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M. V. Bilan and J. J. Stransky[1]

This study was an initial step toward further experiments exploring the possibility of establishing and maintaining pine plantations in the Texas Post-oak Belt. Before field planting tests could be installed in this area, information was needed on the effect of its soils on pine seedling behavior.

If pine plantations would succeed in the Post-oak Belt, they could replace some of its low quality hardwoods. This could be important for increasing income from forested land; an idea advocated by Bray (1904) around the turn of the century.

The Post-oak Belt's sharp western boundary is the almost treeless Blackland-Prairie. In the east, through a gradual pine-oak transition, it is bordered by the Pineywoods. The pine-oak transition—where loblolly *(Pinus taeda L.)* and shortleaf pine *(P. echinata Mill.)* reach their westernmost extension—is sometimes called the "tension zone," or "pine-fringe."

The occurrence of scattered large pines in the transition zone does not necessarily imply that they may be grown there economically for timber. West of the distribution centers of these species, their natural regeneration becomes progressively more difficult due to sparse seed crops, recurrent droughts, and competition with xerophytic oaks. Presumably, the most dependable method of pine regeneration in this area is planting, which eliminates the seed source problem and the vulnerable stages of seed germination and early seedling development.

The main objective of this study was to observe and compare the survival and growth response of loblolly pine and shortleaf pine seedlings planted in soils of the Post-oak Belt and in a Pineywoods soil. The study consisted of two parts and measured: (1) the length of time seedlings survived under simulated drought, and (2) seedling development after the plants grew in their respective soils for one year.

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METHODS AND MATERIALS

Soils

Soils for this study were collected in Anderson County; a good example of the pine-oak transition in central east Texas (Fig. 1). The western boundary of the pine forest type divides the County diagonally. The southeastern half supports pine and pine-hardwood forests. The northwestern half is occupied by the post-oak type. The isohyets closely overlap with the forest

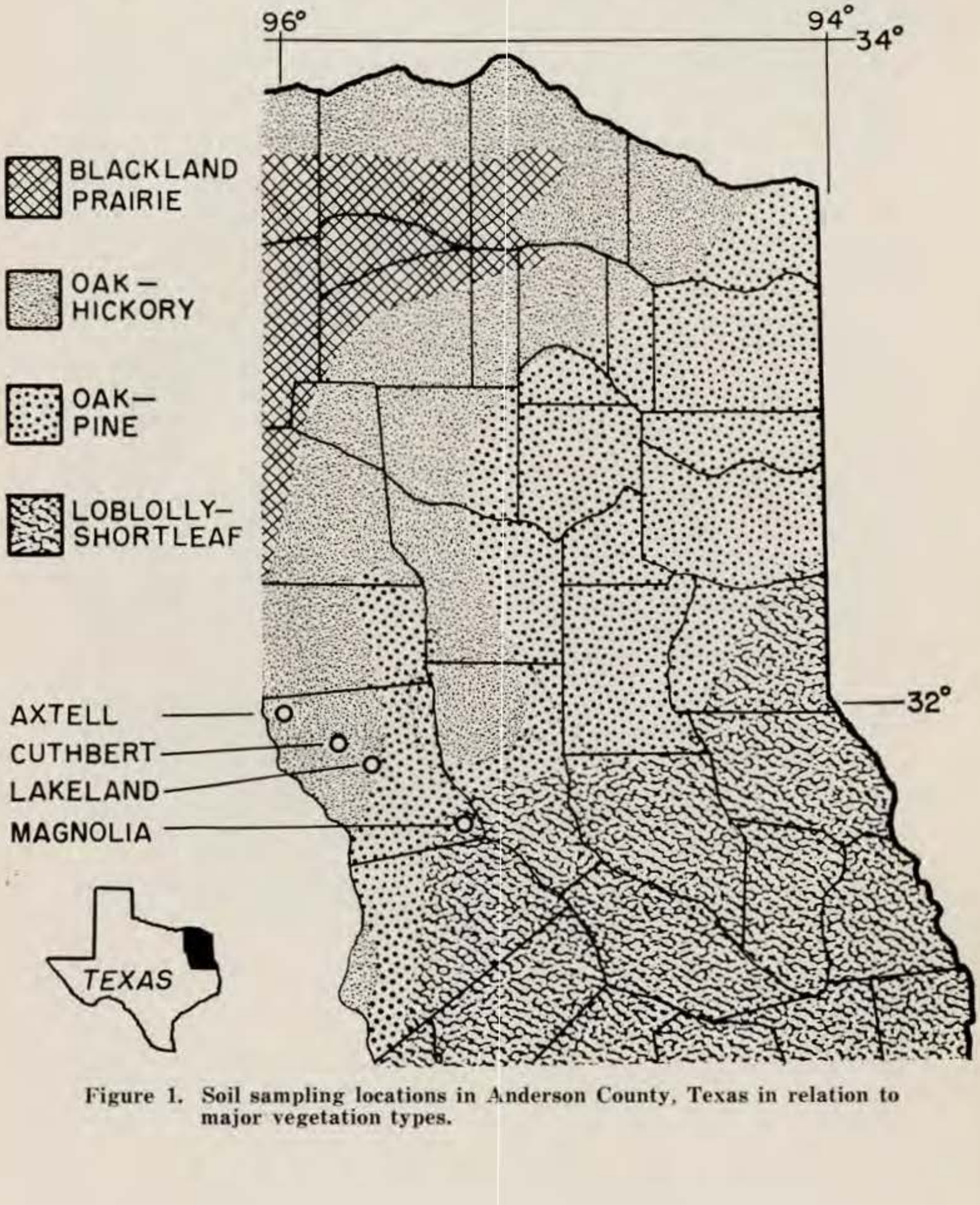

Figure 1. Soil sampling locations in Anderson County, Texas in relation to major vegetation types.

A. Magnolia

C. Cuthbert

B. Lakeland

D. Axtell

Figure 2. Vegetation types representing the four soils.

type boundaries. Average annual precipitation decreases from 44 inches in the southeast to about 40 inches in the northwest corner of the County.

Four soil sampling locations, chosen along a southeast-northwest transect running perpendicularly to the isohyets and the forest type boundaries, were selected because they represent the most frequently encountered forest soils of the County and of the entire Post-oak Belt.[2] The soil from the pine forest type was Magnolia fine sandy loam. Soils from the Post-oak Belt were Lakeland fine sand, Cuthbert stony sandy-loam, and Axtell fine sandy loam (in this order from East to West).

Magnolia soil cores were collected under a 60-year-old loblolly pine-shortleaf pine stand (Fig. 2A). It had an understory of dogwood *(Cornus florida)*, red maple *(Acer rubrum)*, red gum *(Nyssa sylvatica)*, southern red oak *(Quercus falcata)*, green ash *(Fraxinus pennsylvanica)* and rusty black haw *(Viburnum rufidulum)*. The surface of the 25-inch thick fine sandy loam *A* horizon was covered with a three-inch deep layer of leaf litter. The friable red clay *B* horizon extended below the 36-inch sampling depth.

Lakeland cores were collected from a nearly level pasture (Fig. 2B). Gray fine sand extended to a depth of 18 inches, changing gradually into grayish-yellow loamy sand extending below 36 inches.

Cuthbert samples were taken on a hilltop in a rolling landscape (Fig. 2C). The vegetation consisted of a post oak *(Quercus stellata)* overstory, having an understory of winged elm *(Ulmus alata)*, honey locust *(Gleditsia triacanthos)*, yaupon *(Ilex vomitoria)*, and red cedar *(Juniperus virginiana)*. The grayish-brown stony sandy loam top soil changed into a yellowish-brown sandy clay at the depth of 10 to 12 inches. The clay was replaced by coarse yellow sand with stones at the 34-inch depth.

Axtell soil cores were collected from a flat wooded area with an overstory of post oak and an understory of haw *(Crataegus sp.)*, red maple, green ash, and winged elm (Fig. 2D). The fine-sandy surface soil changed into reddish-yellow clay at a depth of 8 inches, which was underlain by a yellowish-gray compact clay at 24 inches.

From each soil, twenty large (9¼ by 12 inch) undisturbed cores were collected. A special power cutter was developed to extract them (Fig. 3). It consisted of a steel cylinder with a saw-toothed cutting edge, rotated by a post-hole digger connected to a farm tractor's power take-off (Stransky and Bilan 1964). This implement facilitated the extraction and insertion of cores in tightly fitting four-gallon cans having perforated bottoms. All cores were collected on the same day in early January.

As expected, the lightest textured soil was Lakeland, and Axtell the heaviest. All soils were slightly acid, Magnolia and Lakeland being nearer to neutral than Cuthbert and Axtell. For all soils, pH of the upper four inches was higher than of the lower layer. The highest acidity was found in the 8-12-inch layer of the Axtell soil (Table 1).

Except for Lakeland, all soils were rated low or very low in nitrogen, phosphate, and potash, and medium or high in calcium. The relatively high phosphate and potash content of Lakeland could have been due to burning of its love-grass cover prior to collecting the samples.

[2]The authors are grateful to Mr. W. B. Buckley, U.S.D.A. Soil Conservation Service, for his help in locating and typing the soils.

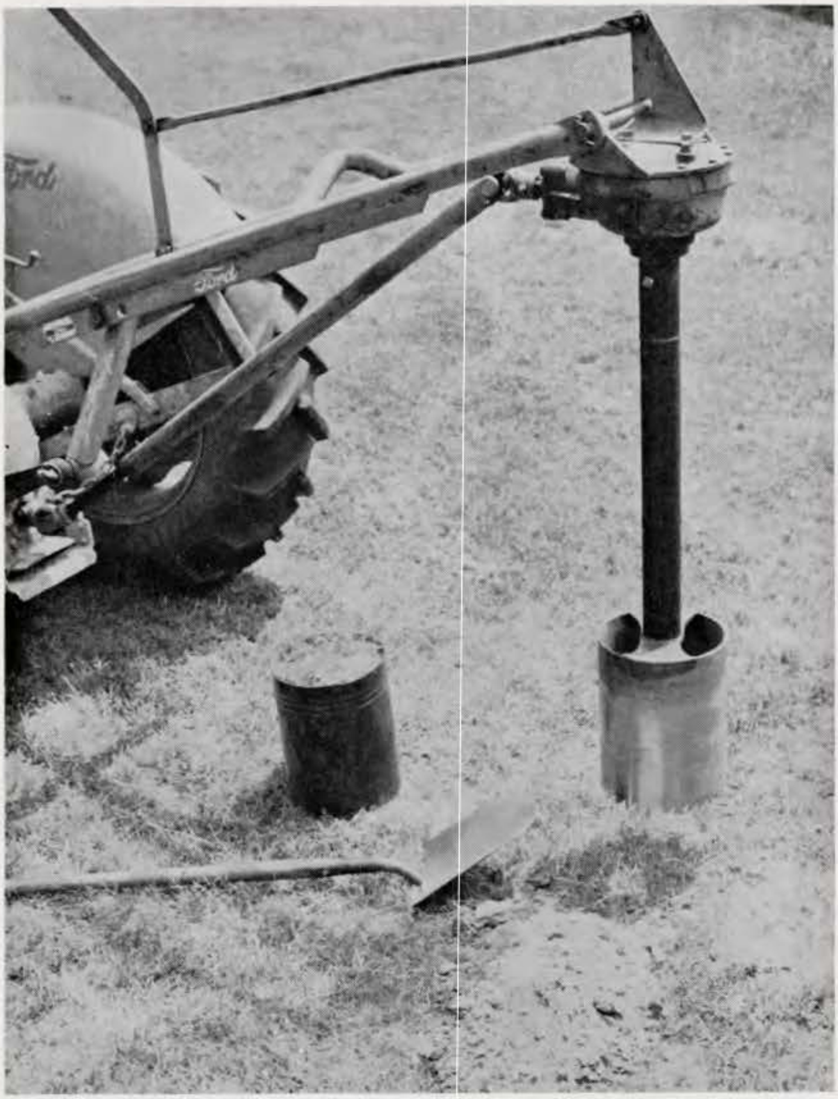

Figure 3. Power cutter for large undisturbed soil cores.

The moisture retention curves were based on duplicate composite samples of each soil (Fig. 4). At ⅓ atmosphere tension (approximate field capacity), Cuthbert and Axtell soils retained about 14 percent moisture, Magnolia 7 percent and Lakeland 2 percent. The available soil moisture between field capacity and wilting point (⅓ atmosphere moisture content minus the 15 atmosphere moisture content, expressed as percentage of oven-dry weight) was 9.9 for Axtell, 8.3 for Cuthbert, 4.7 for Magnolia, and 1.1 for Lakeland soils.

TABLE 1. PHYSICAL COMPONENTS AND CHEMICAL ANALYSIS OF THE FOUR TEST SOILS

Soil	Soil depth	Soil components: Sand	Silt	Clay	pH	Organic matter	Total nitrogen	Phosphate P_2O_5	Potash K_2O	Calcium CaO
	Inches	Percent				Percent		Pounds/acre		
Magnolia	0-4	66.0	26.6	7.6	6.6	0.2	0.01	10.3	55	747
	8-12	61.0	28.7	10.3	6.2	1.0	0.05	5.7	51	894
Lakeland	0-4	94.5	2.8	2.6	6.7	0.1	0.01	25.0	73	133
	8-12	89.5	5.8	4.6	6.6	0.1	0.01	33.0	88	245
Cuthbert	0-4	73.5	17.7	8.8	6.0	1.4	0.07	6.0	52	847
	8-12	67.5	22.7	9.8	5.7	0.5	0.03	6.0	51	142
Axtell	0-4	50.0	37.2	12.8	6.4	0.7	0.04	5.3	70	2,240
	8-12	46.0	32.2	21.8	5.3	0.2	0.01	5.0	65	2,425

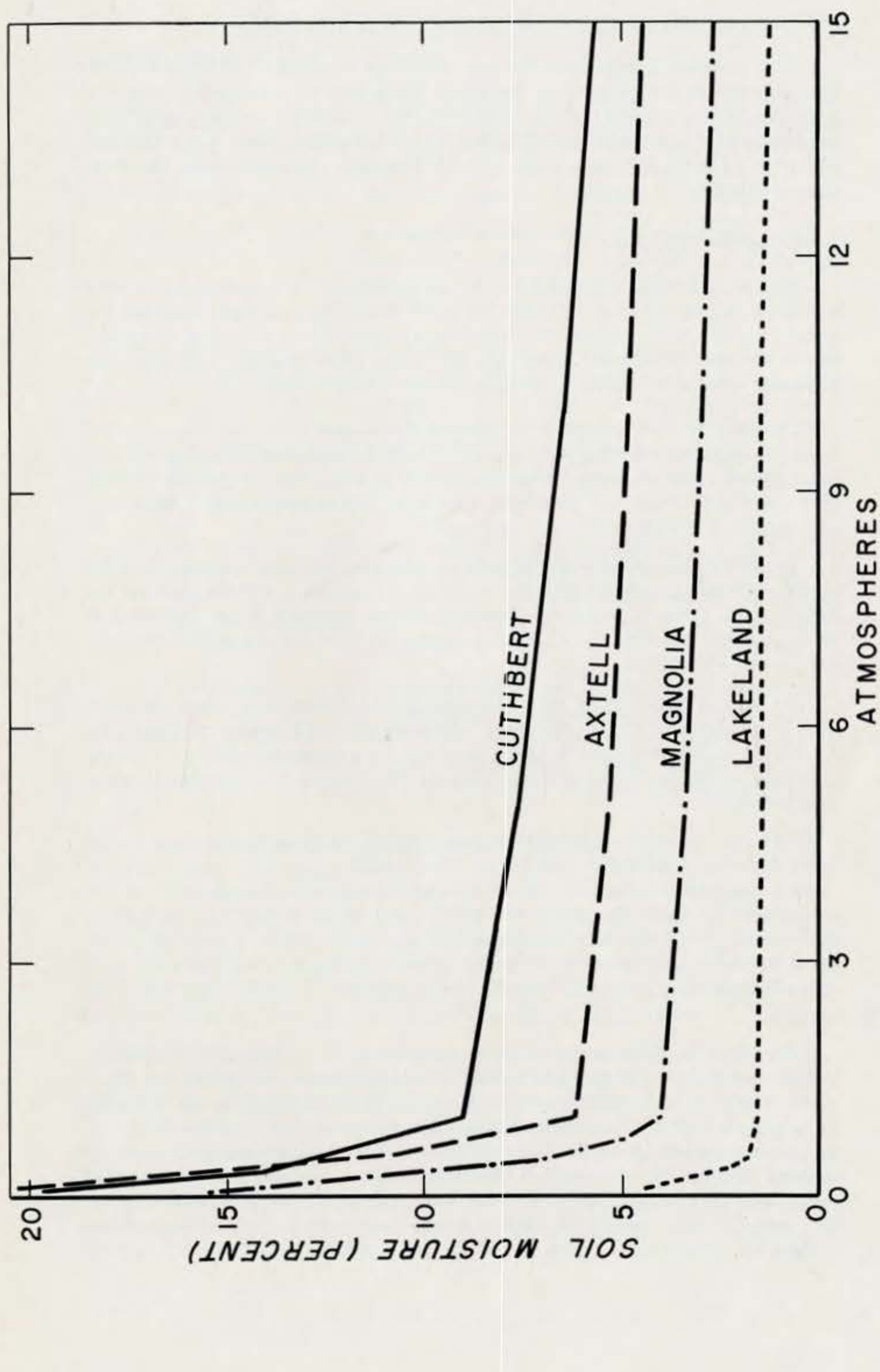

Figure 4. Moisture retention values of the four test soils.

Planting Material

Two nursery grown one-year-old seedlings of either loblolly or shortleaf pines were bar-planted in each can. Both species were from a central east Texas seed source. In late January, the containers were arranged in ten blocks in a low-walled concrete basin in a lathhouse. Each block included two cans of each soil—one with loblolly pine and the other with shortleaf pine seedlings.

Experimental Procedure

The plants were watered from below by filling the concrete basin with water up to just below the rim of the cans. After the soil was saturated (in about four hours) the remaining water was drained from the basin. To maintain soil moisture levels favorable to plant development, watering was repeated whenever the soil surface in the cans became dry.

On July 10, five blocks (forty cans) were randomly selected, removed from the basin, and arranged on a bench in the lathhouse. Beginning July 16, these plants were no longer watered in order to observe the length of time they survived under soil moisture stress in the various soils. Rain was excluded by a plastic roof over the bench.

Death of the seedling under soil moisture stress was determined from needle moisture, using 85 percent moisture (oven-dry weight basis) as the lethal point (Stransky 1963). Needle fascicles, sampled from the current year's mature growth, were collected concurrently with the periodic weighing of the containers.

At the beginning of the dry-down, the containers were weighed weekly to determine soil moisture depletion through evapo-transpiration. As needle moisture began to decrease, the cans were weighed at two-day intervals. Prior to the expected death of the plants, the containers were weighed daily.

The rate of soil moisture loss was determined from the weight differences between successive weighings. The actual amount of water present at any particular weighing date was calculated after termination of the experiment by deducting from the can's total fresh weight the weight of the oven-dry soil, the tare weight of the can, and weight of the dry plant. Total available soil moisture was the amount of water used between field capacity and the point at which needle moisture content fell below 85 percent.

Seedlings in the remaining forty cans, watered as before until December, served to indicate possible differences in development due to soil character. Their heights were measured (from the soil surface) at planting time, and on July 10, September 20, and December 10, 1963. Needle moisture was also sampled on these dates. Diameter (at the soil surface) and the number and length of branches were measured when the experiment was terminated in late December. At that time the plants were washed free of soil, and the dry weight of their foliage, stem and roots obtained. Plant parts were dried for 24 hours at 105°C.

RESULTS AND DISCUSSION

Seedling Survival

With adequate soil moisture, seedlings of both pine species survived well in the Post-oak Belt soils. Under simulated drought, shortleaf seedlings survived for a shorter time in Lakeland than in the other soils. Loblolly pine lived for about the same length of time in all soils, and did not differ greatly from shortleaf pine as seen from the following tabulation:

	Average number of days that seedlings survived			
	Magnolia	Cuthbert	Axtell	Lakeland
Loblolly pine	49	49	52	53
Shortleaf pine	50	54	50	42

Shortleaf pine seedlings had about the same transpiring surface in all soils, judging by their similar average foliage weight per shoot. Yet they depleted available soil moisture sooner from Lakeland than from the other soils. Probably the low moisture retention of Lakeland was responsible for the shorter survival of shortleaf pine in this soil. Loblolly pine, having less average foliage weight (4.60 grams) than shortleaf pine (5.76 grams), survived longer in Lakeland.

At field capacity, Magnolia fine sandy loam had the highest amount of available moisture, while Lakeland fine sand had the lowest. Between 60 and 70 percent of the available moisture was utilized during the first week after water was withheld. By the end of the third week, 90 percent of the available moisture was depleted (Fig. 5).

At field capacity (100 percent available soil moisture) shortleaf pine needles had consistently higher moisture content than loblolly needles (Fig. 5). Needle moisture did not fall below 200 percent until at least 90 to 95 percent of the available soil moisture had been depleted. It fell below 100 percent only when total available soil moisture dropped below one percent.

Stem Elongation, Branching, Diameter Growth

In all soils, over 80 percent of the total seasonal height growth was completed by mid-July (Fig. 6A). Tallest seedlings developed in Magnolia (1.59 ft.) and shortest in Axtell (1.48), with Cuthbert (1.55) and Lakeland (1.52) being intermediate. Though shortleaf pine seedlings were slightly taller than loblolly at planting time, both species grew to about the same average height by the end of the growing season (Fig. 6B).

Seasonal height growth was accomplished in two or three flushes (Fig. 7). In both species, the amount of growth decreased with each successive flush. The length of the first flush on loblolly was about 20 percent greater than on shortleaf pine. However, the second and third flush was somewhat longer on shortleaf pine. It seems that the higher rate of elongation during the early part of the growing season and the greater amount of growth attained in the first flush, give loblolly an advantage over shortleaf pine. This is particularly true when subsequent flushes may be suppressed by drought or damaged by insects.

Apparently, the soils affected the size of the flushes in the same manner in both species (Fig. 7). The first flush was longer in Axtell and Lakeland, than in the other soils. However, the second flush of seedlings in Axtell was less than in others. Also, the third flush in Axtell, and in Lakeland was shorter than in Magnolia or Cuthbert. Thus, while the first flush was longer in Lakeland and Axtell than in the Pineywoods Magnolia soil, subsequent flushes were longer in Magnolia.

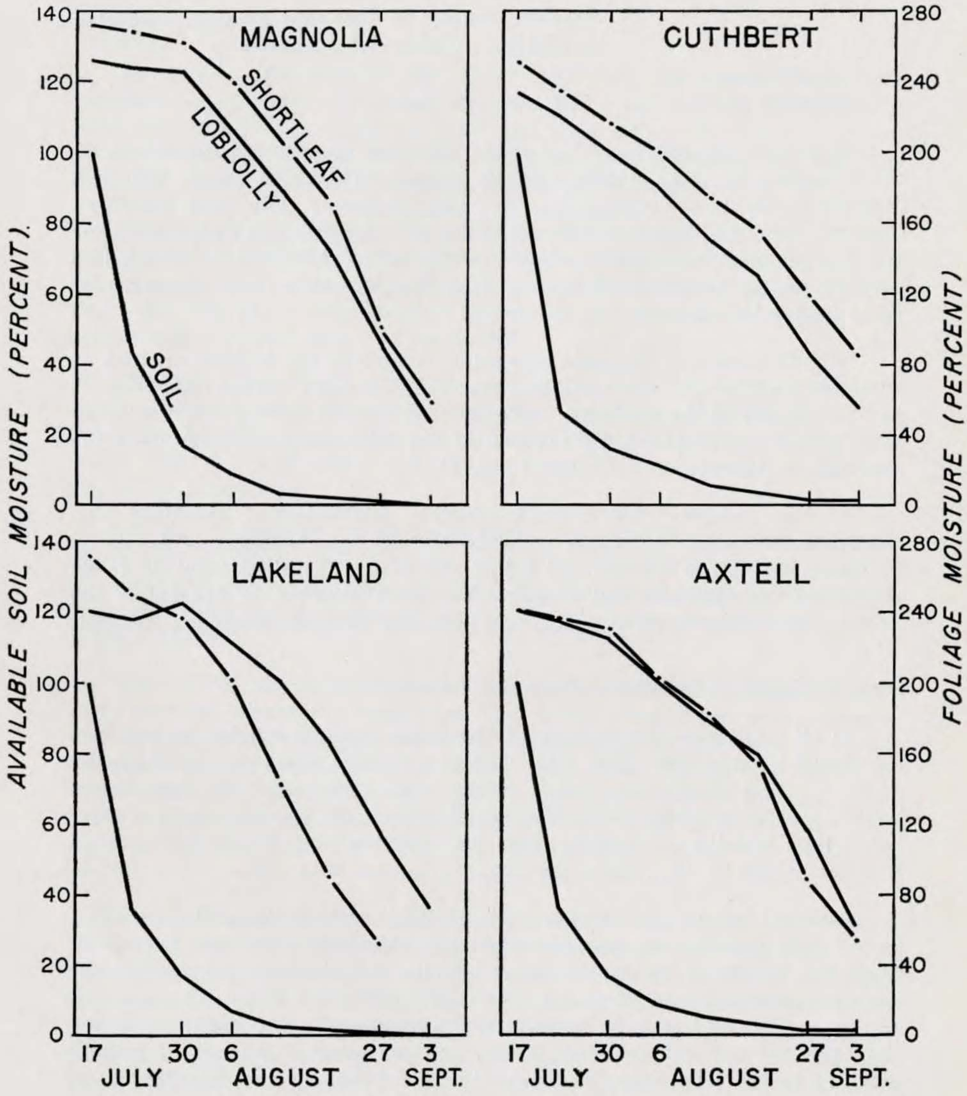

Figure 5.—Depletion of available soil moisture and corresponding decline in foliage moisture content by soils and species.

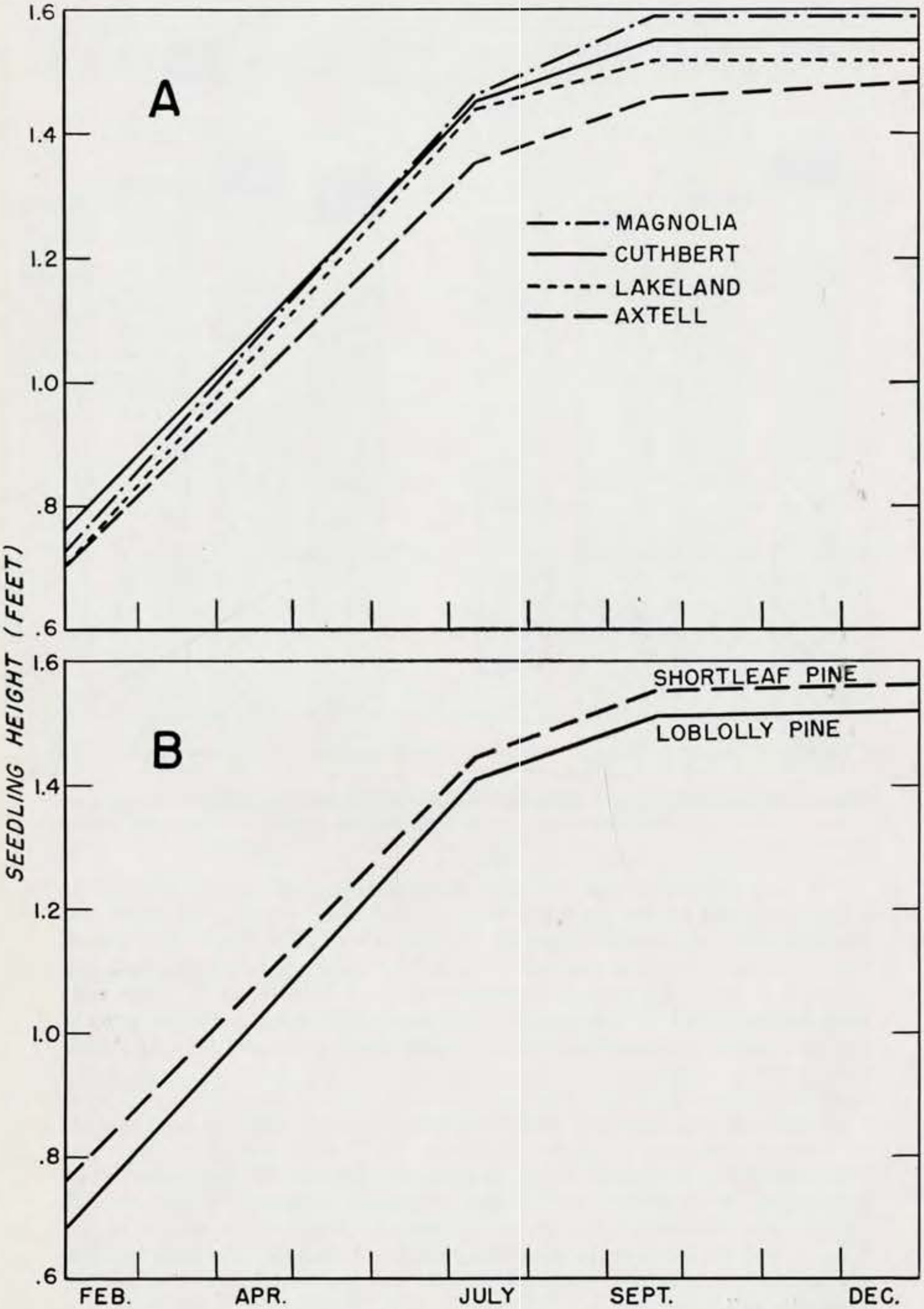

Figure 6—Periodic average height of seedlings by soils (A) and by species (B).

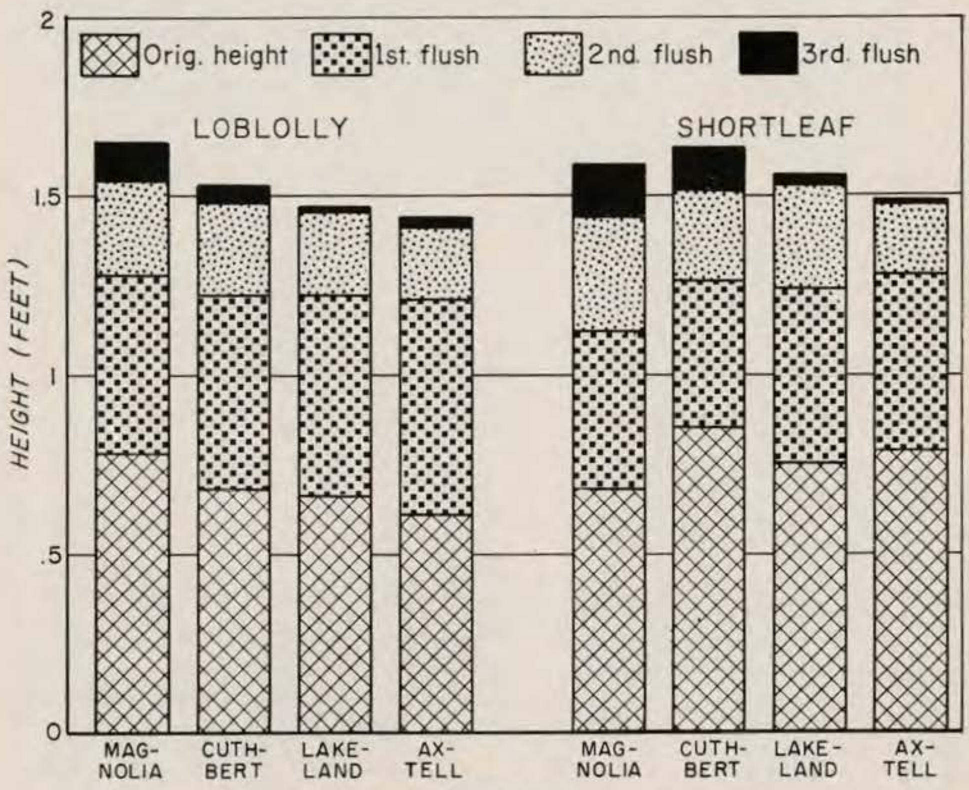

Figure 7—Total height of loblolly and shortleaf pine seedlings at the end of the first growing season; by height growth flushes and soils.

In Axtell and Lakeland soils, the seedlings completed nearly all of their potential annual height growth in one or two flushes, while in Magnolia and Cuthbert the proportional length of the flushes was more evenly distributed. Not only was the actual amount of third-flush-growth less in Lakeland and Axtell but, percentagewise, fewer plants grew a third flush in these soils than in the others. The percentages of plants that produced three growth flushes ranked by soils: Magnolia 65, Cuthbert 45, Lakeland 20, and Axtell 15 percent.

Shortleaf pine seedlings had more branches than loblolly, totaling also to greater cumulative length (Table 2). That both species grew fewer branches in Axtell than in other soils might indicate its restrictive effect on seedling development. As for the cumulative length of branches, only loblolly pine showed a pronounced decrease in Axtell, while shortleaf behaved about the same as in the other Post-oak Belt soils. For both species, the number of branches, and their length was greatest in the Pineywoods Magnolia soil.

TABLE 2. AVERAGE NUMBER OF LATERAL BRANCHES AND THEIR CUMULATIVE LENGTH PER SEEDLING AT THE END OF THE GROWING SEASON; BY SPECIES AND SOILS

Soil	Species	Number of lateral branches	Cumulative length of branches (feet)
Magnolia	Loblolly	4.1	.9
	Shortleaf	5.9	2.1
Cuthbert	Loblolly	3.2	.8
	Shortleaf	5.4	1.7
Lakeland	Loblolly	3.5	.8
	Shortleaf	5.3	1.7
Axtell	Loblolly	1.4	.4
	Shortleaf	4.7	1.7

In comparable soils, the average diameter of shortleaf pine seedlings was consistently greater than that of loblolly (Table 3). Within each species, the diameter differences attributable to soil effects were inconsistent and did not permit valid conclusions about soil influences.

TABLE 3 AVERAGE DIAMETER OF THE SEEDLINGS AT THE END OF THE GROWING SEASON; BY SPECIES AND SOILS

Soil	Average seedling diameter	
	Loblolly	Shortleaf
	Inch	
Magnolia	.27	.30
Cutberth	.28	.31
Lakeland	.27	.30
Axtell	.26	.31

Weight of Plant Components

Foliage dry weight per seedling at the end of the growing season averaged about the same for loblolly pine (9.3 grams) as for shortleaf (9.1 grams), but loblolly pine foliage weights varied more among soils than those of shortleaf pine (Fig. 8). Generally the foliage weight of seedlings grown in Lakeland was less than that of seedlings in other soils.

Stem dry weight of the two species was nearly equal, 4.6 grams for loblolly and 4.7 grams for shortleaf pine. The soil effects did not produce appreciable stem weight differences. The weight variation among soils was less in shortleaf pine than in loblolly (Fig. 8).

Combining the weight of the foliage and the stem into shoot weight, the species averages remained nearly identical: 13.9 grams for loblolly,

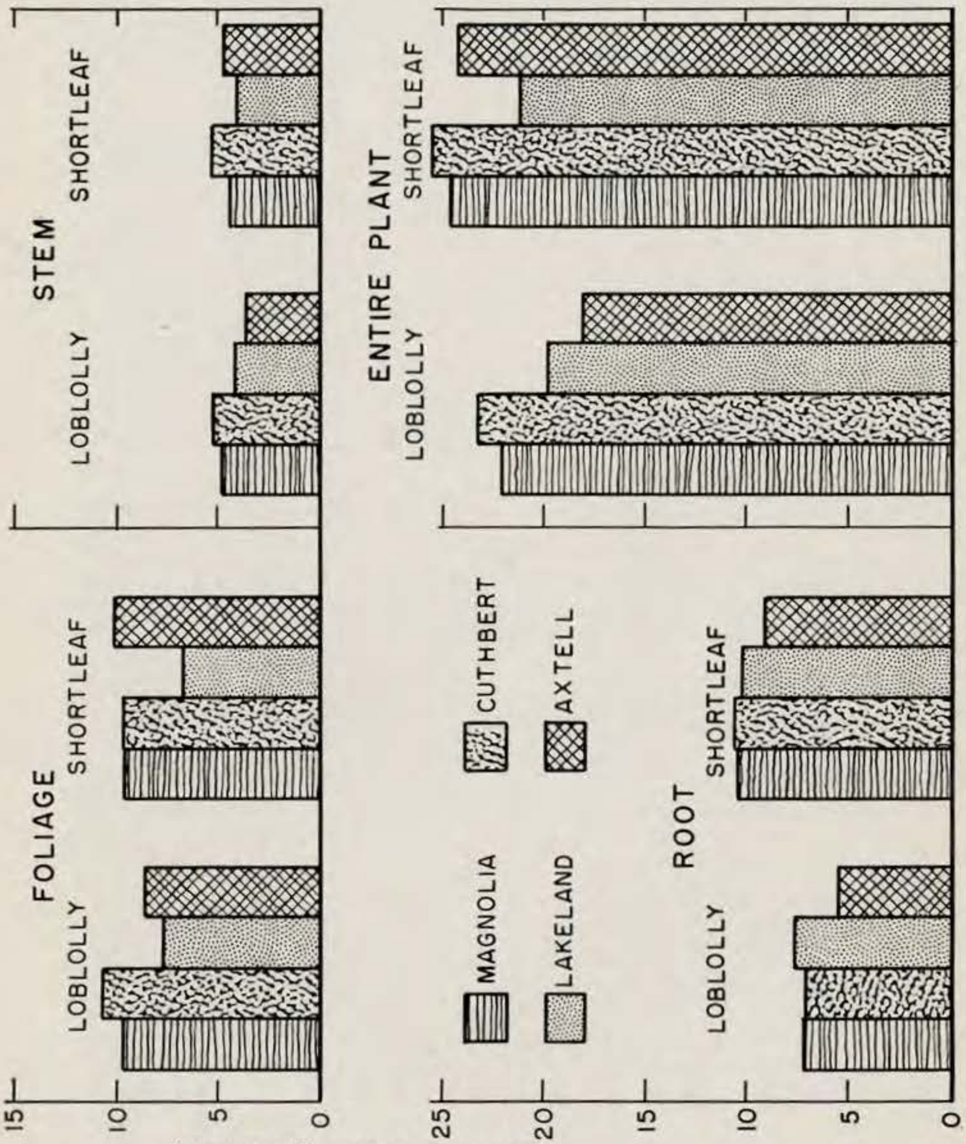

Figure 8.—Average oven-dry weight of plant components and entire plants at the end of the growing season; by species and soils.

and 13.8 grams for shortleaf pine. However, the differences due to soil effects became more pronounced. The seedlings grown in Magnolia (14.5 grams) and Cuthberth (15.6) averaged heavier than those in Axtell (13.8) and Lakeland (11.6).

Root dry weights between species were noticeably different, shortleaf roots being nearly one-third heavier than loblolly pine roots (Fig. 8).

This phenomenon has repeatedly been noted in local greenhouse experiments. As with foliage and stem weight, loblolly pine root weights varied more among soils than shortleaf roots. With both species, root weight in Axtell soil was less than in the others. This could indicate root growth inhibition by Axtell's clay subsoil. If this is so, root growth of planted trees would be limited to the surface 8 inches, making the trees vulnerable to drought and windthrow. Inhibition of root growth would eventually result in reduced top development and, thus, in lower site index on such soils.

Morphologically, loblolly pine roots were long and slender. In contrast, shortleaf pine roots were short and thick, and more finely branched than loblolly roots. The longer roots of loblolly reaching farther and deeper to absorb moisture from a greater volume of soil would at least partially explain loblolly pine's persistence in the pine fringe, and beyond it in the disjunct "Lost Pines" of Bastrop, Fayette, and Caldwell Counties.

Entire seedlings of shortleaf pine averaged heavier than those of loblolly (Fig. 8). This is due to root weights because only they were appreciably different for the two species, while foliage and stem weights were nearly identical. Generally, seedlings in Lakeland and Axtell soils were lighter than plants grown in the other two soils.

Foliage Moisture Content

At soil moisture levels favorable to growth, shortleaf pine had higher foliage moisture content than loblolly (Fig. 5). However, as soil moisture was depleted, the foliage moistures of the two species became nearly equal—a relationship noted in previous experiments using this criterion for diagnosing mortality under drought in loblolly and shortleaf pines (Stransky 1963, Stransky and Wilson 1964).

Both species grew the lightest needles and had the least moisture content in the Lakeland soil (Fig. 9). In comparable soils, loblolly pine needles were always heavier than shortleaf needles, as may be expected. They also contained more water (by weight). However, on a dry-weight percentage basis, shortleaf pine needles generally had higher moisture content than those of loblolly pine.

Seasonally, the amount of moisture per fascicle increased from June to September corresponding to needle dry-weight increase. Thereafter to the end of the growing season, moisture even showed a slight decrease in all but two species—soil combinations (Fig. 9). This could be explained by the gradual hardening of the needles. However, no explanation can be offered for the small decline in needle dry-weight of shortleaf pine in Lakeland and Cuthbert soil during the same period.

The needle color of seedlings growing in Lakeland began to turn lighter green during the first half of June and became almost pale yellow by December. The discoloration was more pronounced in loblolly than in shortleaf pine seedlings. When terminating the experiment in December,

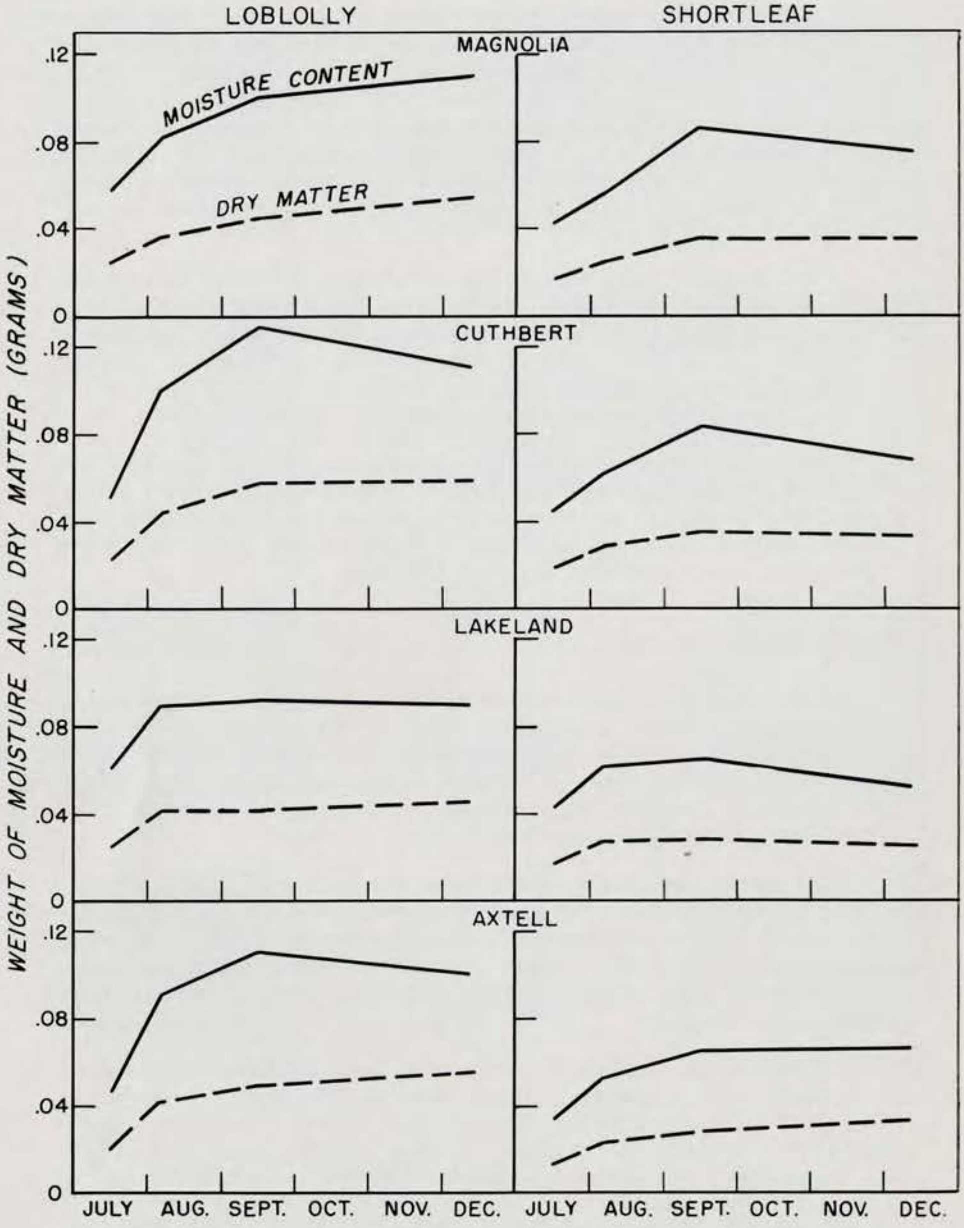

Figure 9—Periodic average weight of moisture and dry matter per needle fascicle; by species and soils.

darkest green foliage for both species was in Magnolia soil. Also, foliage in Axtell was darker green than that of pines growing in Cuthbert.

SUMMARY

In January 1963, one-year-old loblolly pine *(Pinus taeda L.)* and shortleaf pine *(P. echinata Mill.)* seedlings were planted in undisturbed soil cores of three principal forest soils from the Texas Post-oak Belt. Seedling survival under drought conditions during the following summer and seedling growth response after one growing season were observed and compared with seedling performance in a pine forest soil.

With diminishing soil moisture, seedlings of both species lived for about 50 days. There were no pronounced differences in length of survival between most species-soil combinations, except that shortleaf pine died a few days earlier in the sandy soil.

The tallest and heaviest seedlings grew in the pine forest soil (Magnolia fine sandy loan). Among the Post-oak Belt soils, seedlings in Cuthbert stony sandy loam developed almost as well as those in Magnolia. Low water retention of the Lakeland fine sand, and the heavy clay subsoil of the Axtell fine sandy loam soil inhibited seedling growth as expressed by shorter seedlings, lesser root weight, lower foliage weight and moisture content, and fewer and shorter branches than in other soils.

None of the soils seemed to cause notably adverse effect on seedling survival or development. Either species appears suitable for planting trials in the Post-oak Belt. This study should be followed by planting pines on these soils to observe their survival and growth response under field conditions.

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