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by

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Early Growth and Development of Slash Pine Under Drought and Flooding[1]

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INTRODUCTION

The semitropical pattern of precipitation in south Florida poses a difficult problem for direct seeding of pine. Monthly rainfall during December, January, and February averages less than 2 inches. It is not unusual to go without measurable precipitation during any one of these months. Moreover, rains during this period usually are of less than half an inch and are ineffective in replenishing soil moisture.

In contrast, June, July, August, and September average 8 inches or more per month. An occasional 15 inches fall during a single month, and in a single rain 4 inches or more are common. During summer and early autumn, water usually stands above the soil surface over south Florida's wet prairies and much of the pine flatwoods. Rainfall decreases sharply in October. November precipitation is usually as low as that of the following winter months, but soil moisture during the autumn is often ample to excessive, depending on the amount of rain during the preceding months.

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[1] The authors were formerly stationed at Fort Myers, Florida. The study was presented in a thesis by McNab to the Graduate Council of the University of Florida in partial fulfillment of the requirements for the degree of Master of Science in Forestry (McNab, W. Henry. Response to drought and flooding of two varieties of slash pine in south Florida. Unpublished Master's thesis, Univ. Fla. 1965).

Extreme moisture conditions are adverse to the growth and development of pine seedlings and, therefore, are problems to be resolved if direct seeding is to be successful in south Florida. Establishing slash pine by direct seeding may be the most economical way to reforest millions of acres of cutover pineland in this area when there are insufficient seed trees for natural regeneration. The influence of seeding depth and season on germination and survival has been presented in an earlier paper.[2] However, techniques that will insure consistent establishment of seedlings must be developed. Determination of tolerance to drought and flooding of newly established pine seedlings in south Florida is essential for development of reliable seeding techniques.

The objective of this study was to determine the growth and development of typical slash pine (*Pinus elliottii* var. *elliottii*) and South Florida slash pine (*Pinus elliottii* var. *densa* Little & Dorman) seedlings under varying levels of winter drought and summer flooding. The study was conducted in Charlotte County, Florida, on the Caloosa Experimental Range, in cooperation with the Babcock Florida Company and the Florida Division of Forestry.

METHODS

Oil drums (55-gallon) were steam-cleaned and cut in half to form open-top cans 17 inches tall. Twenty-seven cans were arranged in two groups, by pairs, with the long axes extending north and south (fig. 1). The study was divided into three blocks of nine cans each. Each can constituted a whole plot, and the two varieties of slash pine planted in each can constituted two subplots. A wooden wall was built around each group to retain sawdust packed between the drums for insulation.

Four inches of gravel were placed in the bottom of each can. The cans were then filled with Adamsville fine sand surface soil. After being watered-down, the soil was about 11 inches deep and its surface was about 2 inches below the top of each can. Water level was controlled by inserting a stoppered drain hose near the bottom of each can. The installation was sheltered from precipitation by arches of steel pipe covered with clear plastic. Practically no shadow was cast by this structure, and there was free circulation of air.

The soil-filled cans were treated with methyl bromide to eliminate weed growth. Surface litter from pine flatwoods was spread on top of the soil, and seed were evenly sown in mid-December 1963. No attempt was made to plant the seeds, but they were watered frequently to ensure good germination. The seeds germinated promptly, and seedlings were thinned to 30 in each subplot.

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[2] McMinn, James W. Optimum depth and season for direct seeding slash pine in south Florida. Southeast. Forest Exp. Stn., USDA Forest Serv. Res. Pap. SE-73, 7 pp. 1970.

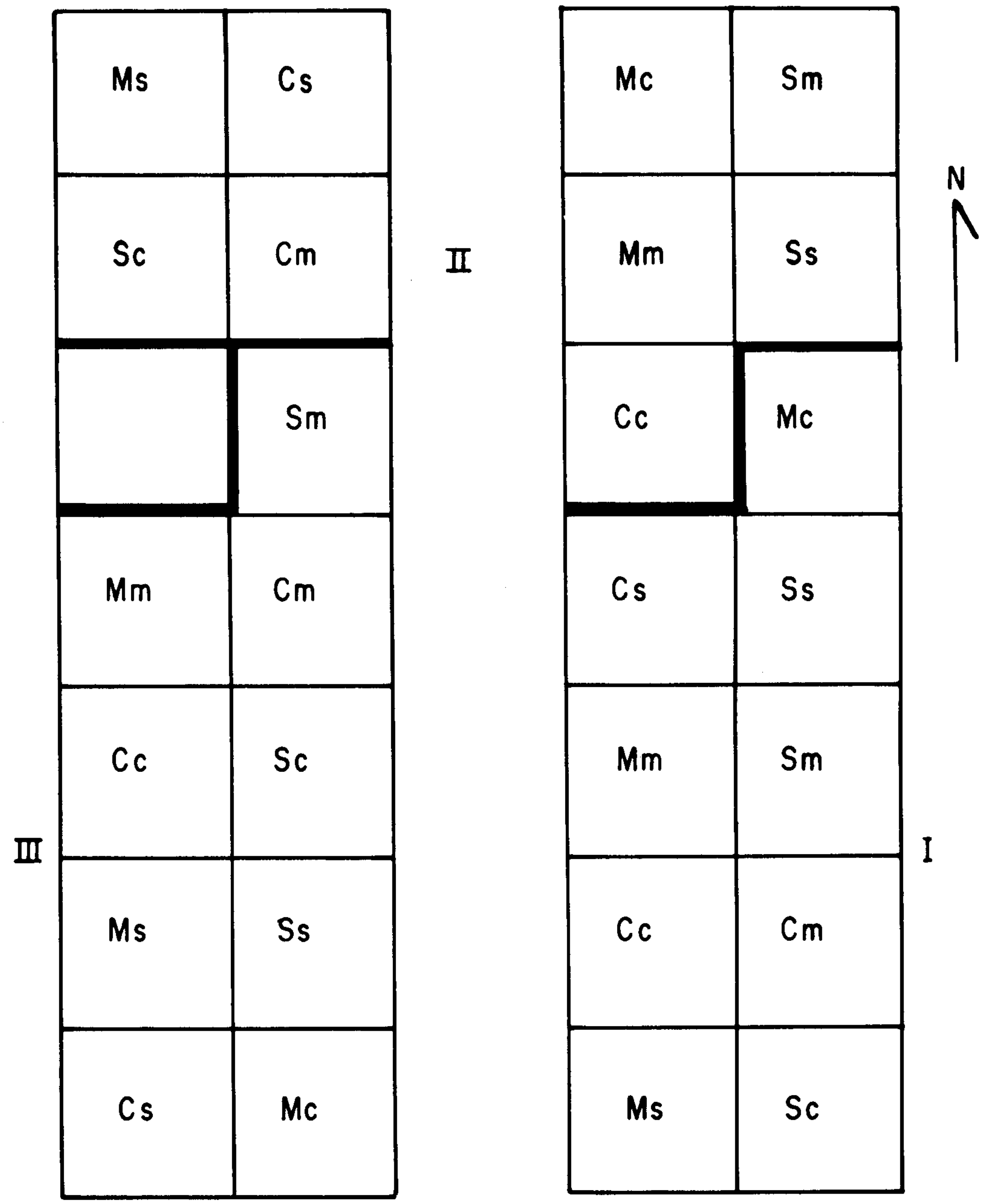

Figure 1.--Arrangement of blocks and whole-plots (cans). Roman numerals designate blocks, uppercase letters denote drought treatments (control, mild, severe), and lowercase letters denote subsequent flooding treatments.

Drought treatments were begun on January 9, 1964, and continued through the following May. Flooding treatments were started in June and terminated the last week of August 1964. Three levels of drought were followed by three levels of flooding. The nine combinations were randomly assigned to the nine whole-plots (cans) within each block.

Levels of drought treatment were:

Control--An approximation of field capacity. Soil moisture was held between 12 and 20 percent and averaged 16 percent.

Mild drought--No water applied until April 1, when the mean moisture level of the soil at 2 inches was 5 percent. Soil moisture was then held between 5 and 10 percent.

Severe drought--Gradual depletion approximately to the wilting point. These plots were not watered until June 1, just before initiation of the flooding phase, when watering was necessary to prevent excessive mortality. At that time the mean moisture level was 4 percent.

The estimate of field capacity was obtained from measurements made directly on the soil in the cans. Wilting point was estimated from laboratory determinations on similar soils from southern Florida. Levels of drought treatment were checked by gravimetric samples in the surface 3 inches of soil. Moisture fluctuation and sampling error were large. The 5-percent confidence intervals of the mild and severe treatments overlapped throughout the drought phase of the study.

Levels of flooding treatment were:

Control--Water level maintained 12 inches below the soil surface.

Mild flooding--Water level maintained for consecutive 2-week intervals at the following depths from the soil surface: 12 inches below, 6 inches below, 1 inch above, and 6 inches below. At the end of the 8 weeks, the cycle was repeated.

Severe flooding--Water level maintained at least 1 inch above the soil surface.

During the flooding phase, water levels were checked at 2-day intervals in 1/2-inch plastic pipe wells which were installed in the center of each can.

Seedling traits were observed at the end of the drought phase in mid-May and at the end of the flooding phase in August 1964. The following aboveground observations were made:

1. Seedling height from the ground line to the tip of the terminal bud

2. Seedling weight

3. Live crown (height and weight)

4. Stem below the live crown (height and weight)

5. Needle number, length, and dry weight.

Below-ground observations were as follows:

1. Taproot length
2. Number of primary and secondary roots
3. Mycorrhizae (number)
4. Weight of root system.

Five seedlings from each subplot were excavated and observed; all subplots were large enough for the initial five to be excavated at the termination of the drought phase with an ample number of undisturbed residuals for subsequent flooding. Data referred to in the following sections are from the August 1964 observations and were subjected to an analysis of variance appropriate to the study design.

RESULTS

Shoot Development

Height of variety elliottii decreased with increasing drought severity (table 1). Average height of this variety under severe drought was only 77 percent of that under the control. Only the most severe drought treatment reduced the height of variety densa, and then only 10 percent below the control.

Both mild and severe flooding retarded height growth of variety elliottii; severe flooding had a less drastic effect than severe drought. Variety densa was unaffected by flooding.

Aboveground weight of both varieties was highest under mild drought and lowest under severe drought (table 2).

Table 1.--Height of elliottii and densa varieties in response to drought and flooding[1]

Treatment and level	Variety: elliottii		Variety: densa	
	Cm.	Percent of control	Cm.	Percent of control
Drought				
Control	14.3	100	7.3	100
Mild	13.0	91	7.5	103
Severe	11.0	77	6.6	90
Flooding				
Control	13.8	100	7.0	100
Mild	12.3	89	7.3	104
Severe	12.2	88	7.0	100

[1]Both variety x drought and variety x flooding interactions significant at the 0.01 level.

Table 2.--Aboveground weight of elliottii and densa varieties in response to drought and flooding[1]

Treatment and level	Variety: elliottii		Variety: densa	
	Grams	Percent of control	Grams	Percent of control
Drought				
Control	0.54	100	0.88	100
Mild	.67	124	.99	112
Severe	.40	74	.62	70
Flooding				
Control	.52	100	.83	100
Mild	.49	94	.85	102
Severe	.56	108	.81	98

[1]Drought response significant at the 0.01 level; flooding response nonsignificant.

Needle Development

None of the observed needle characteristics of the two varieties were affected by flooding. Number of needles per seedling was greatest under mild drought and least under severe drought (table 3). Seedlings from the severe drought treatment had about 10 percent fewer needles than did control seedlings.

Table 3.--Needle characteristics of elliottii and densa varieties in response to drought level

Variety and drought level	Needle count[1]		Needle length[2]		Needle dry weight[2]	
	Number	Percent of control	Mm.	Percent of control	Mg.	Percent of control
elliottii						
Control	101	100	40	100	4.0	100
Mild	120	119	45	112	4.6	115
Severe	91	90	36	90	3.4	85
densa						
Control	71	100	115	100	14.0	100
Mild	82	115	112	97	13.4	96
Severe	65	92	79	69	8.6	61

[1] Drought response significant at the 0.05 level.
[2] Variety x drought response significant at the 0.01 level.

In comparison with the controls, the needles of variety elliottii were about 10 percent longer under mild drought and 10 percent shorter under severe drought. Needle length of densa was about the same in the controls and under mild drought, but it decreased by approximately 30 percent under severe drought. Needle dry weight of both varieties was more sensitive in response to drought treatment, but results followed a pattern similar to that for needle length.

Development of Root System

Weight of the root systems of both varieties decreased with increasing drought (table 4). The difference between mild and severe levels was about 30 percent for variety elliottii and about 40 percent for densa. Severe flooding had a similar effect on root weight of densa, but the effect of flooding on root weight of elliottii was negligible.

Variety densa responded to both mild and severe drought with about a 40 percent increase in taproot length (table 5). Flooding had no significant effect on the development of taproots in either variety, and drought had little effect on the taproot length of elliottii.

Table 4.--Weight of the root systems of elliottii and densa varieties in response to drought and flooding[1]

Treatment and level	Variety			
	elliottii		densa	
	Mg.	Percent of control	Mg.	Percent of control
Drought				
Control	257	100	203	100
Mild	233	91	180	89
Severe	173	67	117	58
Flooding				
Control	227	100	207	100
Mild	213	94	163	79
Severe	223	98	130	63

[1] Drought response significant at the 0.01 level; variety x flooding response significant at the 0.05 level.

Table 5.--Taproot length of elliottii and densa varieties in response to drought and flooding[1]

Treatment and level	Variety			
	elliottii		densa	
	Mm.	Percent of control	Mm.	Percent of control
Drought				
Control	197	100	140	100
Mild	208	106	193	138
Severe	192	97	197	141
Flooding				
Control	195	100	184	100
Mild	200	103	184	100
Severe	203	104	162	88

[1] Variety x drought response significant at the 0.05 level; variety x flooding response nonsignificant.

Number of mycorrhizae and secondary roots per seedling were the only traits observed with a significant response to flooding but not to drought (table 6). Mycorrhizal count decreased with increased flooding to a low of around 30 percent of the control under severe flooding. Production of secondary roots showed no difference between the control and mild flooding treatments for either variety, but both varieties dropped off sharply under severe flooding. There was no significant difference in production of primary roots for any treatment.

Table 6.--Number of mycorrhizae and secondary roots per seedling on densa and elliottii varieties in response to drought and flooding[1]

MYCORRHIZAE

Treatment and level	Variety			
	elliottii		densa	
	Number	Percent of control	Number	Percent of control
Drought				
Control	51	100	38	100
Mild	52	102	34	89
Severe	36	71	23	61
Flooding				
Control	76	100	53	100
Mild	42	55	26	49
Severe	22	29	16	30
SECONDARY ROOTS				
Drought				
Control	3.6	100	2.8	100
Mild	3.0	83	1.7	61
Severe	3.0	83	1.4	50
Flooding				
Control	3.8	100	2.2	100
Mild	3.7	97	2.2	100
Severe	2.2	58	1.5	68

[1] Mycorrhizal response to flooding significant at the 0.01 level; response of secondary roots significant at the 0.05 level. Neither trait responded significantly to drought.

Ratio of root-shoot weights was not significantly affected by flooding or drought. Root-shoot ratio averaged over the entire study was 0.428 for variety elliottii and 0.218 for densa.

Varietal Differences

A significant difference between varieties occurred for nearly every characteristic observed. Following is a varietal comparison based on the observations of all seedlings excavated at the termination of the study:

Characteristic	elliottii	densa
Height (mm.)**	128	71
Aboveground weight (grams)**	0.54	0.83
Needles per seedling**	104	73
Needle length (mm.)**	40	102
Needle dry weight (mg.)**	4	12
Weight of root system (mg.)**	221	167
Taproot length (mm.)**	199	193
Longest lateral (mm.)*	162	145
Second longest lateral (mm.)*	117	105
Number of mycorrhizae*	47	32
Number of primary roots	15.0	9.6
Number of secondary roots**	3.2	2.0
Root-shoot weight ratio**	0.428	0.218

*Significant at the 0.05 level.
**Significant at the 0.01 level.

DISCUSSION AND CONCLUSIONS

Both varieties generally exhibited a more drastic response to drought than to subsequent flooding (and flooding responses were similar regardless of the drought treatment to which the seedlings had been subjected). Drought influenced height, top weight, needle number, needle length, needle weight, and weight of the root system of variety elliottii. In variety densa, the same characteristics plus taproot length were affected by drought. Flooding had a significant effect only on top length of variety elliottii, root system weight of densa, and the number of mycorrhizae and secondary roots of both varieties.

Two responses of variety densa to drought, the development of a longer taproot and a marked decrease in needle size, suggest that this variety may have evolved under more variable conditions of soil moisture than did elliottii. However, these morphological modifications alone would not necessarily mean that densa could survive and grow better than elliottii under extreme drought. Even the reduced top weights of densa were half again as heavy as those of elliottii, and the longer taproots of densa (under drought as contrasted with the control) were the same length as elliottii taproots. Therefore, only accompanying physiological modifications (which were not determined) would give variety densa an advantage over elliottii under extreme drought.

The results of this study amplify those of previous studies of slash pine. The marked decrease in production of secondary roots and mycorrhizal occurrence with flooding offers at least a tentative explanation for the positive growth response of slash pine on ridged flatwoods sites.[3] Also, the varietal differences substantiate earlier reports of the magnitude of genetic variation within Pinus elliottii.[4] [5] [6]

These findings indicate that the winter-spring drought period in south Florida is more limiting to the growth and early development of slash pine seedlings than is the subsequent wet period during the summer. Therefore, in developing and applying guides for direct seeding, research and management should focus attention on this critical period.

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[3] Bethune, J. E. Ridging--low-cost technique for increasing growth on wet flatwoods sites. Forest Farmer 23(2): 6-7, 18. 1963.

[4] Little, Elbert L., Jr., and Dorman, Keith W. Slash pine (Pinus elliottii), including South Florida slash pine, nomenclature and description. USDA Forest Serv. Southeast. Forest Exp. Stn. Pap. 36, 82 pp. 1954.

[5] Bethune, J. E. Performance of two slash pine varieties planted in south Florida. Southeast. Forest Exp. Stn., U. S. Forest Serv. Res. Pap. SE-24, 9 pp. 1966.

[6] Squillace, A. E. Geographic variation in slash pine. Soc. Am. For. Forest Sci. Monogr. 10, 56 pp. 1966.

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McMinn, James W., and McNab, W. Henry
1971. Early growth and development of slash pine under drought and flooding. Southeast. Forest Exp. Stn., USDA Forest Serv. Res. Pap. SE-89, 10 pp.

Development of typical slash pine (*Pinus elliottii* var. *elliottii*) and South Florida slash pine (*Pinus elliottii* var. *densa* Little & Dorman) was studied under conditions simulating south Florida's winter-spring droughts and summer floods. One of three degrees of flooding was imposed on seedlings which had been subjected to one of three degrees of drought. Results indicate that the drought period is more limiting to development of slash pine seedlings than is the subsequent wet period.

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