SOUTHERN FOREST EXPERIMENT STATION

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RESPONSES TO SOIL MOISTURE DEFICIENCY BY SEEDLINGS OF THREE HARDWOOD SPECIES[1]

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Growth of terminal shoots of potted sycamore, sweetgum, and Nuttall oak seedlings began to decrease when leaf water deficits reached 6 to 9 percent. Growth-limiting soil moisture tensions were much lower and occurred much sooner in Commerce silt loam than in Sharkey clay. Transpiration was greatest in the fastest growing individuals; it decreased steadily as tension increased.

This note reports some responses of sweetgum *(Liquidambar styraciflua* L.), sycamore *(Platanus occidentalis* L.), and Nuttall oak *(Quercus nuttallii* Palmer) to increasing soil moisture tensions. Seedlings of the three species were planted in Sharkey clay and Commerce silt loam, two important alluvial forest soils of the Mississippi River Valley, and changes in water use, shoot growth, and leaf moisture stress were measured as soil moisture tension increased.

METHODS

Seventy 1-year-old dormant seedlings of each species were taken from the nursery at Stoneville, Mississippi, in February. Half were planted in 1-gallon cans containing clay, half in silt loam. Each can contained a single seedling. The planted seedlings were placed in a greenhouse, and in May, when shoots were growing rapidly, the tops of the cans were covered with oilcloth and sealed with tape. Spaces around stems and the drainage holes in the can bottoms were filled with cotton and coated with a paraffin-vaseline mixture to prevent all water loss except by transpiration. Examination of roots at the end of the study revealed no apparent damage from sealing the cans.

Soil moisture tensions were adjusted to an estimated 1/3 atmosphere by adding distilled water. Amounts to be added were calculated from original soil moisture content, weight of

[1] The study was conducted at the Southern Hardwoods Laboratory, Southern Forest Experiment Station, Forest Service, U. S. Department of Agriculture, Stoneville, Mississippi. The Laboratory is maintained in cooperation with the Mississippi Agricultural Experiment Station and the Southern Hardwood Forest Research Group.

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soil in each can, and the weight of the soils at 1/3 atmosphere of tension. Terminal growth and can weights were recorded daily at 8 p.m. All weight loss was attributed to transpiration, and distilled water was added daily to replace this loss. During the experiment, daily greenhouse temperatures fluctuated between minimums of 66 to 80° F. and maximums of 95 to 126° F.

After 1 week of these measurements, all cans were brought to 1/3 atmosphere at 8 p.m., and watering was discontinued. Five seedlings of each species in each soil were randomly selected the following morning for measurement of (1) transpiration, (2) terminal growth, (3) leaf water deficit, (4) total leaf area, (5) shoot fresh weight, (6) shoot dry weight, and (7) soil moisture tension. Six other groups were similarly analyzed as soil moisture was depleted by transpiration—the last group when the leaves had wilted and the plants appeared to be nearly dead.

Leaf water deficits were estimated by a modification of Weatherley's method[2] on 10 disks, 0.7 cm. in diameter, which were cut from the two fully expanded leaves nearest the terminal of each seedling. The disks were quickly placed in tared weighing bottles, weighed to the nearest 0.1 mg., and floated in distilled water in Petri dishes for 4 hours under 100 foot-candles of light. They were then blotted dry between eight sheets of Whatman No. 1 filter paper pressed together with a weight of 2,500 g., reweighed, and dried. Water deficit in percent (WD) was calculated from the formula:

$$WD = \frac{\text{Turgid weight} - \text{fresh weight}}{\text{Turgid weight} - \text{ovendry weight}} \times 100$$

To find dry weight, vegetation was dried for 24 hours in a forced-air oven at 65° C.; soil was dried for 48 hours at 105° C. Weights of the current year's shoots were kept separate from those of the previous year. Leaf areas were estimated from dot-grid counts of leaf-outline tracings.

Moisture percent by weight for each can was determined from two randomly selected complete vertical profile samples taken with a soil tube. These values were used to estimate soil moisture tensions with the moisture retention curves (fig. 1), which were constructed from data obtained by standard pressure plate and membrane procedures for samples from the soil lots used in the study.

[2] Weatherley, P. E. Studies in the water relations of the cotton plant. I. The field measurement of water deficits in leaves. New Phytol. 49: 81-97. 1950.

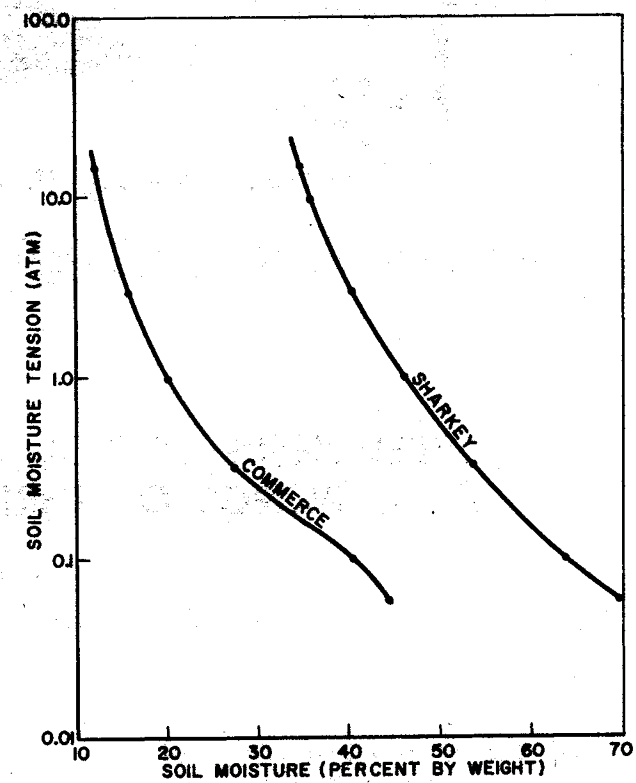

Figure 1.—*Relation of soil moisture tension to soil moisture content.*

RESULTS

In general, seedlings that grew fastest transpired most. By species, average transpiration per seedling prior to the drying cycle was proportional to the amount of terminal growth (table 1). To remove the effect of growth rate, transpiration was thereafter expressed

Table 1.—*Average dry weight of current shoots and daily transpiration prior to the drying cycle*

Species	Transpiration		Weight of current shoots	
	Clay	Silt loam	Clay	Silt loam
	Grams per day		*– Grams –*	
Sycamore	55.3	82.3	1.52	1.97
Sweetgum	31.0	36.2	.94	1.02
Nuttall oak	47.5	22.0	2.65	1.61

in grams per day per gram of the current year's shoot dry weight. This expression gave more consistent results than expressions based on leaf area or fresh weight of shoots, and it equalized, in general, rates on the two soil types (table 2). As expected, transpiration rates decreased as soil moisture was depleted.

Terminal growth slowed when leaf water deficits reached 6 to 9 percent, i.e., after 5 to 7 days without water in Sharkey clay and 3 to 5 days in Commerce silt loam (table 2). Estimated soil moisture tensions at this stage ranged from 12 to 17 atmospheres in clay, and from 1 to 3 atmospheres in silt loam. Terminal growth stopped completely after 13 to 15 days without water in clay, and after about 11 days in silt loam. Average leaf water deficits at these times varied widely among species, but, in both soils, they were highest in sycamore and lowest in sweetgum leaves.

As soil moisture tension increased, older leaves were the first to wilt and die on sycamore and sweetgum. On Nuttall oak, all leaves appeared to die at once, and mature leaves did not appear to wilt before they died.

DISCUSSION

Although they could not be accurately determined, the soil moisture tensions at which terminal growth slowed or ceased were surprisingly high in Sharkey clay in most cases. When seedlings appeared to be at the point of death, soil moisture percents by weight in the clay averaged 30.4 for sycamore, 29.8 for sweetgum, and 25.9 for Nuttall oak, and the seedlings were still slowly transpiring. These values are considerably below the 34.7 percent that is equivalent to 15 atmospheres of tension, the limit commonly suggested for this activity. Additional studies of soil-water relations of tree seedlings seem warranted, especially in clay soils.

Table 2.—*Seedling reactions to moisture deficiency by species and soil*

Species and days without water	Sharkey clay				Commerce silt loam			
	Leaf water deficit	Soil moisture tension	Transpiration	Cumulative terminal growth	Leaf water deficit	Soil moisture tension	Transpiration	Cumulative terminal growth
	Percent	*Atmospheres*	*G./day/g.*	*Cm.*	*Percent*	*Atmospheres*	*G./day/g.*	*Cm.*
Sweetgum								
0	4.5	<1	65.9	0.0	6.0	<1	55.0	0.0
3	5.0	1	51.1	.4	4.5	1	61.9	.4
5	5.9	10	30.5	.7	5.9	1	47.5	.6
10	8.0	11	21.2	.9	7.4	6	31.4	.7
13	8.2	20+	3.5	.9	12.9	13	3.1	.7
17	9.4	20+	10.2	1.0	14.0	15	4.6	.7
Sycamore								
0	2.7	<1	47.8	.0	3.8	<1	56.0	.0
3	6.9	14	42.7	1.2	6.9	2	40.8	1.8
5	6.9	16	41.7	1.7	8.9	5	10.1	2.1
8	7.5	17	28.6	1.9	12.9	12	14.6	2.3
11	11.7	20+	9.5	2.0	23.6	14	4.2	2.4
15	13.1	20+	4.6	2.1	41.0	20+	2.7	2.4
Nuttall oak								
0	9.7	1	31.0	.0	8.6	<1	25.8	.0
3	9.0	12	27.4	.6	7.6	1	21.2	.4
6	7.8	10	21.2	.9	...	...	...	.4
8	...	...	...	1.1	6.7	2	21.3	.4
9	11.1	20+	11.9	1.1	...	...	...	.5
11	...	...	...	1.2	10.2	3	11.3	.5
13	10.3	20+	8.2	1.3	...	...	...	.5
14	...	...	...	1.3	8.7	2	5.5	.5
20	26.4	20+	3.9	1.3	...	...	...	.5
22	...	...	...	1.3	11.3	10	3.7	.5