United States Department of Agriculture

Forest Service

Southern Forest Experiment Station

Research Note

SO-278
October 1981

Biomass and Nutrient Accumulation in a Cottonwood Plantation-The First Four Years

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SUMMARY

For the first 4 years, height increment of an eastern cottonwood plantation on a clayey soil was greatest in the first growing season; diameter growth was greatest in the second growing season; and annual production of biomass was greatest in the third year. Nitrogen, phosphorus, and possibly magnesium are translocated from leaves into bark and other tissue before leaf abscission in the fall. There is no evidence for translocation of potassium or calcium. While removal of nutrients per ton of biomass would be greatest the first year, loss per hectare would be as great or greater in later years, due to higher annual yield. Whole-tree chipping would remove considerably more nutrients from the site than harvesting of boles only. After year 2, there is little difference in nutrient loss between summer and winter bole removal.

Additional keywords: *Populus deltoides* Bartr., nutrient cycling, nutrient translocation.

INTRODUCTION

Intensive plantation management, with possible future mechanized harvesting of biomass, has made early growth and nutrient dynamics of plantations an important area of study. Baker and Blackmon (1977) reported trends in biomass and nutrient accumulation in an eastern cottonwood (*Populus deltoides* Bartr.) plantation during the first growing season. Biomass and nutrient accumulation and distribution; internal cycling of nutrients; growth, and nutrient losses which would be caused by harvest during the first 4 years in that same plantation are now reported.

METHODS

The trees sampled in this study grew in a 2-hectare (5-acre) cottonwood plantation on the Delta Experimental Forest near Stoneville, Mississippi. The plantation was established on an area that recently had been cleared of natural, mixed hardwoods and prepared for planting by shearing, root raking, and disking. The soil is a Sharkey clay, a member of the montmorillonitic, thermic family of Vertic Haplaquepts. Site index for cottonwood is about 29 meters (95 feet) at 30 years.

In January 1973, 50-centimeter-long (20-inch) unrooted cottonwood cuttings (Stoneville clone 124) were planted at a 3 x3-m (10 x 1 0-ft) spacing. The plantation was cross-cultivated three times during the first growing season and thinned by removing every other row of trees at the end of the third growing season.

The plantation was divided into five .4-ha (1 -a) blocks which were measured each year. Sampling in the first 4 years was conducted about September 1, when annual growth was complete, and again in November after the leaves had fallen. For each sample period, one tree per block was selected, using the mean tree technique described by Ovington, Forrest,and Armstrong (1967). Each of the sample trees chosen had the block mean dbh and height. Each was felled and separated into leaves (September only), current branches, old branchwood, old branchbark, stemwood, and stembark. In November of years 1, 2, and 4, freshly fallen leaves from under each November sample tree were collected.

All material was dried at 70° C (156" F), weighed,and analyzed for total N, P, K, Ca, and Mg concentration. Nitrogen concentration was determined by the standard Kjeldahl procedure; P by colorimetry, using molybdenum blue color development; and K, Ca, and Mg by atomic absorption spectrophotometry after the samples had been dry-ashed and taken up in dilute HCl.

RESULTS AND DISCUSSION

Height growth was greatest (3.6 m or 11.8 ft) in the first growing season and decreased annually through the fourth season (table 1). Mean total height at the end of 4 years was 9.6 m (31.5 ft). Diameter growth was greatest (4.1 cm or 1.6 in) in the second growing season but dropped to 1.3 cm (.5 in) in the fourth growing season despite thinning the previous year. Four-year growth of cottonwood on Sharkey clay is perhaps half of what might be expected on a medium-textured soil in the area (Mohn and Randall 1973).

Diameter and height growth culminate early in plantation-grown cottonwood (Krinard 1979). The rapid decrease in growth after culmination on the clayey soil in our plantation is, in the authors' opinion, a result of competition for the limited supply of available moisture in the favorably structured and aerated upper 75 cm (30 in) of soil. Soil nutrients are in good supply (Broadfoot, Blackmon, and Baker 1972) and competition for light seems not to have occurred since the canopy has never approached closure.

Dry weight of current foliage and biomass accumulated in branches and stems is given in figure 1. The addition of new biomass was greatest in year 3 (10.0 kg or 22.0 Ibs per tree) and then decreased considerably in year 4 (4.3 kg or 9.4 Ibs per tree). Foliar weight culminated during year 3 at about 6 kg (13 Ibs) per tree. However, the proportion of foliage to total tree mass decreased from the first through the fourth year. Percent of biomass in branches reached a peak in year 3, then decreased. Stem weight and percentage increased steadily throughout the 4 years.

In August of year 3, standing biomass would have been 17 metric tons per ha (7.6 tons per a), based on a known 85-percent survival. Between years 3 and 4, the plantation was row-thinned. Assuming a 1 -percent mortality of the remaining growing stock, standing biomass in August of year 4 would have been about 10.6 metric tons per ha (4.7 t per a).

Table 1 .-*Height, diameter, and growth in years 1 through 4 of a cottonwood plantation on Sharkey clay*

Growth component	Year 1	2	3	4
Total height (m)	3.6	6.0	8.1	9.6
Height growth (m)	3.6	2.4	2.1	1.5
Diameter b.h. (cm)	2.7	6.8	9.4	10.7
Diameter growth (cm)	2.7	4.1	2.6	1.3

Table P.-*Nutrient contentper tree in years 1 through 4 in a cottonwood plantation*

Component	N	P	K	Ca	Mg
			g/tree		
			Year 1		
Leaves	16.3	1.0	11.6	10.8	2.3
Branches	1.9	.3	3.4	2.7	.3
Stems	1.4	.2	1.9	1.8	.2
Total	19.6	1.5	16.9	15.3	2.8
			Year 2		
Leaves	42.1	3.4	22.5	61.4	10.0
Branches	12.7	3.1	14.2	21.9	2.3
Stems	9.7	2.0	9.9	13.3	1.4
Total	64.5	8.5	46.6	96.6	13.7
			Year 3		
Leaves	53.7	5.4	28.6	84.2	13.4
Branches	31.2	5.8	28.6	57.9	5.2
Stems	23.4	3.8	23.1	33.4	4.7
Total	108.3	15.0	80.3	175.5	23.3
			Year 4		
Leaves	58.0	5.8	37.0	77.6	17.3
Branches	26.7	6.5	37.3	73.7	10.6
Stems	32.7	5.4	33.0	62.1	5.9
Total	117.4	17.7	107.3	213.4	33.8

Accumulation of nutrients in the first growing season was small, followed by larger second- and third-year accumulations (table 2). By the fourth year, nutrient accumulation had slowed, a reflection of smaller increases in weight of leaves and branches (fig. 1).

Samples of freshly fallen leaves revealed changes, usually a reduction, in leaf nutrients from earlier leaf concentrations (table 3). The fate of the missing nutrients is unknown; however, they could have been lost from the leaf by leaching or translocated to other tissues. Data from year 1 of this same plantation (Baker and Blackmon 1977) indicated that N and P were translocated from leaves into branches, stems, and roots. The bark of branches and stems are particularly important sites of redeposition. We compared nutrient concentrations in September and November stem- and branchbark samples from years 1 through 4. Nitrogen, P, and Mg were found to have increased significantly (P = .95) in both branch- and stembark. Potassium and Ca did not change.

The percentage of nutrients translocated was calculated on the assumption that nutrient increases in bark and wood arise from material translocated from leaves. Estimated average translocation in years 1 through 4 of N

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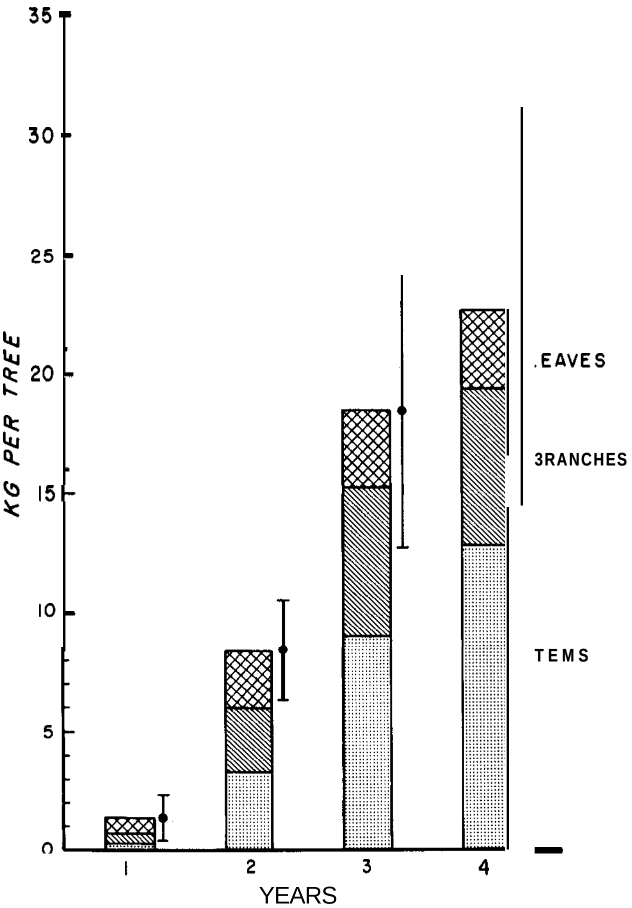

Figure 1.-*Mean dry weight of leaves, branches, and stems per tree in a cottonwood plantation in September of years 1 through 4. Brackets give 95 percent confidence interval for total biomass.*

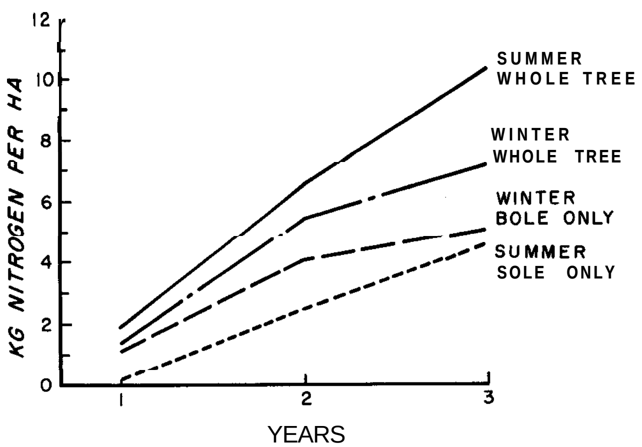

Figure 2.—*Nitrogen contained in tissues of a cottonwood plantation and potentially removed by different harvesting methods and times.*

Table 3.—*Nutrient levels in green leaves in September and in freshly fallen leaves in November in years 1, 2, and 4 in a cottonwood plantation*

Leaf type	Nutrient	Year 1	2	4
		percent nutrient		
Green	N	2.40	1.76	1.23
Freshly fallen	N	1.59	1.12	1.27
Green	P	.16	.14	.17
Freshly fallen	P	.12	.16	.19
Green	K	1.25	.94	1.09
Freshly fallen	K	.77	.85	1.11
Green	Ca	2.25	2.57	2.29
Freshly fallen	Ca	2.82	2.30	2.21
Green	Mg	.40	.42	.51
Freshly fallen	Mg	.48	.42	.47

and P ranged from 29 to 33 percent and 33 to 38 percent respectively! If trends of nutrient storage of N and P in roots reported in year 1 (Baker and Blackmon 1977) hold true for later years, approximately half of the leaf N and P may be conserved by translocation. Magnesium translocation estimated by this method ranged from 3 to 48 percent. A more precise monitoring of this nutrient is needed. Tr nslocation of nutrients from senescing leaves to other tissues has been observed by a number of workers (Duvigneaud and Denaeyer-De Smet 1970, Hopkinson 1966, Oland 1963, Switzer and Nelson 1972).

With the advent of short rotations and complete-tree utilization, concern has grown about nutrient depletion from a site. Table 4 gives the quantity of nutrients which would leave the site in years 1 through 4 with each ton of dry matter removed if a harvest were conducted. Loss of N and K by whole-tree chipping during the summer of the first year would be larger because of high concentrations of nutrients in the leaves and because of the larger proportion of leaves to total biomass. All nutrient concentrations were more stable and lower in years 3 and 4. By this time, leaf and branch mass had nearly stabilized, while bole volume steadily increased. As a result of these changes, loss of nutrient per ton of material removed by summer whole-tree chipping should be lower in later years. Whole-tree chipping in the dormant season would produce similar results, except that nutrient levels would not be so high in year 1 and would not decline as much through year 3. Harvesting just the boles in either September or November would remove smaller quantities of nutrients than whole-tree chipping.

If nutrient1 removal per unit area rather than per ton of material is considered, losses due to harvest in the first year become less important because of low first-year biomass yields. First-year uptake and potential loss of N would have been less than in subsequent years (fig. 2).

The greatest loss of N would occur with a summer whole-tree harvest. Whole-tree harvesting in winter or summer would consistently remove more N than would bole-only harvests. A summer bole-only harvest would remove the smallest quantities of N from the site, followed by a winter bole-only harvest. The advantage of summer bole-only harvest is small in year 3 and nearly disappears by year 4.

Could short-rotation harvests deplete this site of nutrients? Given a summer whole-tree harvest every 3 years (assuming replanting every rotation or that coppice yield equals planted cuttings), nutrients removed per rotation would range from 1 kg per ha of P to 16 kg per ha of Ca. These small amounts removed about equal the quantity of nutrients added by rainfall (Wells, Nicholas, and Buol 1975). If there is no net loss of nutrients by other means, this site could be cropped for cottonwood continuously without depleting the site of nutrients.

Table 4.--*Quantities of nutrients which would be removed per ton of dry material harvested in years 1 through 4 of a cottonwood plantation*

Time and type of harvest	N	P	K	Ca	Mg
			grams per dry ton		
			Year 1		
Sept.[1] whole tree	13,400	105	1,040	1,086	211
Sept. bole only	420	60	490	470	60
Nov.[2] whole tree	994	104	453	672	119
Nov. bole only	790	90	370	510	100
			Year 2		
Sept. whole tree	766	100	554	1,150	162
Sept. bole only	290	60	300	400	40
Nov. whole tree	640	91	316	570	89
Nov. bole only	480	71	221	364	63
			Year 3		
Sept. whole tree	589	80	434	954	125
Sept. bole only	260	40	250	370	50
Nov. whole tree	409	80	392	833	107
Nov. bole only	296	57	300	581	94
			Year 4		
Sept. whole tree	513	76	473	936	151
Sept. bole only	250	40	260	480	50
Nov. whole tree	369	65	327	736	85
Nov. bole only	258	44	247	526	50

[1]Represents late growing season harvest.
[2]Represents dormant season harvest.

LITERATURE CITED

Baker, James B., and B. G. Blackmon.
1977. Biomass and nutrient accumulation in a cottonwood plantation-The first growing season. Soil Sci. Soc. Am. J. 41:632–636.

Broadfoot, W. M., B. G. Blackmon, and J. B. Baker.
1972. Soil management for hardwood production. Proc., Southeast. Hardwoods Symp. 1971:17–29. U.S. Dep. Agric. For. Serv. Southeast. Area, State and Priv. For., Atlanta, Ga.

Duvigneaud, P., and S. Denaeyer-De Smet.
1970. Biological cycling of minerals. Pages 199-255 *In* D. E. Reichle, ed. Analysis of Temperate Forest Ecosystems. Springer-Verlag, New York. 304 p.

Hopkinson, J. M.
1966. Studies on the expansion of the leaf surface. VI. Senescence and the usefulness of old leaves. J. Exp. Bot. 17:762–770.

Krinard, R. M.
1979. Five years' growth of pruned and unpruned cottonwood planted at 40- by 40-foot spacing. U.S. Dep. Agric. For. Serv. Res. Note SO-252, 5 p. South. For. Exp. Stn., New Orleans, La.

Mohn, C. A., and W. K. Randall.
1973. Interaction of cottonwood clones with site and planting year. Can. J. For. Res. 3:329–332.

Oland, K.
1963. Changes in the content of dry matter and nutrient elements of apple foliage during senescence and abscission. Phys. Plant. 16:682–694.

Ovington, J. D., W. G. Forrest, and J. S. Armstrong.
1967. Tree biomass estimation. Pages 4-31 *In* H. Young, ed. Symp. on Primary Productivity and Mineral Cycling in Natural Ecosystems. Univ. of Maine Press, Orono. 245 p.

Switzer, G. L., and L. E. Nelson.
1972. Nutrient accumulation and cycling in loblolly pine (*Pinus taeda* L.) plantation ecosystems: The first twenty years. Soil Sci. Soc. Am. Proc. 36:143–147.

Wells, C. G., A. K. Nicholas, and S. W. Buol.
1975. Some effects of fertilization on mineral cycling in loblolly pine. Pages 754-764 *In* Mineral Cycling in Southeastern Ecosystems. U.S. Energy Res. Dev. Adm.

*U.S. GOVERNMENT PRINTING OFFICE: 1981—569-082/8