews Nursery have changed since 1982. These include: (1) planting in early April instead of late April, (2) mulching with chopped coastal Bermudagrass hay, wood chips, or bark chips instead of hydromulch or pine straw, (3) use of bay meb 6447 (Bayleton) rather than ferbam for fusiform rust control, and (4) root pruning. These new practices will most likely alter the seasonal patterns reported in this study. For example, earlier planting should shift many of the growth and mortality parameters forward in time; the new mulches could change the seedbed microenvironment, thereby altering patterns of germination and disease incidence; use of Bayleton may slow mycorrhizal colonization because it is known to inhibit their growth (2); and root pruning may reduce the rate of top growth as well as induce greater development of lateral roots (5).

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