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TREE-CHARACTER RELATIONS IN SOUTHERN
HARDWOOD STANDSW. M. Broadfoot¹

SOUTHERN FOREST EXPERIMENT STATION

Site index and other characters of sweetgum are compared with those of green ash, eastern cottonwood, and cherrybark, Nuttall, water, and willow oaks growing close to and of the same age as the sweetgums.

During a comprehensive study of the relations between soil and site index for seven major southern hardwoods,² measurements were made on a number of plots that contained more than one of the test species in an even-aged overstory. Plots were selected to be representative of undisturbed hardwood stands in the Midsouth. Data presented here indicate the approximate relative performance of the species in terms of site index, basal area, diameter, number of potential 16-foot logs, log grade, tree bark vigor, and insect incidence.

Study trees were sweetgum (*Liquidambar styraciflua* L.), green ash (*Fraxinus pennsylvanica* Marsh.), eastern cottonwood (*Populus*

deltoides Bartr.), and water (*Quercus nigra* L.), willow (*Q. phellos* L.), Nuttall (*Q. nuttallii* Palmer), and cherrybark (*Q. falcata* var. *pagodaefolia* Ell.) oaks. Because it occurs commonly on a wide variety of sites, sweetgum was used as the reference species in the comparisons.

PROCEDURES

Plots covered 1/5 acre and had uniform soil conditions. The stands on them were well stocked, even aged, and had not been recently logged or burned. Minimum stocking was 70 square feet of basal area in trees 6 inches or larger in diameter. To minimize the effects of errors in site curves, site index was estimated only from trees that were within 10 years of index age. Measurements were made only on dominant and codominant trees.

Total height, d.b.h., and age at breast height were measured. Estimates were made of number of actual or potential 16-foot saw logs to the nearest 1/2 log, grade of the bottom log in the tree, tree vigor, and incidence of insect attack. Vigor was estimated by a method des-

¹ Stationed at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., in cooperation with the Mississippi Agricultural Experiment Station and the Southern Hardwood Forest Research Group.

² Broadfoot, W. M. Problems in relating soil to site index for southern hardwoods. *Forest Sci.* 15: 354-364. 1969.

cribed by Guttenberg and Putnam.³ A relative scale was prepared to classify severity of insect attacks: 1 = no attacks, 2 = one to five insect holes or scars on the log grading face, and 3 = six or more insect holes or scars on the log grading face.

Between 10 and 20 sample trees of each species from a variety of soils were felled and sectioned to establish partial height-over-age curves for estimating 50-year heights of trees above or below this age (the index age for cottonwood was 30 years). On each sectioned tree, age was counted at intervals of 8 feet from a 1-foot stump to the top. A large number of seedlings and saplings were cut to determine the time required for each species to reach breast height. This value was added to age at d.b.h. to get total age.

Individual tree characters were compared only on the plots that contained sweetgum. Data were compiled into four sweetgum site-index classes: less than 85 feet, 85 through 94 feet, 95 through 104 feet, and 105 feet or more. Tree characters for the seven species were compared within these classes.

Site-index relations were computed by regression analysis. The site index of each species was related to that of sweetgum and vice versa.

RESULTS

Species combinations with sweetgum are presented by sweetgum site-index class in table 1. The most frequent combination was water

Table 1.—Number of stands in which each species occurred with sweetgum, by sweetgum site-index class

Sweetgum site-index class	Cottonwood	Cherrybark oak	Water oak	Willow oak	Nuttall oak	Green ash
	----- Number of stands -----					
Less than 85 feet	0	17	15	12	9	5
85-94 feet	6	25	29	28	19	13
95-104 feet	10	48	47	28	20	20
105 feet plus	8	17	23	11	8	9
All site classes	24	107	114	77	56	47

oak and sweetgum; the least frequent was cottonwood and sweetgum. There were no stands of sweetgum and cottonwood where sweetgum site index was less than 85 feet. Where sweetgum and green ash were growing

³ Guttenberg, S., and Putnam, J. A. Financial maturity of bottomland red oaks and sweetgum. USDA Forest Serv. South. Forest Exp. Sta. Occas. Pap. 117, 24 pp. 1951.

together, sweetgum site index was usually low. Sweetgum apparently does not grow well on the poorly aerated soils where green ash is common.

The relations among site index of sweetgum and those of the other six species are shown in figures 1 through 6. The regression equations presented are not recommended for estimating site index. They are meant only to

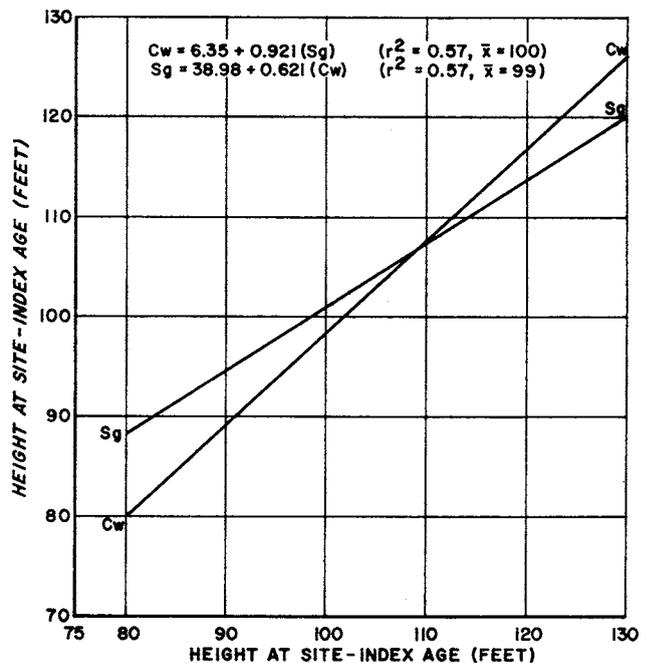


Figure 1.—Site-index relations between sweetgum (Sg) and cottonwood (Cw) (N = 24).

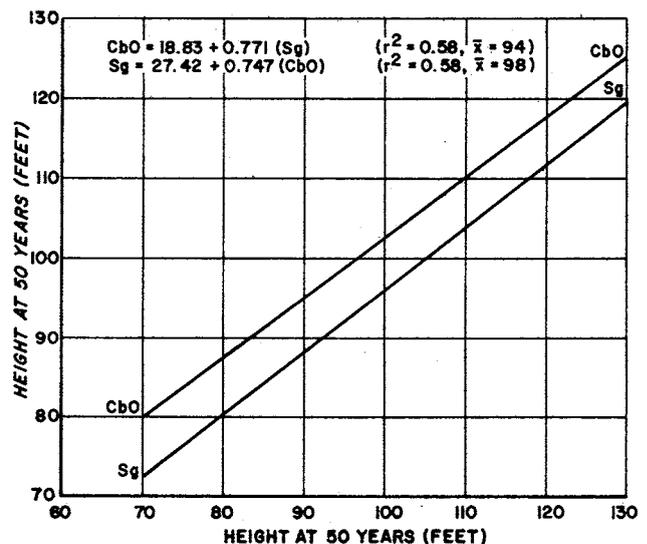


Figure 2.—Site-index relations between sweetgum (Sg) and cherrybark oak (CbO) (N = 107).

show relations that existed on the study plots. The squared correlation coefficient was highest between sweetgum and cherrybark oak and lowest between sweetgum and willow oak.

To compare site indexes from the regression lines, enter the known site index on X-axis and read up to the site-index line of the species being compared to the known. To find the value sought, read across to the Y-axis from the point on the site-index line. For example, assume site index for sweetgum is 100 feet (fig. 1). To get cottonwood site index on the same site, enter 100 on X-axis to cottonwood line, and read Y-axis at 98.4 To get sweetgum site index from cottonwood, enter cottonwood value on X-axis to sweetgum line, then read across to the Y-axis. Thus, if cottonwood site index is 100, sweetgum site index is 101.1.

The figures illustrate at least four striking results. The first is the remarkable growth potential of cottonwood on good sites. As mentioned previously, it did not appear on poor sweetgum sites. On the best sweetgum sites it grew about 5 feet taller in 30 years than sweetgum did in 50 years (fig. 1). Second, cherrybark oak consistently outgrew sweetgum on all sites by about 5 feet in 50 years (fig. 2).

The difference was slightly greater on the low-quality sweetgum sites than on the better sites. Third, green ash grew considerably slower than sweetgum on all sites (fig. 6). The average difference was about 12 feet on all site classes. Fourth, site indexes of sweetgum and water, willow, and Nuttall oaks were about the same when the species occurred together.

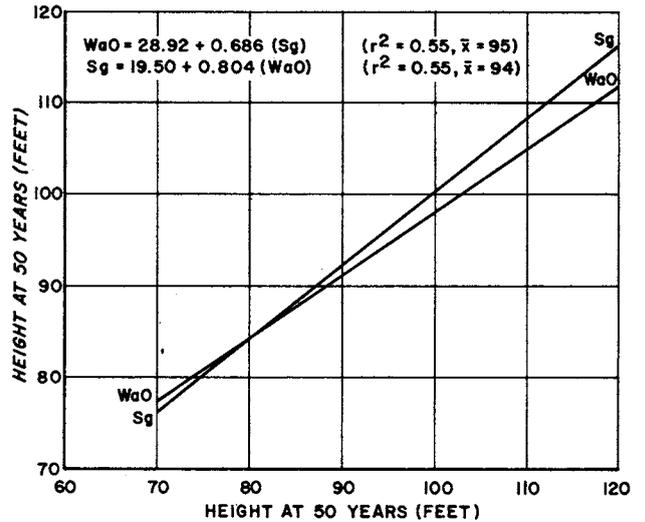


Figure 3.—Site-index relations between sweetgum (Sg) and water oak (WaO) (N = 114).

Table 2.—Average basal areas of stands in which each species combination occurred, by sweetgum site-index class

Sweetgum site-index class	Species occurring with sweetgum					
	Cottonwood	Cherrybark oak	Water oak	Willow oak	Nuttall oak	Green ash
----- Square feet -----						
Less than 85 feet						
Mean	...	122	124	115	121	139
Range	...	69-159	66-159	66-153	100-153	118-165
Std. deviation	...	23	23	27	17	19
85-94 feet						
Mean	166	123	124	129	143	137
Range	110-243	90-179	87-198	87-243	87-243	87-198
Std. deviation	46	27	30	38	43	32
95-104 feet						
Mean	152	128	132	137	137	146
Range	108-210	84-228	84-228	89-226	87-210	98-205
Std. deviation	38	29	31	33	38	34
105 feet plus						
Mean	148	126	130	145	157	132
Range	121-174	89-163	89-201	65-330	92-330	110-174
Std. deviation	34	25	29	72	74	19
All site classes						
Mean	154	125	128	132	140	140
Std. deviation	34	27	29	42	44	30

Stand basal areas for all species combinations with sweetgum are shown in table 2. Several stands had exceptionally high basal areas. The averages ranged from 125 square feet for the sweetgum-cherrybark oak stands to 154 square feet for the sweetgum-cottonwood.

All species grew faster in diameter as sweetgum site improved (table 3). Best diameter growth was made by cottonwood, followed by cherrybark, water, Nuttall, and willow oak, and green ash. In stands where sweetgum site index was less than 85 feet, sweetgum diameter

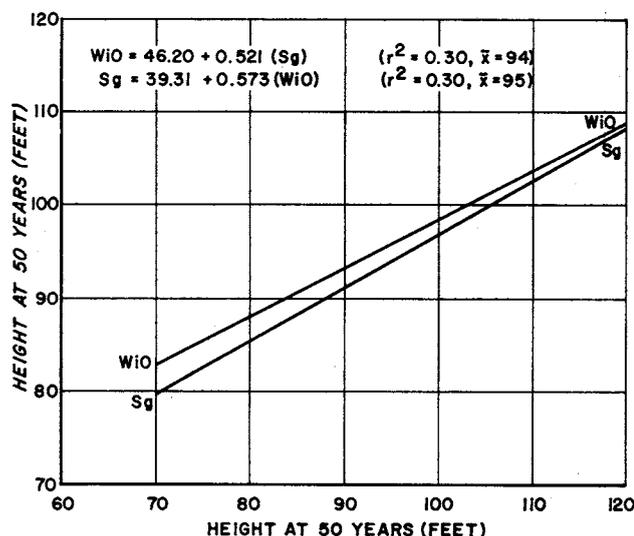


Figure 4.—Site-index relations between sweetgum (Sg) and willow oak (WiO) (N = 77).

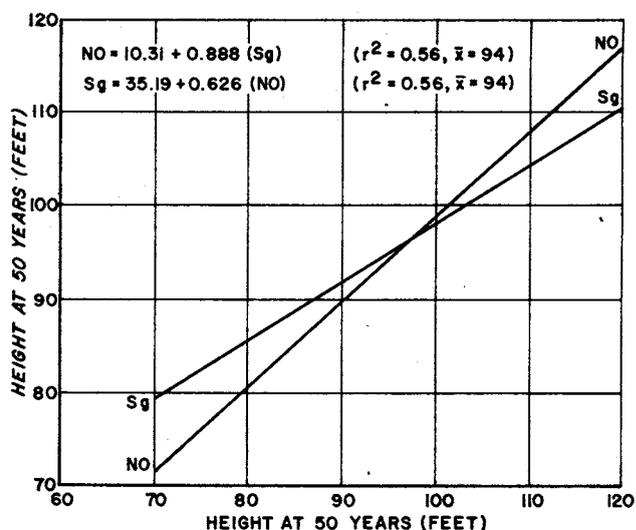


Figure 5.—Site-index relations between sweetgum (Sg) and Nuttall oak (NO) (N = 56).

growth was about 30 percent less than that of all oaks, but 30 percent more than ash. In the better sweetgum site classes, its diameter growth in 10 years averaged about 20 percent less than cottonwood and the oaks, and 5 to 10 percent more than green ash.

Sweetgums had more merchantable logs on all sites than water oak, Nuttall oak, and ash (table 4). The differences in sweetgum-green ash stands amounted to about ½ log on poor sites and 1 log on good sites. Log lengths in cottonwood and willow oak were not compared with those in sweetgum. Lengths of merchant-

Table 3.—Relative 10-year diameter growths of sweetgum and each of six species, by sweetgum site-index class (inches)

Sweetgum site-index class	Species combination											
	Sweetgum	Cottonwood	Sweetgum	Cherrybark oak	Sweetgum	Water oak	Sweetgum	Willow oak	Sweetgum	Nuttall oak	Sweetgum	Green ash
Less than 85 feet	...	...	2.5	3.4	2.5	3.1	2.8	3.4	2.7	3.4	2.9	2.2
Mean	...	...	1.8-3.0	2.5-5.2	1.8-3.0	2.3-3.6	2.3-3.6	2.4-4.5	2.3-3.2	2.5-4.2	2.3-3.4	2.0-2.8
Range	...	...	.4	.7	.5	.4	.4	.6	.3	.6	.4	.4
Std. deviation												
85-94 feet	3.4	4.2	3.0	3.9	3.0	3.8	3.5	3.8	3.2	3.6	3.2	2.9
Mean	2.8-4.5	3.5-5.0	2.2-4.5	2.6-7.0	2.2-3.9	2.5-6.0	2.3-4.4	2.3-5.5	2.5-3.7	2.4-4.6	2.5-4.4	1.5-4.0
Range	.6	.5	.5	.9	.4	.7	.4	.8	.3	.6	.5	.8
Std. deviation												
95-104 feet	3.7	5.0	3.2	4.0	3.3	3.8	3.2	3.7	3.4	3.9	3.3	2.9
Mean	3.1-4.7	3.6-6.4	2.3-4.5	2.3-5.5	2.3-4.5	2.7-6.0	2.3-4.5	3.0-4.9	2.3-4.5	2.7-5.1	2.3-4.2	2.0-4.0
Range	.5	.9	.6	.7	.5	.6	.6	.5	.6	.7	.5	.6
Std. deviation												
105 feet plus	4.0	5.6	3.8	5.0	3.9	4.5	3.8	4.0	3.6	4.3	3.4	3.1
Mean	3.6-4.3	4.4-8.0	2.9-4.7	3.9-6.7	2.9-4.7	2.7-5.6	2.5-4.7	2.9-4.6	2.6-4.7	3.9-5.3	2.6-4.0	1.8-3.8
Range	.3	1.2	.5	.8	.4	.7	.6	.5	.6	.5	.5	.7
Std. deviation												
All site classes	3.7	5.0	3.2	4.0	3.2	3.8	3.3	3.7	3.2	3.8	3.2	2.9
Mean	.5	1.0	.6	.9	.6	.8	.7	.6	.5	.6	.5	.7
Std. deviation												

able logs were about the same for sweetgum and cherrybark oak on all site classes.

Log grade was consistently better for all species on the best sites (table 5). Sweetgum's improvement was the most pronounced with increasing site quality, while the least influenced was Nuttall oak. On the poor sweetgum sites, only water oak had log grades as poor as sweetgum's. With increase in site class,

sweetgum log grade became better than all other species except cherrybark oak and cottonwood.

Ash vigor was the same on the poorest sweetgum sites as it was on the best (table 6). Vigor of all other species increased with site quality, though improvement in Nuttall oak was slight. The lack of improvement in ash and the small improvement in Nuttall vigor are probably due

Table 4.—Average numbers of merchantable 16-foot logs produced by sweetgum and four other species, by sweetgum site-index class

Sweetgum site-index class	Species combination							
	Sweetgum	Cherrybark oak	Sweetgum	Water oak	Sweetgum	Nuttall oak	Sweetgum	Green ash
Less than 85 feet								
Mean	2.6	2.6	2.6	2.6	2.3	2.2	2.4	2.1
Range	2.0-3.0	1.8-3.0	2.0-3.0	1.5-3.0	2.0-2.8	2.0-2.8	2.2-2.5	1.8-2.5
Std. deviation	.4	.4	.4	.6	.3	.3	.2	.4
85-94 feet								
Mean	2.5	3.0	2.6	2.6	2.4	2.2	2.9	2.5
Range	1.2-3.2	2.5-3.8	1.2-3.5	2.0-3.0	1.2-3.0	2.0-2.5	2.5-3.2	2.0-3.0
Std. deviation	.8	.5	.7	.3	.6	.2	.2	.4
95-104 feet								
Mean	3.0	2.6	3.0	2.7	3.1	3.0	3.1	2.4
Range	2.2-4.0	2.0-3.5	2.2-4.0	2.0-3.5	2.5-3.8	2.5-3.5	2.5-3.5	2.0-3.5
Std. deviation	.4	.5	.5	.4	.4	.4	.3	.5
105 feet plus								
Mean	3.2	3.1	2.9	2.4	3.5	3.0	3.5	2.5
Range	3.0-3.5	3.0-3.5	2.5-3.0	2.0-3.0	3.5-3.5	3.0-3.0	3.5-3.5	2.5-2.5
Std. deviation	.3	.2	.2	.4	.0	.0	.0	.0
All site classes								
Mean	2.8	2.8	2.8	2.6	2.6	2.5	2.9	2.4
Std. deviation	.5	.5	.6	.4	.6	.5	.4	.4

Table 5.—Average grades¹ of butt logs produced by sweetgum and six other species, by sweetgum site-index class

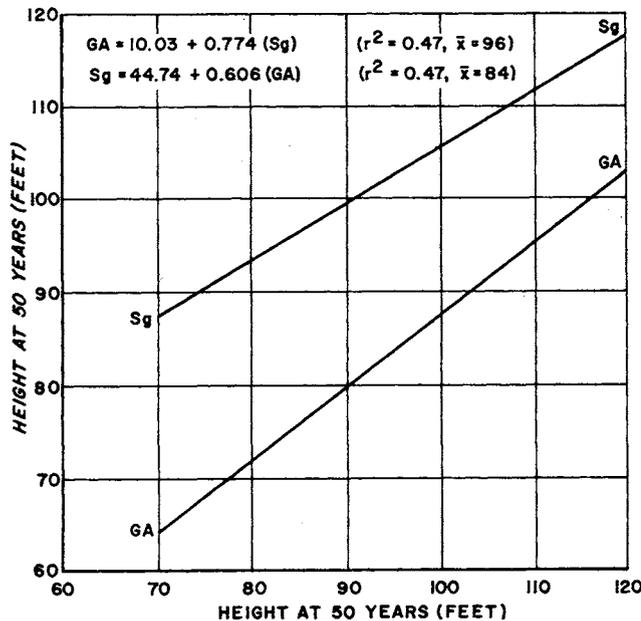
Sweetgum site-index class	Species combination											
	Sweetgum	Cottonwood	Sweetgum	Cherrybark oak	Sweetgum	Water oak	Sweetgum	Willow oak	Sweetgum	Nuttall oak	Sweetgum	Green ash
Less than 85 feet												
Mean	...	...	2.5	2.0	2.5	2.5	2.5	2.3	2.4	2.1	2.5	2.4
Range	...	...	2.0-3.0	1.0-3.0	2.0-3.0	1.0-3.0	2.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	2.0-3.0	2.0-3.0
Std. deviation	...	...	.5	.7	.5	.6	.5	.6	.6	.7	.5	.5
85-94 feet												
Mean	2.3	2.3	2.2	1.8	2.2	2.0	2.2	2.2	2.3	2.0	1.9	2.2
Range	1.5-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.5-3.0	1.0-3.0	1.0-3.0	1.0-3.0
Std. deviation	.6	.8	.5	.5	.5	.6	.6	.6	.5	.6	.5	.6
95-104 feet												
Mean	2.0	1.7	1.9	1.6	1.9	2.0	1.9	1.9	2.0	1.8	1.8	2.0
Range	1.0-3.0	1.0-2.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0
Std. deviation	.6	.5	.5	.5	.6	.5	.5	.6	.4	.5	.6	.7
105 feet plus												
Mean	1.6	1.5	1.8	1.5	1.9	2.0	1.6	1.8	1.6	1.9	1.7	1.8
Range	1.0-2.0	1.0-2.0	1.0-3.0	1.0-2.0	1.0-3.0	1.0-3.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0
Std. deviation	.4	.5	.5	.5	.5	.5	.4	.4	.5	.3	.5	.5
All site classes												
Mean	2.0	1.8	2.0	1.7	2.0	2.1	2.0	2.0	2.1	1.9	1.9	2.1
Std. deviation	.6	.6	.5	.6	.6	.6	.6	.6	.6	.5	.6	.6

¹ Logs were graded 1, 2, or 3 for their quality for production of standard lumber. Grade 1 is best.

Table 6.—Average tree vigors¹ for sweetgum and six other species, by sweetgum site-index class

Sweetgum site-index class	Species combination											
	Sweet-gum	Cotton-wood	Sweet-gum	Cherry-bark oak	Sweet-gum	Water oak	Sweet-gum	Willow oak	Sweet-gum	Nuttall oak	Sweet-gum	Green ash
Less than 85 feet												
Mean	...	...	2.3	1.8	2.5	1.9	2.1	2.1	2.1	1.8	1.8	1.8
Range	...	...	1.5-3.0	1.0-3.0	2.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.5-3.0	1.0-2.0	1.5-2.0	1.0-2.0
Std. deviation	...	...	.5	.7	.5	.6	.5	.5	.5	.5	.3	.5
85-94 feet												
Mean	1.7	2.0	2.1	1.6	2.0	1.7	2.0	1.7	1.8	1.5	1.6	1.8
Range	1.0-2.0	1.0-3.0	1.0-3.0	1.0-2.5	1.0-3.0	1.0-3.0	1.0-3.0	1.0-2.5	1.0-3.0	1.0-2.0	1.0-2.0	1.0-3.0
Std. deviation	.5	.6	.5	.5	.6	.6	.4	.5	.6	.5	.5	.7
95-104 feet												
Mean	1.4	1.4	1.6	1.6	1.6	1.5	1.7	1.6	1.5	1.4	1.5	1.8
Range	1.0-2.0	1.0-2.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-2.0	1.0-3.0	1.0-3.0	1.0-3.0
Std. deviation	.4	.5	.6	.6	.6	.5	.5	.6	.5	.6	.6	.5
105 feet plus												
Mean	1.1	1.6	1.2	1.5	1.2	1.2	1.5	1.4	1.4	1.6	1.2	1.8
Range	1.0-2.0	1.0-3.0	1.0-2.0	1.0-3.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-3.0	1.0-2.0	1.0-3.0
Std. deviation	.4	.6	.4	.6	.4	.4	.5	.5	.5	.7	.5	.5
All site classes												
Mean	1.4	1.6	1.8	1.6	1.7	1.6	1.8	1.7	1.6	1.5	1.5	1.8
Std. deviation	.5	.8	.6	.6	.7	.6	.5	.6	.6	.6	.5	.6

¹1 = high vigor, 2 = medium, and 3 = low.



to the affinity of these species for wet sites, where sweetgum grows poorly. In general, oak vigor was better than sweetgum on poor sites, but less, or about the same, on the best sites.

Insect incidence was high on all the oaks on the poorest sweetgum sites. Damage in cherry-bark and water oaks declined rapidly as site quality increased (table 7). Attacks on other species did not appear to be related to sweetgum site class.

Figure 6.—
Site-index relations between sweetgum (Sg) and green ash (GA) (N = 47).

Table 7.—Average insect incidence¹ on trunks of sweetgum and six other species, by sweetgum site-index class

Sweetgum site-index class	Species combination											
	Sweetgum	Cottonwood	Sweetgum	Cherry-bark oak	Sweetgum	Water oak	Sweetgum	Willow oak	Sweetgum	Nuttall oak	Sweetgum	Green ash
Less than 85 feet												
Mean	...	...	1.0	1.3	1.0	1.7	1.0	1.5	1.1	1.5	1.0	1.0
Range	...	...	1.0-1.0	1.0-3.0	1.0-1.0	1.0-3.0	1.0-1.5	1.0-3.0	1.0-1.5	1.0-3.0	1.0-1.0	1.0-1.0
Std. deviation	...	...	.0	.6	.0	.6	.2	.7	.2	.7	.0	.0
85-94 feet												
Mean	1.0	1.3	1.1	1.1	1.1	1.3	1.5	1.6	1.0	1.2	1.1	1.2
Range	1.0-1.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-3.0	1.0-3.0	1.0-3.0	1.0-2.0	1.0-2.0	1.0-3.0	1.0-3.0
Std. deviation	.0	.5	.3	.3	.3	.6	.7	.6	.3	.4	.3	.6
95-104 feet												
Mean	1.0	1.2	1.0	1.1	1.0	1.3	1.0	1.4	1.0	1.4	1.0	1.0
Range	1.0-1.0	1.0-2.0	1.0-1.0	1.0-2.0	1.0-1.0	1.0-3.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-1.0	1.0-2.0
Std. deviation	.0	.4	.0	.3	.0	.5	.2	.5	.2	.5	.0	.3
105 feet plus												
Mean	1.1	1.5	1.1	1.1	1.0	1.1	1.1	1.3	1.0	1.4	1.0	1.0
Range	1.0-1.5	1.0-2.0	1.0-2.0	1.0-2.0	1.0-1.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-2.0	1.0-1.0	1.0-1.0
Std. deviation	.2	.5	.3	.3	.0	.3	.3	.5	.2	.5	.0	.0
All site classes												
Mean	1.1	1.3	1.0	1.1	1.0	1.3	1.2	1.4	1.1	1.3	1.0	1.1
Std. deviation	.2	.5	.2	.4	.2	.5	.4	.5	.3	.5	.3	.4

¹ 1 = no evidence of attack, 2 = moderate attack, and 3 = heavy attack.