United States Department of Argriculture

Forest Service

Southern Forest Experiment Station

Research Note

so-371
January 1993

Effects of Crown Position and Initial Spacing on Foliar Nutrient Composition of Seven Bottomland Hardwoods

Harvey E. Kennedy, Jr.

SUMMARY

Seven plantation-grown bottomland hardwoods, sweetgum (*Liquidambar stryaciflua* L.), green ash (*Fraxinus pennsylvanica* Marsh.), American sycamore (*Platanus occidentalis* L.), water oak *(Quercus nigra* L.), Nuttall oak *(Q. nuttallii* Palmer), cherrybark oak (Q. *falcata* var. *pagodifolia* Ell.), and swamp chestnut oak (Q. *michauxii* Nutt.), were sampled after the seventh growing season to determine foliar nutrient concentrations. Foliage samples were collected from the upper, middle, and lower crown positions and from the entire crown. Determinations were made for levels of nitrogen, phosphorus, potassium, calcium, and magnesium. Spacing had no effect on nutrient concentrations. Nutrient levels differed by crown position for some nutrients in most species. Most of the differences were in the nitrogen, calcium, and magnesium levels.

Keywords: Calcium, *Fraxinus pennsylvanica,* nitrogen, plantation, *Quercus nigra.*

INTRODUCTION

Extensive clearing of bottomland hardwood forests for agricultural crop production in the Southern and Southeastern United States occurred during the late 1960's and early 1970's. Recently, however, several incentives to reforest some of these lands have been offered. Perhaps the best known of these is the Conservation Reserve Program (CRP) established under the 1985 Farm Bill (P.L. 100–233), which provides cost sharing and annual rental payments for reforestation and a number of other soil conservation practices. In February 1989, flood-prone croplands were brought under the 1985 Farm Bill (CP-14), which made millions of acres of croplands-those suitable for hardwood reforestation—eligible for benefits.

Inexpensive reforestation methods are required to take full advantage of opportunities under CRP. Work at the USDA Forest Service's Southern Hardwoods Laboratory at Stoneville, MS, has shown that direct-seeding of oaks *(Quercus* spp.) and planting of 1-O bare-root nursery stock of a number of bottomland hardwood species can work well when reforesting agricultural fields (Baker and Blackmon 1978, Francis 1983, Johnson 1983, Johnson and Krinard 1987, Kennedy 1985, Kennedy and others 1986). A number of State and Federal natural resource management agencies, private landowners, and hunting clubs have begun to apply these methods on a relatively large scale. For example, the Louisiana Department of Wildlife and Fisheries has planted and direct-seeded over 4,000 acres of bottomland oaks on the Ouachita Wildlife Management Area since 1985. And the Mississippi Department of Wildlife, Fisheries and Parks is well into a 1 O-year project to reforest nearly 1,000 acres on the Malmaison Wildlife Management Area by direct-seeding. These are only two examples of many that could be cited.

Most southern hardwood reforestation projects are being undertaken on land that has been in agronomic production (old fields) for a number of years. Information on the effects of agronomic practices on the nutrient properties of soils and the resultant influence on tree growth are unavailable. Past research at the Southern

Southern Forest Experiment Station/T-10210 U.S. Postal Services Bldg., 701 Loyola Avenue, New Orleans, La. 70113
Forest Service, U.S. Department of Agriculture.
Serving Alabama, Arkansas, Louisiana, Mississippi, E. Oklahoma, Tennessee, E. Texas, Puerto Rico, U.S. Virgin Islands

Hardwoods Laboratory has shown that trees planted on old-field sites can often respond favorably to fertilizer amendments (Francis 1985). If tree growth on old-field sites is not satisfactory, landowners may want to fertilize to possibly accelerate growth rates. One way to get an indication of whether trees will respond to fertilization is to determine foliar nutrient levels and compare these levels with levels in trees growing at acceptable rates. Growth rates on the study sites had been good for 10 years (Kennedy and others 1987, Schlaegel and Kennedy 1985). Therefore, nutrient levels reported in this paper may give an indication of productivity on similar sites.

Researchers have examined various aspects of sampling at different times during the growing season and have chemically analyzed different components of the leaf (Haines and others 1979, Shelton and others 1981, Smalley 1976). Most studies, however, have included only one species and one spacing. In this paper, comparisons of nutrient levels are made by crown position for seven hardwood species planted at five spacings in a minor stream bottom.

METHODS

This study, during its seventh growing season, was superimposed on an earlier study, "Effects of Spacing on Species Yields in Minor Bottoms."[1]

The principal soil series on the study area is Arkabutla, a member of the fine-silty, mixed, acid, thermic family of Aeric Fluvaquents. These are somewhat poorly drained soils that usually develop on slopes of 0 to 2 percent in flood plains within the silty uplands. They are good hardwood sites with a site index range at 50 years of 95 to 115 ft for cherrybark oak (*Quercus falcata* var. *pagodifolia* Ell.) and 90 to 110 ft for sweetgum (*Liquidambar styraciflua* L.). Broadfoot (1976) classifies the site as favorable for plantation management and suitable for planting all of the species in these two studies.

Species investigated were American sycamore (*Platanus occidentalis* L.), sweetgum, green ash (*Fraxinus pennsylvanica* Marsh), swamp chestnut oak (*Quercus michauxii* Nutt.), water oak (*Q. nigra* L.), Nuttall oak (*Q. nuttallii* Palmer), and cherrybark oak. The trees were planted at spacings of 2 by 8, 3 by 8, 4 by 8, 8 by 8, and 12 by 12ft.

[1]Schlaegel, Bryce E.; Kennedy, Harvey E., Jr. 1976. Study plan on file with Southern Hardwoods Laboratory, U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Stoneville, MS 38776.

Each plot consisted of 169 trees planted in a rectangular grid of 13 by 13 rows. The interior 5 by 5 rows were designated as a permanent remeasurement area in the earlier study, with the four rows outside this area (on each side) being the border rows. The interior two rows of the four border rows were designated for destructive sampling. Beginning in the fall of 1977 in the earlier study, three of the four plots for each spacing and species were selected for destructive sampling. Trees from these same three plots had been sampled in the fall of each year. Because of the vast amount of work involved in the earlier study, it was impractical to sample all plots; therefore, the plots used for sampling in that study were systematically chosen from blocks by species and spacing based on survival and growth (Kennedy and others 1986).

Foliar sampling was done during the first and second week in August following the recommendations of Smalley (1976). In this study, two trees representative of the average tree of the whole plot were selected for sampling. The trees were cut to facilitate sampling and measuring. The live crown was then divided into thirds, representing the lower, middle, and upper crown. Two representative branches, opposite each other, were selected from the center of the lower, middle, and upper crown, and foliar samples were collected from these branches. Samples were kept separate by plot and crown position, but samples from the two trees per plot were composited for each crown position for nutrient determinations. After samples for each crown position were obtained, a sample from the whole crown was taken so that nutrient levels for the whole tree crown for each plot could be determined. A total of 210 trees was sampled on 105 plots (3 blocks by 5 spacings by 7 species = 105). There were 4 foliar samples per plot for a total of 420 samples.

Foliar samples were dried at 70 °C and ground enough to pass through a 2-mm sieve in preparation for chemical analyses. Concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) were determined for each sample. Nitrogen level was determined by using standard Kjeldahl procedures; P level by colorimetry with molybdenum blue color development; and K, Ca, and Mg levels by atomic absorption spectrophotometry after samples had been dry-ashed and taken up in dilute HCl.

STATISTICAL ANALYSES

As stated earlier, the plots from which trees were sampled were selected from the blocks in the earlier study (Kennedy and others 1986) by species and spac-

Harvey E. Kennedy, Jr. is principal silviculturist at the Southern Hardwoods Laboratory, U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Stoneville, MS 38776. In cooperation with: Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group.

ing. Because of the manner in which plots were selected, blocks were not considered a factor in analyzing the data. A split-plot, completely randomized design was used with spacing being the whole plot and crown position the subplot. There were three replications of each treatment-spacing by crown position. A separate analysis was performed for each species/nutrient combination. Analyses of variance (ANOVA's) of foliar nutrient concentrations by spacing and crown position for each of the seven species (a total of 35 ANOVA's) were made at the 0.05 level. The ANOVA format is given in table 1. Duncans' new multiple-range test was used to determine differences among means.

Table 1 .— *The format used for individual ANOVA's*

Source	d.f.*
Replications (R)	2
Spacing (S)	4
Error A	8
Crown Position (CP)	3
R × CP	6
S × CP	12
Error B	24
Total	59

* d.f.=degrees of freedom

RESULTS AND DISCUSSION

Statistical analyses revealed that spacing had no significant effect on nutrient concentrations for any of the species or nutrients tested. The replication by crown position interaction was statistically significant for K in cherrybark oak, for K and Ca in sweetgum, and for N in sycamore. Spacing can be discounted as having an effect on the interactions because it had no effect on nutrient concentrations. Probable explanations for the significant interactions between replications and crown position are differences in site quality due to drainage, soil moisture, or other site factors and/or minor differences in plant nutrient concentrations resulting from differences in sampling procedures. None of the other interactions were statistically significant. Nutrient concentrations for the upper, middle, lower, and entire crown positions are given in table 2. Nutrient concentrations differed by crown position for some nutrients in most species. These differences are discussed separately by nutrient category in the following paragraphs.

Nitrogen

Nitrogen concentrations differed significantly by crown position for all species except sycamore (table 2). The upper crown was highest in N concentrations for water oak, Nuttall oak, sweetgum, and green ash; the middle crown was highest in N for cherrybark oak and swamp chestnut oak. There was a significant replication by crown position interaction for N in sycamore. The lowest concentrations were found in the lower crown and entire crown. Higher N concentrations in the upper crown could have been due to the mobility of N and its translocation to areas where new foliage and tissue were being formed near the meristem; lower concentrations in the lower crown indicate slower growth rates (Shelton and others 1981).

Table 2.— *Means for tested nutrients by species and crown position averaged over all spacings**

Crown position	N	P	K	Ca	Mg
			Percent		
Water oak					
Lower	1.4391,	0.083b	0.593	0.828a	0.167a
Middle	1.515a	.087a	.579	.709b	.147b
Upper	1.539a	.085a	.575	.620c	.135c
Entire	1.440b	.087a	.609	.721b	.145b
Nuttall oak					
Lower	1.488bc	0.091	0.663b	0.733a	0.134a
Middle	1.538ab	.092	.731a	.604bc	.119bc
Upper	1.563a	.093	.734a	.576c	.113c
Entire	1.451c	.094	.726a	.634b	.123b
Cherrybark oak					
Lower	1.601b	0.091b	0.670ab	1.177a	0.193a
Middle	1.688a	.095a	.642b	.945b	.157b
Upper	1.651ab	.091ab	.719a	.747c	.135c
Entire	1.538c	.093ab	.700ab	.911b	.154b
Swamp chestnut oak					
Lower	1.680ab	0.109	0.571b	1.477a	0.130a
Middle	1.720a	.112	.599ab	1.232b	.114bc
Upper	1.641bc	.107	.641a	.998c	.106c
Entire	1.591c	.110	.627a	1.265b	.122ab
Sweetgum					
Lower	1.120c	0.110	0.521b	1.519a	0.348a
Middle	1.185b	.112	.571ab	1.187b	.265b
Upper	1.279a	.112	.556ab	.705c	.199c
Entire	1.161bc	.111	.636a	.933b	.242b
Green ash					
Lower	1.469c	0.143	0.829	0.950a	0.178
Middle	1.537b	.149	.851	.791b	.175
Upper	1.621a	.140	.841	.686c	.169
Entire	1.455c	.141	.873	.757b	.173
Sycamore					
Lower	1.322	0.109b	0.65613	0.990a	0.238a
Middle	1.347	.111ab	.654b	.831b	.217b
Upper	1.416	.116a	.670ab	.729c	.203c
Entire	1.323	.114ab	.715a	.840b	.219b

*Values in a column followed by the same letter are not significantly different at the 0.05 level. Where no letters appear, overall tests were not significant.

Phosphorus

Crown position had no significant effect on P concentrations in Nuttall oak, swamp chestnut oak, sweetgum, and green ash but did in water oak, cherrybark oak, and sycamore (table 2). Crown positions with the highest P concentrations varied by species. The numerical nutrient concentrations in water oak, cherrybark oak, and sycamore generally differed only at the third decimal place; these differences have little practical importance.

Potassium

Potassium levels differed significantly by crown position for all species tested except water oak and green ash (table 2). Levels varied by crown position among species but generally were highest in the upper crown and entire crown and lowest in the lower crown. As with P, the numerical differences in nutrient concentrations were very small.

Calcium

Concentration levels differed significantly by crown position for all seven species tested. Levels were significantly highest in the lower crown and lowest in the upper crown in all species (table 2). Concentrations in the middle crown and entire crown were intermediate in value and did not differ from each other. The higher concentrations in the lower crown were probably due to the relative immobility of Ca, which is not translocated as rapidly to the middle and upper crowns as are the more mobile nutrients such as N (Baker and Blackmon 1978, Shelton and others 1981).

Magnesium

Magnesium concentrations were affected by crown position in all species except green ash (table 2). As with Ca, the highest concentrations were in the lower crown and the lowest concentrations in the upper crown. Concentrations in the middle crown and entire crown were intermediate in value. Again, as with Ca, the low concentrations in the upper crown can probably be attributed to the relative immobility of Mg and its inability to readily translocate to the upper crown.

Nutrient Concentrations

Concentrations of nutrients in tree tissue are accepted as good indicators of growth and soil fertility on a site and indicate whether trees on a given site may or may not respond to fertilizer amendments (Haines and others 1979, Shelton and others 1981, White and Carter 1970). Using these assumptions, the upper or middle crown would be the most appropriate area for sampling the highest N concentrations in most of the species tested in this study. The upper crown or entire crown would be the most appropriate area for sampling K. The highest concentrations of Ca and Mg were found in the lower crown. From a practical standpoint, however, it appears that a representative sample from the entire crown would be adequate for sampling all nutrients. Ranges in nutrient concentrations among crown positions are small. Also, concentrations in samples for the entire crown for most nutrients and species are within the range of concentrations in samples for the different crown positions (table 2). If sampling is done to determine the nutrient concentrations of several elements in a large number of species, keeping tissue samples separate by crown position during sampling, tissue preparation, and laboratory analyses would be a laborious task. One sample from the entire crown could be used to eliminate the task of collecting and keeping up with separate samples by crown position for each species.

The average size of trees for each spacing after seven growing seasons for the seven species are given in table 3. Good growth rates for the four oaks continued

Table 3.— *Average d.b.h. and total height (Ht.) at age 7 for the seven plantation-grown species by spacing*

	Spacing									
	2 by 8		3 by 8		4 by 8		8 by 8		12 by 12	
Species*	D.b.h.	Ht.	D.b.h.	Ht.	D.b.h.	Ht.	D.b.h.	Ht.	D.b.h.	Ht.
	In	*Ft*	*In*	*Ft*	*In*	*Ft*	*In*	*Ft*	*In*	*Ft*
SG	2.03	23.2	2.21	23.4	2.59	25.5	3.18	27.1	3.79	28.0
GA	1.53	18.9	1.43	16.2	1.89	20.8	2.36	22.1	3.22	25.9
SYC	1.42	18.4	1.63	19.5	1.83	20.8	2.83	28.5	3.33	27.3
WAO	1.50	16.7	1.49	16.5	1.83	18.6	1.90	17.7	2.36	18.6
NO	1.40	14.3	1.44	13.5	1.77	15.3	1.68	12.9	2.10	15.3
CBO	1.20	12.8	1.22	13.0	1.63	15.6	1.67	13.9	1.88	13.9
SCO	.93	9.4	.59	7.6	1.07	10.2	1.03	9.5	.97	8.5

*SG=sweetgum; GA=green ash; SYC=sycamore; WAO=water oak; NO=Nuttall oak; CBO=cherrybark oak; and SCO=swamp chestnut oak.

through age 10 in the earlier study (Kennedy and others 1987) and were predicted to be good for the three non-oak species (Schlaegel and Kennedy 1985). Concentrations of tissue nutrients for most species in this study, particularly N, were lower than the concentrations suggested by others for good growth in various bottomland hardwoods (Norris and others 1980, White and Carter 1970). These results indicate that more research is needed to determine minimum nutrient requirements for good growth in most hardwoods.

Past research at the Southern Hardwoods Laboratory has shown that trees planted on old-field sites can often respond favorably to fertilizer amendments (Francis 1985). Good growth was achieved for 10 years in the earlier study with the same species tested at the nutrient levels measured in this study. Landowners may want to use these nutrient levels and growth responses as an indication of site productivity in this area, particularly with plantings in the CRP where many such reforestation efforts are being done on old-field sites. If the growth and nutrient levels of trees are not satisfactory on a site, small fertilizer tests could be established to determine whether fertilization over the entire plantation might accelerate growth to a more satisfactory level.

SUMMARY AND CONCLUSIONS

Statistical analyses revealed that spacing had no effect on nutrient concentrations for any of the species tested. Crown position did significantly affect some nutrient concentrations by species; concentrations of N, Ca, and Mg were affected the most. Nitrogen concentrations were generally highest in the upper crown, and Ca and Mg were highest in the lower crown.

LITERATURE CITED

Baker, James B.; Blackmon, B.G. 1978. Summer fallowing-a simple technique for improving old-field sites for cottonwood. Res. Pap. SO-1 42. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 5 p.

Broadfoot, Walter M. 1976. Hardwood suitability for and properties of important Midsouth soils. Res. Pap. SO-127. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 84 p.

Francis, John K. 1983. Cherrybark and Shumard oaks successfully planted on eroded ridges. Tree Planters' Notes. 34(2): 2830.

Francis, John K. 1985. Bottomland hardwood fertilization-the Stoneville experience. In: Shoulders, Eugene, ed. Proceedings of the 3d biennial Southern silvicultural research conference; 1984 November 7-8; Atlanta, GA. Gen. Tech. Rep. SO-54. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 346-350.

Haines, Sharon G.; Haines, L. Wayne; White, Gordon. 1979. Nutrient composition of sycamore blades, petioles, and whole leaves. Forest Science. 25(1): 154-160.

Johnson, R.L. 1983. Nuttall oak direct seedings still successful after 11 years. Res. Note SO-301. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 3 p.

Johnson, Robert L.; Krinard, Roger M. 1987. Direct seeding of southern oaks-a progress report. In: 15th annual hardwood symposium of the Hardwood Research Council: applying the latest research to hardwood problems; Proceedings; 1987 May 1 O-l 2; Memphis, TN. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry: 1 O-l 6.

Kennedy, Harvey E., Jr. 1985. Cultural treatments influence hardwood growth and foliar nutrient concentration on a minor stream bottom site. Res. Pap. SO-215. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 6 p.

Kennedy, Harvey E., Jr.; Krinard, Roger M.; Schlaegel, Bryce E. 1987. Growth and development of four oaks through age 10 planted at five spacings in a minor stream bottom. In: Daniels, Robert A.; Watson, W.F.; Savelle, I. Winston, eds. Proceedings of the 1987 southern forest biomass workshop: 9th annual meeting of the Southern Forest Biomass Working Group; 1987 June 8-l 1; Biloxi, MS. Mississippi State, MS: Mississippi State University: 81-91.

Kennedy, Harvey E., Jr.; Schlaegel, Bryce E.; Krinard, Roger M. 1986. Nutrient distribution and tree development through age 8 of four oaks planted at five spacings in a minor stream bottom. In: Brooks, Robert T., ed. Proceedings of the 1986 Southern forest biomass workshop: 8th annual meeting of the Southern Forest Biomass Working Group; 1986 June 16-19; Knoxville, TN. Norris, TN: Tennessee Valley Authority: 65-70.

Norris, James Lawrence; White, Gordon; Sims, Donald. 1980. The relationship of soil, foliar, and topographical conditions to American sycamore (*Platanus occidental&* L.) growth in a plantation. Tech. Rep. 63.

Raleigh, NC: School of Forest Resources, North Carolina State Forest Fertilization Cooperative. 35 p.

Schlaegel, Bryce E.; Kennedy, Harvey E., Jr. 1985. Do different young plantation-grown species require different biomass models? In: Saucier, J.R., ed. Proceedings of the 1984 southern forest biomass workshop: 6th annual meeting of the Southern Forest Biomass Working Group; 1984 June 5-7; Athens, GA. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 23-35.

Shelton, M.G.; Nelson, L.E.; Switzer, G.L.; Blackmon, B.G. 1981. The concentration of nutrients in tissues of plantation-grown eastern cottonwood (*Populus deltoides* Bartr.). Tech. Bull. 106. Mississippi State, MS: Mississippi Agricultural and Forestry Experiment Station, Mississippi State University. 10 p.

Smalley, G.W. 1976. Seasonal variation in the nutrient composition of yellow-poplar leaves. In: Fralish, James S.; Weaver, George T.; Schlesinger, Richard C., eds. Proceedings of the central hardwood forest conference; 1976 October 17-l 9; Carbondale, IL. Carbondale, IL: Southern Illinois University: 377-385.

White, E.H.; Carter, M.C. 1970. Relationships between foliage nutrient levels and growth of young natural stands of *Populus deltoides* Bartr. In: Youngberg, C.T.; Davey, C.B., eds. Tree growth and forest soils. Proceedings of the 3d North American forest soils conference; 1968 August; Raleigh, NC. Corvallis, OR: Oregon State University Press: 283-294.