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BIOMASS AND NUTRIENT DISTRIBUTION IN 3-YEAR OLD GREEN ASH AND SWAMP CHESTNUT OAK GROWN IN A MINOR STREAM BOTTOM

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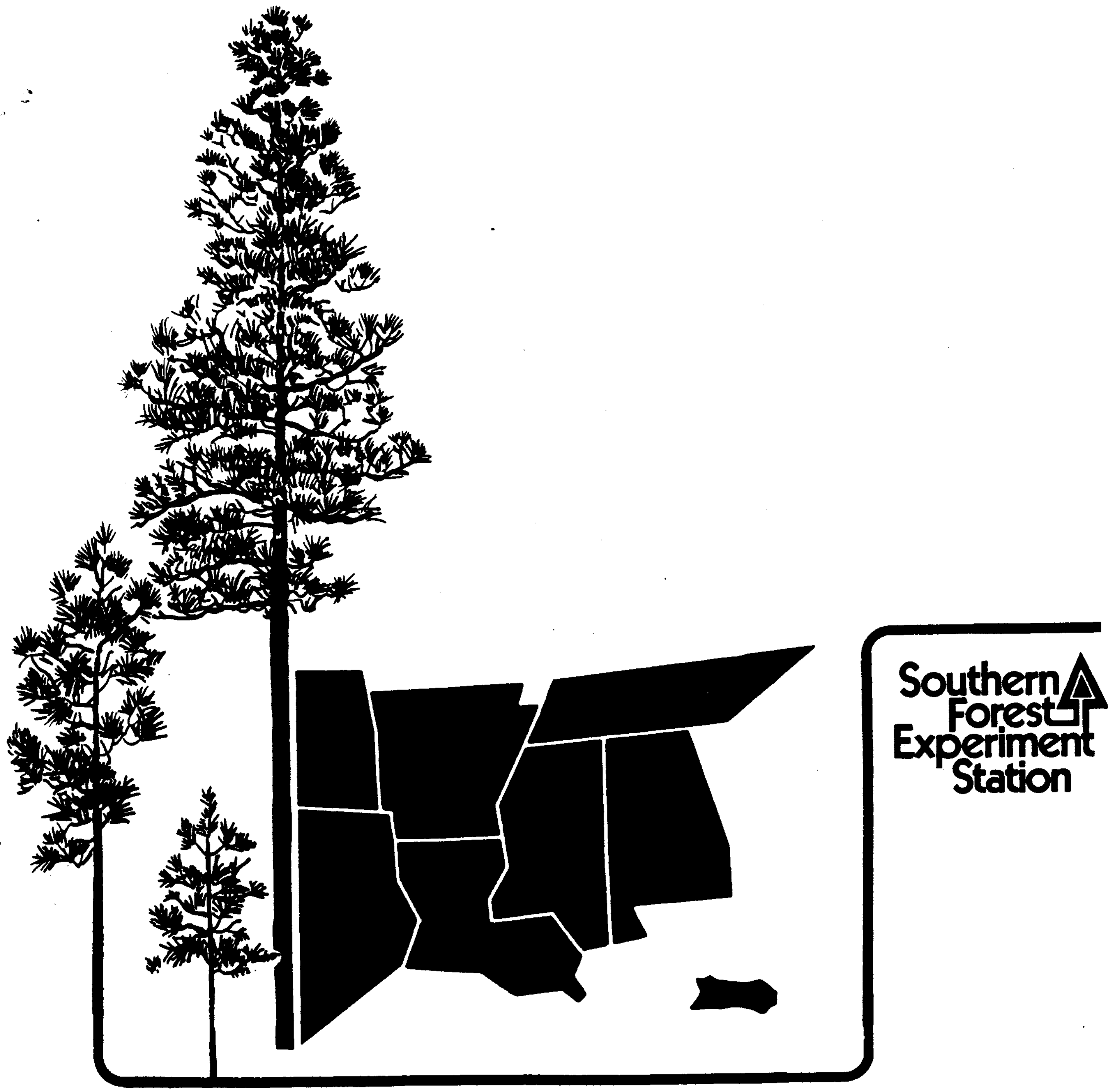

BIOMASS AND NUTRIENT DISTRIBUTION IN 3-YEAR-OLD GREEN ASH AND SWAMP CHESTNUT OAK GROWN IN A MINOR STREAM BOTTOM[1/]

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

Abstract.—After three growing seasons, green ash had produced 7,342 pounds per acre of above-ground dry matter compared to 3,572 for oak. Of the total biomass, ash had 53% in the bole (wood plus bark), 22% in old branches, 21% in leaves and 4% in new growth; oak had 50%, 21%, 24%, and 5% in the same components. These proportions changed after leaf fall. Concentrations of N, P, K, and Mg followed the general order of: leaves > new growth > bole bark and branch bark > bole wood and branch wood. Calcium concentrations were highest in bole bark and branch bark followed by leaves, new growth, and bole wood and branch wood.

INTRODUCTION

An understanding of biomass and nutrient distribution in forest systems is prerequisite to proper evaluation of the effects of imposed soils and silvicultural treatments. This paper reports biomass and concentrations and distribution of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) in leaves, new growth, bole wood and bark, and branch wood and bark of green ash (Fraxinus pennsylvanica Marsh.) and swamp chestnut oak (Quercus michauxii Nutt.) during the third year of a plantation.

METHODS

This study was superimposed on a larger study being conducted near Monticello, Arkansas.[3/] The study occupies about 55 acres in a minor stream bottom that transects pine uplands. The site was cleared of a mixed hardwood-pine stand and prepared for planting by shearing, root raking, and disking. The soil is classified Arkabutla, a member of the fine-silty, mixed, acid, thermic family of Aeric Fluvaquents. These somewhat poorly-drained soils formed in silty alluvium. Estimated site indices (Broadfoot 1976) range from 85-105 feet for green ash and 80-100 feet for swamp chestnut oak, both at age 50 years.

The larger study site was planted with eight species at five different spacings. Species were green ash, swamp chestnut oak, sycamore (Platanus occidentalis L.), sweetgum (Liquidambar styraciflua L.), cottonwood (Populus deltoides Bartr. ex Marsh.), water oak (Quercus nigra L.), cherrybark oak (Q. falcata var. pagodifolia Ell.), and Nuttall oak (Q. nuttallii Palmer).

The five spacings in feet were 2 x 8, 3 x 8, 4 x 8, 8 x 8, and 12 x 12. Spacings were chosen to span from the narrow coppice spacings to the more usual pulpwood and saw log spacings. The 8-foot distance between rows was chosen to allow tending by standard farm equipment.

Each plot consists of 169 trees of one species planted in a rectangular grid of 13 by 13 rows. The interior 5 by 5 rows were designated as permanent remeasurement rows with the exterior four rows as a buffer.

The minor stream floodplains, such as represented in this study, typically consist of flats, slopes, and small ridges. Two species, green ash and swamp chestnut oak, were chosen for sampling. These represent one of the faster and one of the slower growing species in the initial study. One plot for each species on a ridge and flat was chosen for sampling. The study was limited to these

[1/] Paper presented at Southern Silvicultural Research Conference, Atlanta, Georgia, November 7-8, 1984.

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[3/] Schlaegel, Bryce E., and Harvey E. Kennedy, Jr. 1976. Effects of spacing on species yields in minor bottoms. Study Plan FS-SO-1110-29, on file at Southern Hardwoods Laboratory, Stoneville, Miss.

two species on two sites because of the tremendous amount of sampling time required. Sampling was done on the second Monday of each month starting in April 1979 and continuing through March 1980.

The present study was set up in plots with 4- x 8-foot spacing. Three trees, representative of those on the whole plot, were selected from the second and third border rows around each sample plot. In the field, all leaves were removed from a tree before cutting and stored in plastic bags in an ice-chest. Tall trees were pulled over to remove the upper leaves. New growth, defined as woody growth that occurred during the third growing season, was separated, bagged, and labeled. Old branches were clipped into small segments, bagged, and labeled. Main stem was severed at groundline, diameter outside bark measured at 0.5 and 4.5 feet, and total height recorded. The bole was then cut into 0.5-foot sections, bagged, and labeled. Components of each tree on a plot were kept separate for subsequent weighing and nutrient determinations.

Green weights of all materials were recorded upon returning to the Southern Hardwoods Laboratory. A representative sample of branches was randomly selected and the bark separated from the wood. Each third section of the bole was selected and bark removed from the wood. The bark samples included cambium and phloem tissues. Green weights of each sample were then recorded. Samples and the remainder of each tree were dried to a constant weight at 70°C and dry weights obtained.

Leaves and samples of woody material and bark were ground to pass a 2-mm mesh in preparation for chemical analyses. Nitrogen was determined by 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.

Differences in nutrient concentrations between sites for each species and monthly concentrations in each tree component for each nutrient were tested using a split-plot analysis of variance. Species were tested separately because of inherent growth differences and possible differences in nutrient uptake. Comparisons among means were made using Duncan's New Multiple Range Test. All comparisons were made at the 0.05 level of confidence.

RESULTS

Biomass

Averaged across both sites at the end of the third growing season, green ash was 1.2 inches dbh and 13.0 feet tall compared to 0.6 inches and 6.8 feet for swamp chestnut oak. Green ash had produced 7,342 pounds per acre of above-ground biomass, whereas the oaks had produced 3,572 pounds per acre.

The proportion of above-ground biomass in the tree components measured was very similar during the growing season regardless of species (table 1). Green ash, during the growing season, averaged 21 percent of its biomass in the leaves, 53 percent in the bole (wood plus bark), 22 percent in branches (wood plus bark), and 4 percent in new growth. Swamp chestnut oak had 24, 50, 21, and 5 percent in the same components. The proportions of the various components are shown during the dormant season for each species in table 1. Each component makes up a larger part of the total without the leaves, but again ratios are very similar for both species. The proportions of biomass contained in the various components remained relatively constant throughout the sampling period.

Nitrogen

Leaves of both species were at their highest N concentration in May. During the other months, green ash had lower concentrations[4/] in October than June (fig. 1). Concentrations for oak were higher in May than the last three months of the growing season. Sites did not differ. Averaged across sites, green ash contained 1.85% and oak 1.75% N in May. These values had declined to 1.16% and 1.29% respectively in October. All leaves had fallen by the November sampling date. During the growing season 21% of the green ash biomass and 55% of the N was in leaves. Swamp chestnut oak had 24% of its biomass and 58% of the N in leaves.

Bole wood and bark in both species started out with high N concentrations at the beginning of the growing season, decreased to their minimum value late in the growing season, and then increased during the dormant season (figs. 2 and 3). Branch wood for green ash on the ridge contained higher N concentrations than trees on the flat site. April concentration for green ash branch wood was greater than all other months. No trends were really discernible, with some growing season months not different from some dormant season months. Oaks had higher N concentrations in branch wood on the flat than on the ridge site. Months and the site by months interaction were significant. The trend appeared to be to start high in April, decrease to low values during the growing season and increase again during the dormant season. Branch bark for both species started with high N concentrations at the beginning of the growing season, decreased during the growing season, then increased during the dormant season—a trend similar to bole bark. Nitrogen concentrations

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[4/] All differences discussed are significant at the 0.05 level.

Table 1.—Biomass and nutrient proportions in components of green ash and swamp chestnut oak trees

Component and species		Dry weight	N	P	K	Ca	Mg
			Percent with leaves (May-Oct.)				
Leaves	Green ash	21	55	46	49	34	47
	Oak	24	58	44	40	30	40
Bole wood	Green ash	43	16	24	18	8	14
	Oak	39	13	21	21	9	17
Bole bark	Green ash	10	14	10	16	31	20
	Oak	11	11	13	14	29	14
Branch wood	Green ash	14	5	7	5	5	4
	Oak	14	5	6	7	5	6
Branch bark	Green ash	8	7	6	7	15	10
	Oak	7	9	10	9	23	15
New growth	Green ash	4	4	8	6	6	6
	Oak	5	4	6	8	5	7
			Percent without leaves (Oct.-Apr.)				
Bole wood	Green ash	56	42	55	43	20	31
	Oak	52	33	38	30	15	21
Bole bark	Green ash	12	22	15	24	41	36
	Oak	16	26	21	27	42	30
Branch wood	Green ash	17	13	14	13	8	8
	Oak	18	13	14	12	6	9
Branch bark	Green ash	8	13	8	13	22	17
	Oak	9	21	17	23	28	30
New growth	Green ash	8	11	8	7	10	9
	Oak	6	7	11	11	7	10

were about two to three times higher in bark than wood (figs. 2 and 3). New growth in both species started with its highest N concentration in May, decreased in June, then decreased again but did not differ the remaining 9 months. Nitrogen was higher in oak on the flat than on the ridge site.

Because of space limitations and similar trends among many elements in the various tree components, only N, K, and Ca for leaves, bole wood, and bole bark are shown in the graphs. Other nutrients will be discussed and the similarities pointed out when appropriate.

Proportions of N contained in the various tree components are shown in table 1. Even though branches and boles accounted for a large proportion of the biomass, they contained small amounts of N compared to the leaves. These proportions changed after leaf fall.

Phosphorus

Foliar P levels for green ash did not differ during the growing season. For oak, May had higher concentrations than all other months, which did not differ among themselves. Trends in P for green ash bole wood were similar to that of N. Oak bole wood had significant differences between sites and months, as well as the site by months interaction. Trees on the flat site were higher in P than those on the ridge. Fluctuations from month to month made any trends hard to discern. Both green ash and oak had higher P concentrations in bole bark on the flat than ridge site. Green

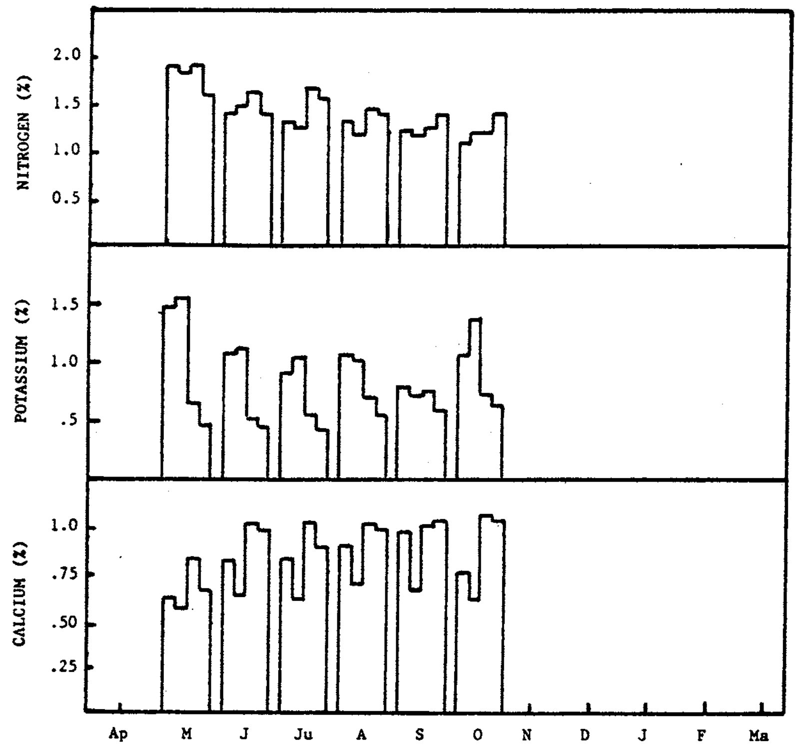

Figure 1.--Nitrogen, potassium, and calcium concentrations in green ash and oak leaves during the third year. First bar is GA ridge; second, GA flat; third, oak ridge; and fourth, oak flat.

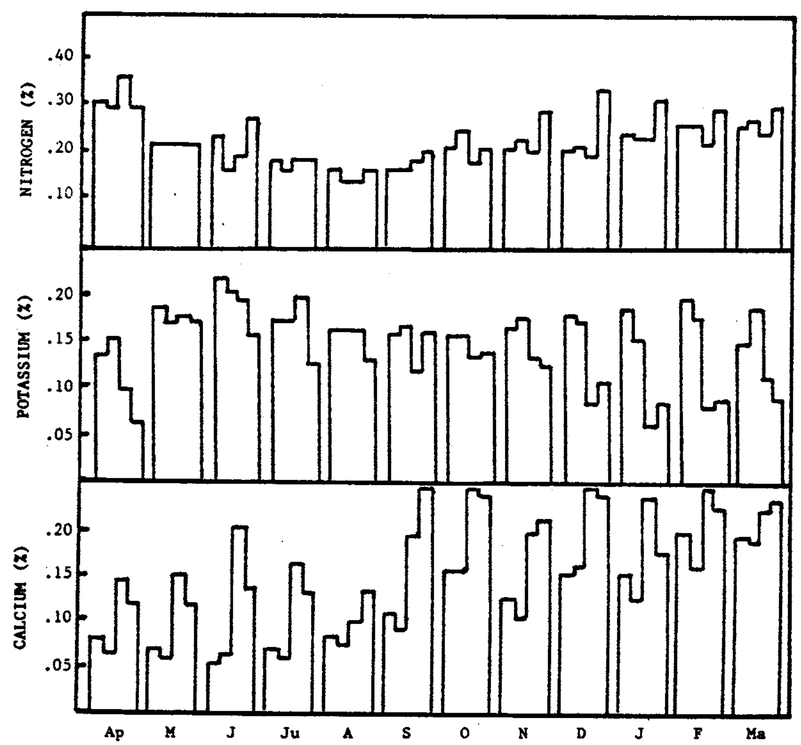

Figure 2.--Nitrogen, potassium, and calcium concentrations in green ash and oak bole wood during the third year. First bar is GA ridge; second, GA flat; third, oak ridge; and fourth, oak flat.

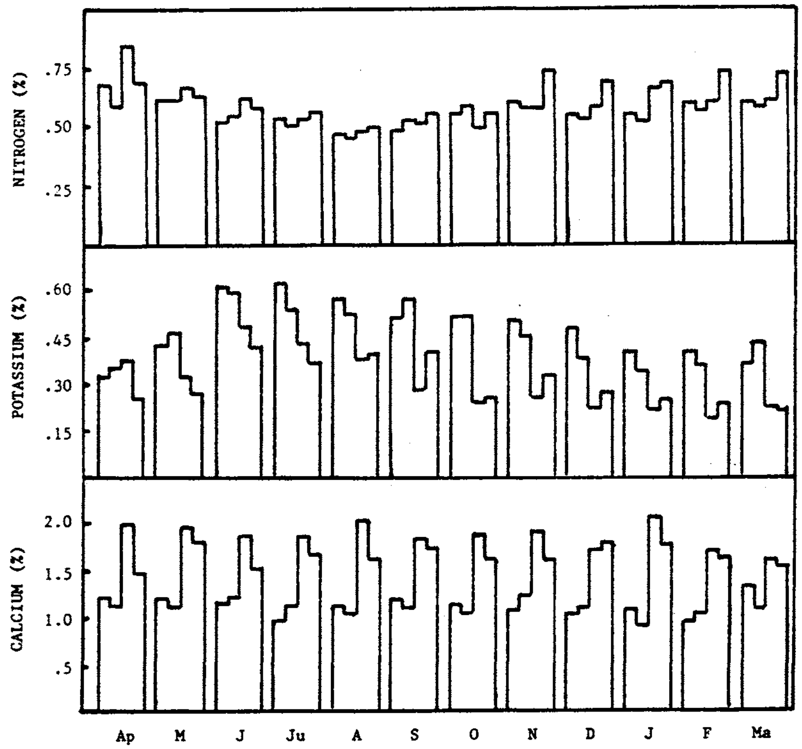

Figure 3.--Nitrogen, potassium, and calcium concentrations in green ash and oak bole bark during the third growing season. First bar is GA ridge; second, GA flat; third, oak ridge; and fourth, oak flat.

ash had higher P in April and June compared to January, but no trends could be discerned because of monthly variations. There was a significant site by months interaction for P in oak bole bark. The apparent trend was low P during the growing season followed by increased P during the dormant season.

P was also highest in branch wood of both species on the flat site. Monthly trends showed P in branch wood started high at the beginning of the growing season in green ash, decreased during the summer, then increased during the dormant season. Oaks had a significant site by months interaction. Trends appeared to be that oak on the ridge started out high in April, dropped rapidly in May and remained relatively stable the remainder of the year. On the flat, however, P concentrations were low during the growing season and increased during the dormant season.

Concentrations in branch bark in green ash started out high at the beginning of the growing season, then decreased through July, with a low from July into most of the dormant season. Again, there was a significant site by months interaction for P in oak branch bark. The trend, however, appeared to be that trees on the ridge and flat started out high at the beginning of the growing season, decreased in the growing season, and increased in the dormant season. The interaction appeared to be mainly from an extremely high value for the oak ridge site in April. There were no differences in P concentrations in new growth.

Leaves again contained the highest P levels, but in contrast to N, bole and branch wood and bark had similar P concentrations.

Leaves also contained a high proportion of the P found in trees (table 1), with other components having a much lower proportion.

Potassium

Foliar K levels for green ash were higher in May than all other months, which did not differ from each other (fig. 1). Oak on the other hand, had higher concentrations the last 2 months of the growing season than the first 3 months (fig. 1).

Concentrations in new growth of green ash decreased each month from May through August, with the remaining months having lower, but stable concentrations. Oak was maximum in May, decreased the next 2 months, then decreased again and remained stable the remainder of the year.

There were no differences in K concentrations in green ash bole wood (fig. 2). However, oak started low early in the growing season, maximized from May through October, then decreased during the dormant season (fig. 2). Ash and oak bole bark concentrations started out low, maximized during the mid- and late-growing season, then decreased during the dormant season (fig. 3). There were no differences in concentrations in ash and oak branch wood. Potassium in branch bark in green ash was greatest in June with no real trend discernible during the year. Oak was similar to the green ash. Proportions of K in the various components with and without leaves are shown in table 1.

Calcium

Calcium concentrations in green ash foliage started at a low level in May, peaked in August and September, then decreased in October (fig. 1). Oak leaves, however, started low in May and increased during the summer to a high in October. Green ash and oak trees had higher Ca concentrations in new growth on the ridge than flat sites. No other differences occurred.

Calcium concentrations in ash bole wood on both sites started low at the beginning of the growing season, then increased in the late growing season until a maximum was reached during the dormant season (fig. 2). Calcium in bole wood of oak was low during the growing season, increased rapidly in September and October, then remained relatively stable during the dormant season. Branch wood of both species started out low, then increased in the late growing season and dormant period. Oak branch wood had higher concentrations on the ridge site. There were no significant differences in bole bark for either species (fig. 3), and branch bark for oaks during the sampling period. There were monthly differences in green ash branch bark, but no trend was discernible since 11 of the 12 months did not differ. Calcium in oak bole bark and branch bark was higher on the ridge site.

Proportions of Ca in the various components are shown in table 1. Leaves and bole bark contained a high proportion of Ca. After leaf fall, bole and branch bark and bole wood appeared to be major storage areas for this element. Calcium concentrations (fig. 2) indicate possible absorption through the roots and consequent storage in bole wood during the dormant season.

Magnesium

Magnesium levels in most components remained relatively stable throughout the sampling periods. Exceptions were in monthly Mg concentrations in ash new growth, bole bark, branch wood and bark, and oak branch bark. However, even in these components there were variations up and down, and definite trends were not discernible. Leaves again contained a high proportion of Mg when they were present (table 1). As with Ca, bole and branch bark and bole wood seemed to be the major storage components during the dormant season.

SUMMARY AND CONCLUSIONS

These data characterize biomass and nutrient concentrations and distribution in two hardwood species grown at 4- x 8-foot spacing over a 1-year period in the life of the plantation. Site, age, species, and stand density affect proportions of nutrients in individual parts by altering the distribution of the total biomass among tissues and perhaps affecting concentrations of nutrients in individual segments (Shoulders 1981).

After three growing seasons, green ash had produced 7,342 pounds per acre of above-ground dry matter compared to only 3,572 for swamp chestnut oak. Of the total biomass, ash averaged 53% in the bole (wood plus bark), 21% in leaves, 22% in old branches (wood plus bark), and 4% in new or current-year growth. Swamp chestnut oak had 50, 24, 21, and 5% in the same components. These proportions changed after leaf fall. Concentrations of N, P, K, and Mg followed the general order of leaves > current-year growth > bole and branch bark > bole and branch wood. Calcium was highest in bole and branch bark followed by leaves, current-year growth, and bole and branch wood. Foliage of ash accounted for 21% of the total biomass and contained 34-55% of the individual nutrients, while oak foliage comprised 24% of the biomass and contained 30-58% of the individual nutrients. Fifty-three percent of the total biomass and 47-51% of individual nutrients were in the bole of ash, while in oak the bole accounted for 50% of the biomass and 41-47% of the nutrients. These results are similar in trends and concentrations to those reported for different species by other researchers (Baker and Blackmon 1977, Carter and White 1971, Shoulders 1981, Shelton et al. 1981, Francis 1984).

Some elements, as shown by higher concentrations, probably were absorbed by roots and stored in stems and branches even when trees were in dormancy.

Because of the high concentration of individual elements contained 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 maintenance of site quality.

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