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ABSTRACT

Average contents of N, P, K, Ca, and Na and total aboveground dry matter were determined in 19-year-old unthinned loblolly pine (**Pinus taeda** L.) plantations in southeastern Arkansas. Three stands were sampled on each of four sites: well and poorly drained coastal plain soils and well and poorly drained loessial soils. Total dry weights, determined from 15 felled trees on each of the 12 plots, ranged from 127,000 kg/ha on poorly drained loessial soil to 173,300 kg/ha on poorly drained coastal plain soil. Ranking of sites, in descending order of production of dry matter, P, K, and Na was: coastal plain poorly drained, coastal plain well drained, loess well drained, and loess poorly drained. Quantity of Ca in stemwood and stembark was 36% higher on well than poorly drained soils; P was 30% higher on coastal plain than loess soils. Results permit calculation of nutrient drain in timber harvests. Bark in 19-year-old plantations contained 44, 44, 25, and 50% of total N, P, K, and Ca in the stems.

INTRODUCTION

Increasing intensity of timber management and tree utilization leads to a need for accurate information on the nutrient budget and dry matter production levels in pulpwood plantations on different site classes. Quantities of minerals in trees may be expected to differ between sites: Wells (1965) found highly significant correlations between foliar N, P, K, Ca, and Mg percentages in 5-year-old loblolly pines and the concentrations of these elements in the soil. Switzer et al. (1966) harvested five trees in each of five size classes, from saplings to sawtimber, on good and poor sites. Accumulation rates of dry matter and nitrogen in stemwood and total trees were roughly twice as great on the good as on the poor sites; N percentages in foliage, branches, stemwood, and stembark were nearly the same on both sites. Metz and Wells (1965) harvested 10 trees of different sizes, 7-21 years old, and found distribution of N, P, K, Ca, and Mg on a weight basis by tree parts related to tree size but not necessarily to age. Bark contained 15-20% of the elements, regardless of tree size.

To obtain data on dry matter production and nutrient immobilization for the four land types most commonly planted to loblolly pine in southeastern Arkansas, a study was begun in February 1967. The study also yielded information on weight and volume of total and merchantible wood per acre, which will be published in another paper.

MATERIAL AND METHODS

Field. The 12 stands of loblolly pine (*Pinus taeda* L.) selected for sampling had the following attributes: age 19 from seed germination, 6x7-ft spacing, good survival, uniform canopy height, and homogeneous soil morphology. Three plantations were selected on each of four sites: well and poorly drained coastal plain soils (Savannah and Caddo series) and well and poorly drained loessial soils (Calloway and Crowley series).

In each plantation a square 0.1-acre plot was laid out, and diameter at breast height (d.b.h.) of every tree was measured with a diameter tape. Fifteen trees in each plot, representing all d.b.h. classes present, were felled; total height was measured and boles were bucked into 63-in. bolts up to 4-in. top diameter outside bark. The stem portion above this 4-in. diameter is called the leader.

Fresh weights of felled trees were determined on site. All bolts, plus leader, of each tree were weighed to obtain stemwood plus stembark weight. Live branches with foliage and then dead branches were weighed. Foliage weight was obtained as a fraction of live branches by sampling: live branches were selected from the upper, middle, and lower crown; all needles were plucked from these branches and weighed.

A 2-in. thick sample disk with bark was cut from the base of the basal bolt and from the upper end of each additional bolt to determine dry weight/fresh weight ratio.

For nutrient determinations, three codominants were selected from the 15 felled trees—those whose basal areas were nearest the plot mean. A sample disk 2 in. thick, complete with bark, was cut at breast height and at the midpoint between the 4-in. diameter and the apical bud. The complete ring of bark and a sample sector of wood were taken from each disk. A composite sample of needles was collected from all shoots in the uppermost whorl.

Laboratory. Fresh weight of each sample disk was obtained, with and without bark, and samples were oven-dried. Foliage plucked from live sample branches was oven-dried.

Tissue samples for chemical analysis were oven-dried at 105 C and ground in a Wiley mill. Total N was determined by a macro-Kjeldahl procedure, P by a vanadomolybdic-nitric acid method, K and Na by flame photometry with a magnesium acetate-ammonium acetate solution (Jackson, 1958), and Ca by flame photometry (Wells and Corey, 1960).

Calculations. Dry weights of wood and bark in each bolt were calculated by using fresh weights and the average moisture content of the sample disks at each end of the bolt. Dry weights of wood and bark in each leader were calculated by using fresh weights and the moisture content of the sample disk at the 4-in.-diameter outside bark.

Equations expressing dry weight of foliage, live branches, dead branches, stemwood, stembark, and total aboveground tree for each of the four soil sites were derived by the form

$$W = a(D^2\ H)^b + k$$

where W = weight of tissue (lb)
D = d.b.h. of tree (in.)
H = total height of tree (ft)
a,b,k = derived coefficient, exponent, and constant.

These equations and the d.b.h. tally of each plot permitted calculations of dry weight of each kind of tissue.

Quantities of N, P, K, Ca, and Na in each tissue were calculated as the products of oven-dry tissue weights and mineral percentages. Foliage was an exception, because needle samples were taken only from the topmost whorls to examine differences associated with soils; foliage samples were not representative of entire crowns. Thus, quantities of minerals were calculated for all aboveground tissues except foliage.

RESULTS AND DISCUSSION

Dry Matter Production. On the basis of stemwood or total tree production, the ranking of the four soil groups, from greatest to least, was: coastal plain poorly drained, coastal plain well drained, loess well drained, and loess poorly drained (Table I). Stemwood production was 52% greater on the best than on the poorest sites. Dry weight in total trees was 36% greater on the most productive than on the least productive sites. These differences were significant at the 0.05 level (Table II).

Table I. Dry Weights of Aboveground Tree Parts by Soil Groups

Tree Part	Dry Weight (kg/ha) Coastal Plain Soil		Loessial Soil	
	Poorly Drained	Well Drained	Well Drained	Poorly Drained
Foliage		6,800	5,000$	6,200
Live branches	15,500	15,000	14,700	16,600
Dead branches	8,000	7,800	6,600	8,700
Stembark	15,400	14,400	13,300	9,300
Stemwood	128,900	114,600	103,500	84,700
Total tree[1]	173,300	159,100	143,800	127,200

[1] Each entry in the table was derived from a separate regression equation; therefore, the weights of tree parts are not additive. Total tree weights will not equal arithmetic sums of part weights.

Table II. Weights of Dry Matter of Aboveground Tree Tissues: Significant Differences Between Site Means According to Duncan's New Multiple Range Test[1]

Tissue	Mean Weight (kg/ha) Coastal Plain Soil		Loessial Soil	
	Poorly Drained	Well Drained	Well Drained	Poorly Drained
Stembark	15,400 [a]	14,400 [a,b]	13,300 [b]	9,300
Stemwood	128,900 [a]	114,600 [a,b]	103,500 [b]	84,700
Entire tree	173,300 [a]	159,100 [a,b]	143,800 [b,c]	127,200 [c]

[1] Any two means in the same row not denoted by same letters are significantly different at $P < 0.05$.

Relative efficiency of stands on different sites is indicated by their proportions in photosynthetic apparatus (foliage plus live branches). This averaged 12% of total stand dry weight on coastal poorly drained, 14% on coastal well drained, 14% on loess well drained, and 18% on loess poorly drained soils. Switzer et al. (1966) likewise found stemwood forming a greater percentage of stand total dry weight on good than on poor sites.

Ten to 11% of the dry weight of entire stems (wood plus bark) was in bark on all sites.

Mean annual rates of net accumulation of dry matter in stems and in entire trees in these plantations are very high (Table III). Loblolly pine is a very efficient fiber crop; cotton (*Gossypium* spp.) on these soils probably would not produce nearly as much dry fiber.

Table III. Mean Annual Rates of Dry Matter Accumulation in Stemwood and Entire Tree by Soil Group

	Mean Annual Accumulation (kg/ha) Coastal Plain Soil		Loessial Soil	
	Poorly Drained	Well Drained	Well Drained	Poorly Drained
Stemwood	6,780	6,030	5,450	4,460
Entire tree	9,120	8,370	7,570	6,690

The Official Soil Series Descriptions of the Soil Conservation Service give site index for loblolly pine on these soils as Caddo 90, Savannah 88, Calloway 90, and Crowley 90. These figures indicate that the four soil series would be similar in productivity class with stands at age 50. However, results from this study showed that the ranking of dry matter production is not the same as the ranking of mean total height at age 19 which was 61, 53, 55, and 49 ft for Caddo, Savannah, Calloway, and Crowley soil series, respectively.

Other workers have found instances in which stands having the same site index at age 50 showed sharp differences in height-age relations in early youth (Carmean, 1961; Spurr, 1964). Site index ratings for soil series deal with the general, whereas the writers are dealing with the particular.

Mineral Fraction. Concentrations of N, P, K, and particularly N, were higher in apical than in breast-height stemwood and stembark. Ovington (1959) also found these elements increasing with height up the stem in Scotch pine (*Pinus sylvestris* L.) plantations.

Analysis of variance was computed for each of the five elements in each of the tree tissues. Foliar P was the only tissue nutrient that varied in the same order as total production among the four sites. Significant differences were found among site means for other nutrients, but their rankings were not the same as the ranking of stemwood production (Table IV). On the basis of these findings, foliar analysis appears unlikely to provide a useful guide to site productivity in loblolly pine plantations on soils such as those studied.

Accumulation of minerals in stemwood and stembark is shown in Table IV. Weights of P, K, and Na varied in the same order as total production. Calcium in wood and bark was significantly higher on well than on poorly drained soils, and on coastal plain soil than on loess. Phosphorus fractions were significantly greater (0.05 level) on coastal plain than on loessial soil, but were not different between drainage classes. Phosphorus availabiltiy ordinarily is increased by waterlogging (Black, 1968; Redman and Patrick, 1965), but enhanced availability apparently does not lead invariably to increased uptake in all crop species alike.

The values shown in Table IV are the quantities of nutrients likely to be removed in tree-length pulpwood harvests. Nitrogen in total stems ranges from 111 kg/ha on well drained loess to 156 kg/ha on poorly drained coastal plain soils. Calcium is second in abundance and first in variability: 76 kg/ha on poorly drained loess to 138 kg/ha on well drained coastal plain soils. Phosphorus is the nutrient accumulated in boles in least quantity: 11-18 kg/ha.

CONCLUSIONS

Unthinned pulpwood plantations on the four soil groups most commonly planted to loblolly pine in southeastern Arkansas accumulated dry matter at rates of 6,700-9,100 kg/ha. Coastal plain poorly drained soils are the most productive, loessial poorly drained soils are least; coastal plain well drained and loessial well drained soils are intermediate. Productivity of the best sites is more than 50% greater than that of the poorest. Uncut stands at age 19 contain substantial quantities of N and Ca in stemwood and stembark. More than 10% of the dry weight of tree stems is bark. In view of the substantial expenditures for fertilizer application by some paper industries, it is interesting to note that debarking on site would lessen removal of N and Ca by 44 and 50%.

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Table IV. Quantities of Nutrients in Stemwood, Stembark, and Entire Boles by Soil Group: Significant Differences Between Site Means According to Duncan's New Multiple Range Test[1]

		Mean Quantity (kg/ha)				
Soil Group	Tissue	N	P	K	Ca	Na
Coastal plain poorly drained	Wood	105	11	69	83	14
	Bark	51	7	21	34	2
	Entire bole	156 [a]	18	90	117 [a]	16
Coastal plain well drained	Wood	82	9	53	86	12
	Bark	40	3	15	52	2
	Entire bole	122 [a, b]	12 [a]	68 [a]	138 [b]	14 [a]
Loess well drained	Wood	74	8	52	77	13
	Bark	37	4	13	48	1
	Entire bole	111 [b]	12 [a]	65 [a]	125 [a, b]	14 [a]
Loess poorly drained	Wood	94	9	49	58	10
	Bark	30	2	10	18	1
	Entire bole	124 [a, b]	11 [a]	59 [a]	76	11
Average	Wood	89	9	56	76	12
	Bark	39	4	14	38	2
	Entire bole	128	13	70	114	14

[1] Any two means in the same column not denoted by same letters are significantly different at P 0.05.