United States
Department of
Agriculture

Forest Service

**Southern Forest
Experiment Station**

New Orleans,
Louisiana

Proceedings Reprint

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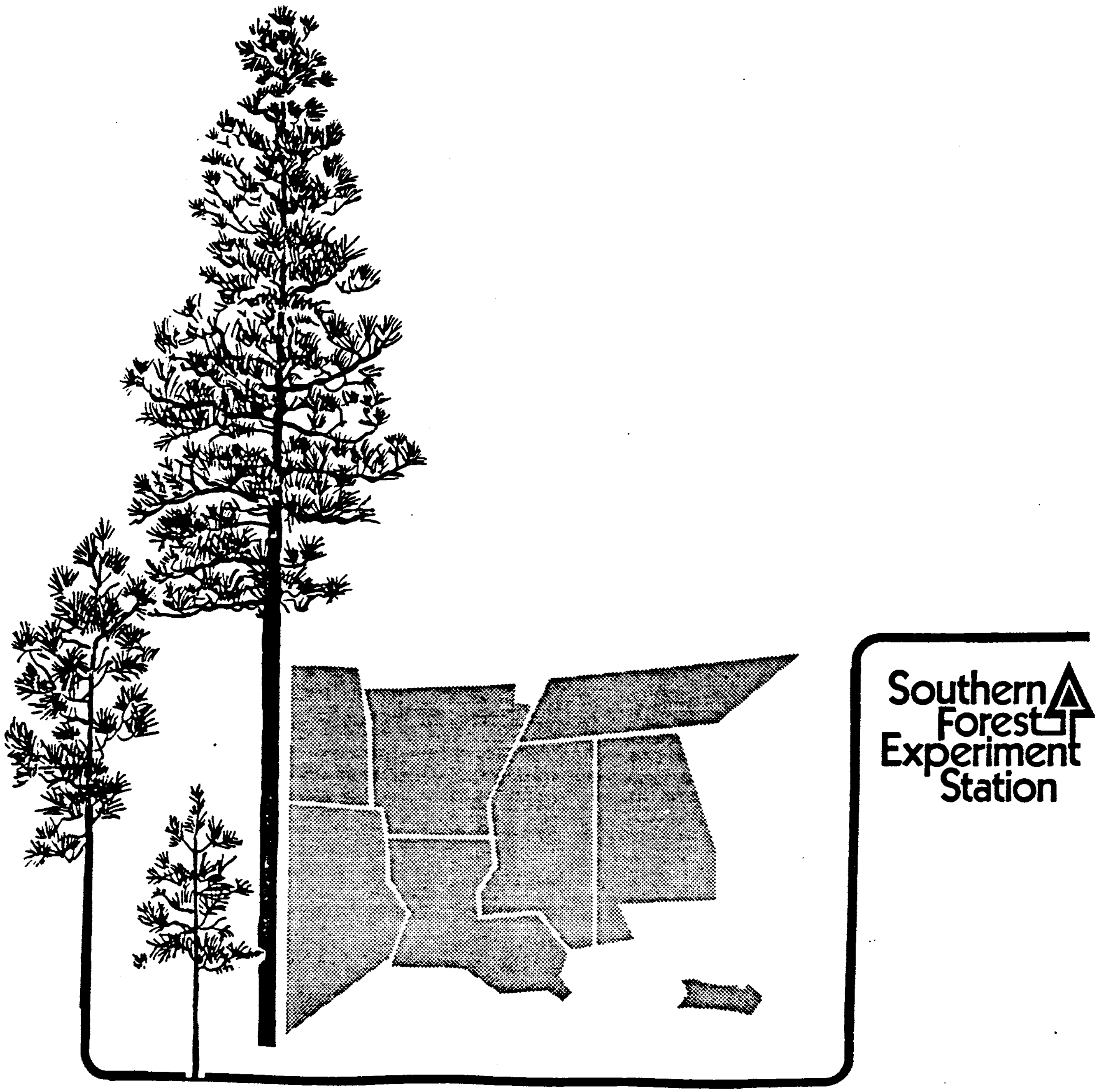
In: Proceedings of the 1986 Southern Forest Biomass Workshop; 1986 June 16-19; Knoxville, TN. Norris, TN: Tennessee Valley Authority; 1986: 65-70.



NUTRIENT DISTRIBUTION AND TREE DEVELOPMENT THROUGH AGE 8 OF FOUR OAKS PLANTED AT FIVE SPACINGS IN A MINOR STREAM BOTTOM[1/]

Harvey E. Kennedy, Jr., Bryce E. Schlaegel, and Roger M. Krinard[2/]

Abstract.--Eight hardwood species were planted at five spacings in a minor stream bottom in southeast Arkansas. Because of inherent differences in nutrient requirements and tree development, only four oak species are covered in this paper. Spacing generally did not affect nutrient concentrations, but differences did exist among species. Leaves constituted only 10-15 percent of aboveground biomass but contained 25-60 percent of individual nutrients.

INTRODUCTION

World-wide demand for wood products is increasing, along with demand for recreational and watershed uses of forest lands. These factors are causing society to place more diverse demands on forested land, some of which will take precedence over wood production in certain areas. Large areas of prime hardwood and pine forest lands are being cleared for agriculture, urban and industrial development, and highways and utility rights-of-way. These factors have motivated foresters to seek ways to maximize timber production on lands available for forestry uses but at the same time not cause short- or long-term nutrient depletion of the site, which may eventually reduce yields. The purpose of this paper is to give quantitative data on nutrient concentrations and distribution in leaves and woody material, tree growth and development, and soil nutrient levels of four oak species in a hardwood plantation.

TEST SITE

The test site was an 8-year-old hardwood plantation growing in a minor stream bottom in southeastern Arkansas, about 10 miles south of Monticello. Eight tree species were planted at five spacings in a randomized complete block design, with four blocks of each of the 40 factorial spacing and species combinations. The species are: water oak (Quercus nigra L.), Nuttall oak (Q. nuttallii Palmer), cherrybark oak (Q. falcata var. pagodifolia Ell.), swamp chestnut oak (Q. michauxii Nutt.), sycamore (Platanus occidentalis L.), sweetgum (Liquidambar styraciflua L.), cottonwood (Populus deltoides Bartr. ex Marsh.), and green ash (Fraxinus pennsylvanica Marsh.). Because of inherent differences in growth and development and possible nutrient uptake among the eight species, only data from the four oak species are presented in this paper.

The soil series is Arkabutla, a member of the fine-silty, mixed, acid, thermic family of Aeric Fluvaquents. These somewhat poorly drained soils, formed in silty alluvium, have dark-brown silt loam A horizons (surface layers) and dark-brown silty clay loam upper B horizons (subsoils) underlain by light brownish-gray silt loam. Estimated site indices for the four oaks range from 90 feet at age 50 for swamp chestnut oak to 110 feet at the same age for Nuttall (Broadfoot 1976).

The spacings in feet and respective number of trees per acre (in parentheses) were 2 by 8 (2723), 3 by 8 (1815), 4 by 8 (1361), 8 by 8 (681), and 12 by 12 (303). Spacings were chosen to span from narrow coppice to the more usual pulpwood and sawlog spacings. The 8-foot distance between rows was chosen to allow cultivation with standard farm equipment during the first growing season.

Each plot (160 total) consisted of 169 trees planted in a rectangular grid of 13 by 13 rows. The interior 5 by 5 rows were designated as

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1/ Paper presented at Eighth Annual Southern Forest Biomass Workshop, Knoxville, TN, June 16-19, 1986.

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permanent remeasurement rows, with the outer 4 rows as a buffer.

METHODS AND MATERIALS

Beginning in the fall of 1977, two trees representative of each plot from the second and third buffer rows on three of the four blocks were destructively sampled each fall. The same three blocks have been sampled each year for a total of eight annual samples. The blocks were chosen primarily on the basis of survival at age 3 and because the vast amount of work involved made it impractical physically or financially to sample all blocks. Tree heights, diameters, and survival were measured, and soil samples were obtained each year on all plots in each of the four blocks. Field measurements on the destructively sampled trees included diameter 6 inches above groundline, d.b.h., total height, height to live crown, total bole weight, and total crown weight. Individual bole, limb, and leaf samples were taken and sealed in polyethylene bags for laboratory determinations of green and dry weights and volume. Two 1-inch-thick disks were cut from the bole at a 6-inch stump and at intervals of 20, 40, 60, and 80 percent of total tree height for growth and chemical determinations. The branch and leaf samples were obtained by selecting two representative branches from each quarter of crown length and consolidating them into an 8-branch tree sample; leaves were detached from the branches in the field and bagged separately. Green weights, dry weights, and volumes of bole and branch components were determined in the laboratory by standard laboratory procedures from a representative sample of the eight branches; the remainder was used for chemical analyses.

Green weights of bole wood and bark for each tree were obtained by multiplying the proportion of each in the bole sample times the total bole green weight measured in the field. Green weights of branch wood, branch bark, and leaves were derived by adding the leaf and branch sample weights, finding the proportion of each component in the sample, and applying the proportions to the total crown weight obtained in the field.

Total dry weights and volumes for each component were calculated by using the moisture contents of the consolidated sample component and their specific gravities. Moisture contents and specific gravities were assumed to be uniform within each component.

After green weights for leaves, bole, and limb samples designated for chemical analyses were determined, samples were oven-dried at 70 °C and ground before chemical analyses. The two trees from each plot were composited into one sample of each component for each plot before analyses. Bole and branch wood and bark were consolidated into one sample (woody material) for years 1-4 and 6-9. At the end of the fifth year, the wood and bark of bole and branch samples were separated. Thus, for the fifth year nutrient concentrations were determined for leaves, bole wood and bark, and limb wood and bark. Again, the two trees per plot were composited into one sample of each component for each plot. Concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) were determined for each sample. Nitrogen was determined by the standard Kjeldahl procedure; P by colorimetry with molybdenum blue color development; and K, Ca, and Mg by atomic absorption spectrophotometry after samples had been dry-ashed and taken up in dilute HCl.

Soil organic matter (OM); total N; extractable P; exchangeable K, Ca, Mg; and pH levels were determined before planting (year 0) and at the end of each growing season. Soil samples from the 0- to 6-inch layer were collected at the four corners and center of the 5- by 5-row remeasurement plot. The samples were collected in August each year and composited to make one sample per plot.

Soil N was determined by standard Kjeldahl procedures. Phosphorus was measured with a colorimeter by the Mississippi soil test method. This is a two-stage extraction: Stage 1 - soak sample 10 minutes in 5 ml of 0.05$\underline{N}$ HCl; stage 2 - add 20 ml of buffered acidic acid (acetic-malic-malonic) AlF_3 solution at pH 4.0. Potassium, Ca, and Mg concentrations were determined by atomic absorption spectrophotometry after extraction in 1$\underline{N}$ NH_4OAc. Soil pH was measured with a glass electrode in a 1:1 soil/water ratio. Oxidizable OM was established by chromic acid oxidation and titrations with $Fe(NH_4)_2(SO_4)_2$, the Walkley-Black method.

STATISTICAL ANALYSES

Because the three blocks, as stated earlier, selected for tissue nutrient determinations came from four blocks in an inconsistent manner by species and spacings, block was not considered a factor in analyzing the data. Thus, a split-plot, completely random design was used, with species and spacings being whole plots and years subplots. Because of some missing first-year data and the use of a different method for calculating fifth-year data, trends over time were determined by using second-, fourth-, sixth-, and eighth-year data. For soil analyses, where measurements were taken from all plots, a split-plot, randomized complete block design was used. The same replications used in tissue nutrient determination were also used in analyzing eighth-year weight, volume, height, and diameter data in a completely random design. Testing was at the 0.05 level. Comparisons among treatment means were made by using Duncan's new multiple range test.

RESULTS AND DISCUSSION

Tissue Nutrients

Significant interactions occurred for nutrient concentrations in foliar and woody material, mostly for years by species in both tissues but also for years by spacing for N, P, and K in woody material. These interactions are a reflection of inherent differences among species in growth rates and nutrient absorption. The main effects of species and spacing appear more important than the interactions and will be discussed in this paper.

Spacing did not affect the concentrations of nutrients in leaves or woody material except for Ca in woody material. Calcium was higher in the wood of trees planted at the 3- by 8-foot spacing than at the 12- by 12-foot spacing. Levels ranged from 0.51% for the 12- by 12-foot spacing to 0.60% for the 3- by 8-foot spacing.

Species did have an effect on concentrations of most nutrients in the leaves and woody material (Tables 1 and 2). Species were different in leaf concentrations of P, K, and Ca but not different in N and Mg levels (Table 1). Swamp chestnut oak was highest in P, with no difference among the other three oaks. Potassium concentrations were lower in swamp chestnut oak than in cherrybark oak, with neither species different from Nuttall and water oak. All four species were different in Ca concentrations, with Nuttall oak the lowest and swamp chestnut oak the highest.

Species were significantly different for all nutrient concentrations in woody material except P (Table 2). Swamp chestnut oak was the highest in N concentration and cherrybark oak the lowest. Nuttall and water oaks were in-between, but not different from each other. Water oak was significantly highest in K, with no difference among the other three species. Water and Nuttall oaks were not different from each other in Ca concentration but were significantly lower than cherrybark and swamp chestnut oaks, which were not different from each other. Nuttall oak was highest in Mg, with no difference among the other three species. Although differences among species in nutrient concentrations in woody material existed, the magnitudes were not large, with the highest concentration being 10 to 30 percent greater than the lowest concentration.

Analyses of individual species by spacing and years showed about the same results as when species were combined. The only differences due to spacing were in K concentrations in the leaves of cherrybark and Nuttall oaks, N in the wood of swamp chestnut oak, and Ca in the wood of cherrybark oak.

Years significantly affected all nutrient concentrations. The years-by-species interaction in leaves was significant; for woody material, all interactions were significant except the years by

Table 1.--Nutrient concentrations in leaves of four oak species averaged over five spacings and 8 years[1/]

Species[2/]	N	P	K	Ca	Mg
	Pct				
WaO	1.64a	0.105b	0.569ab	0.831c	0.130a
CBO	1.68a	0.111b	0.599a	1.019b	0.140a
NO	1.68a	0.112b	0.566ab	0.738d	0.126a
SCO	1.72a	0.123a	0.542b	1.276a	0.115a

[1/] Values in a column followed by the same letter are not significantly different at the 0.05 level.

[2/] WaO = water oak; CBO = cherrybark oak; NO = Nuttall oak; SCO = swamp chestnut oak.

Table 2.--Nutrient concentrations in woody material of four oak species averaged over five spacings and 8 years[1/]

Species[2/]	N	P	K	Ca	Mg
	Pct				
WaO	0.340b	0.040a	0.213a	0.453b	0.057b
CBO	0.313c	0.037a	0.187b	0.624a	0.057b
NO	0.330bc	0.039a	0.198b	0.481b	0.066a
SCO	0.388a	0.040a	0.198b	0.645a	0.058b

[1/] Values in a column followed by the same letter are not significantly different at the 0.05 level.

[2/] WaO = water oak; CBO = cherrybark oak; NO = Nuttall oak; SCO = swamp chestnut oak.

spacing for Ca and Mg. No logical explanation can be given for these effects, but certain tendencies were evident. For leaves during years 1 and 2, N, P, and Mg were generally at the higher end of concentration levels, but K and Ca were at the lower end. For woody material during years 1 and 2, N, P, K, and Mg tended to be at the higher levels, but Ca was at the middle to lower levels. A partial explanation for this may be the "dilution effect," but this is not a total explanation because nutrient concentrations during years 7 and 8 were not always lowest. For leaves during years 7 and 8, concentrations were mostly at the middle to higher concentration levels. In woody material during years 7 and 8, nutrient concentrations tended to be toward the lower end of the levels. Rainfall during the growing season (April through September) does not fully explain concentration levels either. For example, year 3 had the highest growing season rainfall, 44 inches, compared to 20-25 inches during the other 7 years. During year 3, leaf concentrations were lowest in N and P, fourth lowest in K and Ca, and third lowest in Mg. Concentrations in woody material during year 3 were fourth highest in N, K, and Mg; second highest in P; and third highest in Ca.

Tissue data for years 2, 4, 6, and 8 were analyzed to determine possible trends in nutrient concentrations. Spacing only affected leaf P, species affected P and Ca, and years affected all foliar nutrients. The years-by-species interaction was significant for all nutrients except K. There was a linear effect for K, Ca, and Mg; quadratic for N, P, Ca, and Mg; and cubic for P, K, and Ca. However, no meaningful trends could be discerned.

Trends for woody material were somewhat more pronounced than for leaves. Spacing and species generally had no effect. Again, however, years did affect all nutrients for all species. The linear and quadratic effects were significant for all nutrients, but cubic effects were not. Generally, nutrient concentrations decreased with age in N, P, K, and Mg. Calcium was low at age 2, higher at ages 4 and 6, and decreased at age 8.

Nutrient Distribution

Pounds per acre and percentages of nutrients at age 5 in leaves, bole wood and bark, and limb wood and bark are given in Table 3. To give ranges, only data for the highest and lowest yield spacings are presented.

Based on fifth-year data, concentrations of N, P, K, and Mg in tree components followed the general order of leaves > bole and limb bark > bole and limb wood. The ranking in tree components for Ca was bole and limb bark > leaves > bole and limb wood.

Total aboveground tree dry weight was 4 times greater in the 2- by 8-foot spacing than in the 12- by 12-foot spacing. However, pounds per acre of nutrients, depending on species, nutrient, and tree

Table 3.--Average pounds of nutrients per acre and percentages in tree components for two spacings at age 5

	2X8-foot spacing										12X12-foot spacing									
	N		P		K		Ca		Mg		N		P		K		Ca		Mg	
Component[1/]	Lb	Pct	Lb	Pct	Lb	Pct	Lb	Pct	Lb	Pct	Lb	Pct	Lb	Pct	Lb	Pct	Lb	Pct	Lb	Pct
										Water oak										
BW	14.8	14.7	2.1	23.3	16.5	30.4	19.1	14.4	3.2	25.5	3.2	12.9	0.3	17.9	3.7	27.7	2.6	9.4	0.7	24.0
BB	10.4	10.2	0.6	6.3	2.6	4.9	33.6	24.9	0.8	6.2	2.2	8.3	0.1	6.4	1.2	7.9	5.3	18.6	0.2	7.1
LW	14.8	14.9	2.6	29.3	11.3	21.9	18.2	14.1	2.8	22.5	4.4	17.7	0.6	29.5	3.2	24.0	4.6	16.0	1.0	32.9
LB	9.8	9.5	0.6	7.0	3.1	5.7	30.6	24.1	1.5	11.6	2.6	10.4	0.2	8.2	0.7	5.1	7.7	27.1	0.3	10.5
LV	50.4	50.7	3.1	34.1	21.1	37.2	28.8	22.5	4.4	34.2	12.4	50.8	0.7	38.1	4.8	35.3	8.0	29.0	0.8	25.4
										Cherrybark oak										
BW	8.3	15.3	1.1	25.0	8.6	29.8	11.4	14.7	1.9	25.7	2.1	13.9	0.2	21.4	2.0	28.4	2.2	10.5	0.4	29.0
BB	4.1	7.6	0.3	5.7	1.1	4.3	19.3	23.8	0.4	5.8	1.1	7.2	0.1	6.2	0.3	4.6	4.9	22.8	0.1	5.8
LW	6.0	11.1	1.0	21.7	4.1	15.0	7.3	10.1	1.3	20.4	2.3	14.8	0.3	24.0	1.2	16.1	3.2	14.2	0.4	27.9
LB	3.6	6.8	0.2	5.6	1.3	4.7	14.1	17.8	0.6	8.9	1.2	7.8	0.1	7.0	0.4	5.7	4.9	21.6	0.1	9.0
LV	31.7	59.2	1.9	42.0	13.7	46.2	25.5	33.6	2.7	39.2	9.0	56.3	0.5	41.4	3.3	45.2	6.8	30.8	0.4	28.4
										Nuttall oak										
BW	8.8	16.6	1.7	30.5	8.8	35.9	6.0	12.6	2.2	33.1	2.8	19.2	0.4	30.1	3.5	39.4	2.2	13.0	0.8	38.5
BB	4.1	7.7	0.3	5.1	1.2	5.0	12.6	26.7	0.5	7.6	1.4	8.9	0.1	5.9	0.4	4.6	4.5	24.9	0.1	6.5
LW	6.7	12.6	1.1	21.7	4.1	16.7	4.6	9.7	1.4	20.9	1.9	12.4	0.2	18.9	1.3	15.1	1.9	10.8	0.4	22.1
LB	3.9	7.4	0.3	5.0	1.1	4.6	10.7	23.7	0.7	11.1	1.3	8.5	0.1	6.2	0.4	4.1	4.8	27.0	0.2	10.3
LV	29.4	55.8	2.0	37.7	9.2	37.7	12.5	27.3	1.8	27.4	7.2	50.9	0.5	38.9	3.1	36.7	4.2	24.3	0.5	22.6
										Swamp chestnut oak										
BW	7.7	17.5	0.6	20.4	6.3	29.2	10.8	15.4	1.1	31.2	0.7	19.4	0.1	23.9	0.4	31.5	0.7	17.9	0.1	33.8
BB	4.7	10.5	0.3	8.4	1.4	7.4	20.0	29.2	0.4	12.9	0.3	9.9	*	9.1	0.1	7.8	1.1	24.8	*	11.8
LW	4.2	8.6	0.5	15.3	2.5	13.2	6.2	7.2	0.3	11.8	0.4	10.3	0.1	16.4	0.2	13.9	0.4	6.5	*	10.4
LB	3.5	7.1	0.2	6.4	1.4	5.9	12.5	16.7	0.3	9.8	0.3	7.6	*	6.9	0.1	7.5	0.8	16.2	*	10.5
LV	24.5	56.3	1.7	49.6	9.5	44.3	19.5	31.5	1.0	34.3	1.8	52.9	0.1	43.8	0.5	39.3	1.8	34.2	0.1	33.5

1/ BW = bole wood; BB = bole bark; LW = limb wood; LB = limb bark; LV = leaves.

* Less than 0.05 pound.

component, ranged from 2 to 20 times greater in the 2- by 8-foot spacing than in the 12- by 12-foot spacing (Table 3). The proportions for a given nutrient and tree component in all spacings, however, were similar despite the wide range in pounds per acre between spacings.

Foliage constituted only 10 to 15 percent of the total tree weight but contained 25 to 60 percent of the individual nutrients in a tree. Nutrient concentrations in the tree bark were higher than in the wood, but because of large differences in dry weights the wood contained a higher proportion of individual nutrients, except Ca, which was higher in bark (Table 3).

Soil Nutrients

Soil nutrient levels for years averaged over species and spacings are given in Table 4. Species and spacing had no effect on soil nutrient levels over the 8-year period. Years affected nutrient levels, but there were no interactions except for years by spacing for pH and years by species for Ca.

There was considerable year-to-year variation, and no definite trends were discernible for soil nutrients. However, some slight trends are probably worth discussing. The highest or second highest level for N, P, K, Mg, pH, and OM occurred in year 0. Nitrogen then dropped to its lowest level in years 1, 2, 3, and 4, with year 3 numerically the lowest. The decrease in N corresponds with a decrease in OM when year 1 was the lowest. Because the major source of N is from soil OM, this may partially explain the decrease in N. Year 3 had about 2 times more rainfall than the other years, and some N probably was leached below the 0- to 6-inch sampling depth. Disking the first year incorporated OM into the soil and created conditions more favorable for decomposition. Year 8 was the highest and year 7 the third highest in N, indicating that the trees may have begun to return enough litter to the soil to offset OM decomposition. The highest pH levels were in year 0 and the lowest in year 4, followed by years 1 and 3. This is probably a reflection of the release of organic and inorganic acids during OM decomposition. No explanation can be given for the variation in other nutrients.

Although years had a significant effect on all soil nutrient levels, the range from highest to lowest was not very wide, and significant differences probably reflect the high degrees of freedom, 8 and 480, used to test for differences. From a practical standpoint, these differences would probably have little if any impact on tree growth and nutrient uptake.

Tree Growth and Development

Only eighth-year growth data were analyzed for total dry weight without leaves per acre, cubic feet per acre, leaf weights per acre, survival, average diameters at breast height, and average heights (Table 5). Spacings affected all variables except survival and height, and species affected all variables except survival. There were no significant interactions.

Total per acre tree weights, cubic foot volumes, and leaf weights all reacted the same to spacing (Table 5). The 2-, 3-, and 4-foot spacings were not different from each other but were greater than the 8- by 8-foot and 12- by 12-foot spacings, which did not differ from each other. Water oak had the highest yields at 35,400 pounds and swamp chestnut oak the lowest at 9,800 pounds per acre. Nuttall and cherrybark oaks did not differ. Water oak was the highest with a 914 cubic-foot volume and swamp chestnut oak the lowest with 248; Nuttall and cherrybark oaks were not different. Water oak was also highest in leaf yield with 4,003 pounds and swamp chestnut oak the lowest with 1,570 pounds per acre. No difference existed between the Nuttall and cherrybark oaks.

Survival did not differ among species or spacings. As expected, diameters were smallest in the 2- by 8-foot and 3- by 8-foot spacings, followed by the 4- by 8-foot and 8- by 8-foot spacings, with the significantly largest diameters in the 12- by

Table 4.--Soil nutrient levels averaged by year through age 8

Years	N	P	K	Ca	Mg	pH	OM
	Pct	----------	Ppm	----------			Pct
0[1/]	0.1155	12	103	573	189	5.4	2.3
1	0.1067	10	78	471	174	4.9	1.8
2	0.1089	12	110	576	190	5.3	2.1
3	0.1045	15	75	591	114	5.0	2.0
4	0.1056	11	65	572	112	4.5	2.0
5	0.1137	8	72	610	113	5.3	2.3
6	0.1123	7	76	613	121	5.3	2.1
7	0.1148	9	69	608	123	5.3	2.1
8	0.1181	9	77	593	119	5.3	2.0

1/ Sampled before trees were planted.

Table 5.--Eighth-year growth and yield data for each spacing and the four oak species[1/]

	Total wt., lb/acre w/o leaves	Volume, cu ft/ acre	Leaves, lb/acre	Survival	Diameter	Height
				Pct	In	Ft
Spacing (ft)						
2x8	32,100a	829a	4,322a	77a	1.5c	15.2a
3x8	24,000a	619a	3,527b	76a	1.5c	14.5a
4x8	27,200a	700a	3,122ab	83a	1.9b	17.0a
8x8	13,700b	348b	1,775c	75a	1.9b	15.8a
12x12	10,800b	276b	1,304c	83a	2.5a	17.1a
Species[2/]						
WaO	35,400a	914a	4,003a	84a	2.2a	20.1a
CBO	19,800b	484b	2,739b	80a	1.8b	15.8b
NO	21,300b	570b	2,928b	75a	2.1ab	16.7b
SCO	9,800c	248c	1,570c	75a	1.3c	11.0c

1/ Values in a column for spacing or species followed by the same letter are not significantly different at the 0.05 level.

2/ WaO = water oak; CBO = cherrybark oak; NO = Nuttall oak; SCO = swamp chestnut oak.

12-foot spacing. Water and Nuttall oaks at 2.2 and 2.1 inches were significantly larger than swamp chestnut oak.

Spacing did not affect total tree heights. Heights ranged from 14.5 feet in the 3- by 8-foot spacing to 17.1 feet in the 12- by 12-foot spacing. Water oak was the tallest at 20.1 feet and swamp chestnut oak the shortest at 11.0.

SUMMARY AND CONCLUSIONS

The study site is rated relatively infertile for hardwoods because soil nutrient levels are barely at or below acceptable levels for good tree growth, particularly for P, K, and Ca (Davey 1976). Foliar N was below the 2.0-percent level recommended for good growth in cottonwood and sycamore (Carter and White 1971, Norris et al. 1980). Growth for all four oaks was good. The slowest was swamp chestnut oak, which could have been a reflection of the slow growth of small seedlings during the first 5 years, because this species had only started good annual growth in years 6 through 8. Undoubtedly, more research is needed on many different sites before minimal foliar nutrient concentrations and soil nutrient levels can be determined for these four oak species. Differences in foliar nutrient levels among the four oaks also point out the impropriety of generalizing from one species to another.

Based on this study, these four oaks can be grown at any of the five spacings without any serious effects on nutrient uptake or depleting soil nutrient reserves. Choice of spacing would depend on the product objective of the grower. Yields are 3 to 4 times larger at the more narrow spacings, but one must consider that there are 9 times more trees in the 2- by 8-foot spacing and that planting costs are considerably higher than in the 12- by 12-foot spacing.

Spacing generally did not affect tissue nutrients. There were differences among species with regard to nutrient uptake or requirements. Based on fifth-year results, the leaves comprised only 10-15 percent of the aboveground dry weight but contained 25-60 percent of the individual nutrients in a tree. Because of the high concentrations of individual elements in the leaves, any harvesting system that returns the leaves to the site would return a large proportion of the nutrients to the soil and thus contribute to long-term maintenance of site quality.

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