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The Roots of Plantation Cottonwood: Their Characteristics and Properties

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SUMMARY

The root biomass and its distribution and the growth rate of roots of pulpwood-size cottonwood (*Populus* deltoides) in plantations were estimated by excavation and sampling. About 27 percent of the total biomass was in root tissue. Equations for predicting stump-taproot dry weight from d.b.h. and top dry weight were derived. Lateral roots in two plantations increased in length until dieback, and regrowth produced a lateral root of semistable average length to a little more than half the distance between trees.

Additional keywords: *Populus deltoides,* root competition, root biomass.

INTRODUCTION

Cottonwood have been well studied above ground, but examination of the "dark continent" below ground has hardly begun. Tree roots are not only difficult to expose but also lack present commercial markets. Despite small human interest, roots, to the tree, are as indispensable as the top. Roots are a principal source of interaction with the environment. While supporting the cottonwood, they acquire moisture and nutrients from the soil. Roots also require carbohydrates and nutrients for growth.

Roots contain significant amounts of biomass. The cellulose concentration in roots, at least in the stump and taproot, is probably similar to that in the bole. However, because of the difficulty in removing associated dirt, fuel may be the most feasible use. Utilizing this formerly wasted biomass could be less expensive than growing additional wood.

A few investigators have studied cottonwood and hybrid poplar roots. Baker and Blackmon (1977) found that roots of l-year-old planted cottonwood contained 30 percent of the biomass of the plantation and that most of the root biomass was located in the upper 8 inches of soil. Sprackling and Read (1979) described the root system of naturally grown plains cottonwood (*P. deltoides'* var. *occidentalis* Rydb.). Hansen (1981) measured the lateral extension of hybrid poplars (*P. deltoides* X *nigra*) in plantations. Faulkner and Fayle (1979) reported the horizontal and vertical development of the root systems of poplar hybrids and observed that repeated cultivation appeared to reduce the extent of the surface root system. The net primary productivity and biomass distribution, including roots, in a plantation of hybrid poplars are presented by Marcelli et al. (1980).

The study reported here (1980–83) was confined to pulpwood-size cottonwoods in plantations established from cuttings, Research was guided by the following questions: How are the biomass and nutrients in cottonwood root systems distributed? Is the weight of the harvestable portion (stump + taproot) of the root system predictable? How rapidly do roots extend outward to occupy the space between trees?

METHODS

This investigation was conducted in three parts. In the first, measurements of the biomass and nutrient distribution were conducted in an 8-year-old plantation on Alligator clay soil. This soil supports

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natural cottonwood [site index (30 years) ≅ 90 ft] but is not currently recommended for cottonwood plantations. The trees were spaced at 10 by 20 feet (after one thinning) and averaged 5.4 inches d.b.h. and 40 feet tall. Sample trees were selected to reflect the diameter range of the plantation. Ten trees were excavated; the process was as follows. Each tree was felled and weighed green. About 5 percent of the top and bole was dried (70°C) and weighed to obtain a factor for converting to total dry weight. A trench was dug with a backhoe around each stump, leaving a 4- by 4-foot pedestal of soil. The soil was carefully picked away from the roots.

The root system was divided into stump-taproot, lateral roots, and fine roots (<7 mm). The weight of roots at a distance greater than 4 feet from the stump was estimated from the roots in l-foot-square, 2-foot-deep samples of soil dug at 4 feet out from the stump within-row and 9 feet out between rows. Samples of stump wood and bark, lateral-root wood and bark, and fine roots were analyzed in the laboratory for concentrations of N, P, K, Ca, and Mg. Nitrogen concentration was determined by the Kjeldahl method. The molybdenum blue colorimetric method was used for P determination. Concentrations of K, Ca, and Mg were measured by atomic absorption spectroscopy after being taken up from ashed material in 1N HCl .

To establish a relationship between stump-taproot dry weight and properties of the aboveground portion of the tree, 25 trees were excavated and evaluated. Ten of these were trees from the first part of the investigation. Five each were from ll-, 17-, and 23-year-old plantations. The diameters of the 25 trees ranged from 5 to 15 inches. Heights were about 40 to 80 feet. Because of thinnings and mortality at the time the trees were sampled, spacings varied considerably. All the plantations were on Alligator clay soil. The latter 15 trees were measured for diameter and height, felled, and the tops weighed green (leaves present). An approximate 5-percent sample of each top was collected and dried. From this information, aboveground dry weight was calculated. To extract the stump, the upper lateral roots were cut, a chain was attached to the stump, and the stump was then pulled up with a tractor. All remaining lateral roots were then trimmed off. The stumps were dried whole or in pieces in a walk-in oven for 2 weeks to a month, depending on stump size. The relationships between stump-taproot dry weight and aboveground properties of the trees were calculated by regression,

In the third part of the investigation, the extension of major lateral roots was measured. Three stands were utilized. One was the same stand that was described in the first investigation (10- by 20-foot spacing). The roots were excavated at age 9. Another plantation was on Commerce silty clay loam soil. This plantation was 8 years old, and trees were spaced at 10 by 10 feet. The third plantation was adjacent to the second and was the same age, but trees were spaced at 40 by 40 feet. Half of the widely spaced trees sampled were pruned to one-half of their height and half were unpruned. The textural contrast (clay vs. silty clay loam) between the 9- and 8-year-old plantations prohibits perfect comparisons. However, texture probably did not seriously alter root extension,

Two major lateral roots on each sample tree were severed from the taproot and excavated with a shovel to their full length or until they exceeded 3 feet deep. (Deep or steeply descending cottonwood roots usually branch profusely and end in a short distance.) The bias introduced by assuming no further extension after the 3-foot depth was probably minor. Total root length, root extension (radial distance to root tip or farthest extension), crown radius, and d.bh. were measured. The roots were sectioned and the rings counted on a shaved end. Many roots in the two more closely spaced plantations died back and lost some of their former length. Consequently, average root length in the first and second plantations between year 4 and excavation age could only be estimated. Fifteen trees were examined in the first stand, 11 in the second, and 10 in the third. Total root length and root extension were related to crown radius and d.b.h. by regression.

RESULTS AND DISCUSSION

In the 10 original cottonwoods excavated, which ranged from 5.3 to 6 3 inches d.b.h., 72.8 percent of the biomass was in the top and bole (leaves present) and 27.2 percent in the total root system, including a 2-inch-high stump. Root tissue ranged from 19.0 to 37.1 percent of the whole trees. The various root parts, as a percentage of the whole tree, averaged as follows: stump-taproot, 6.8 percent; close laterals (in a 4-foot square around stump), 8.2 percent; close fine roots, 0.7 percent; and extended roots, 11.6 percent. The taproots of

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these trees averaged 15 inches long-about the length the original cutting extended below ground. Apparently, the taproot grew as a thickening of the cutting. Lateral roots radiated out, particularly just below the groundline and near the bottom of the cutting. Most of the root biomass was between 3 and 12 inches deep in this clay soil, although a few small roots extended to the 4-foot depth.

On the average, nutrients were a little more concentrated in root tissue than in aboveground portions. The roots, comprising 27 percent of the biomass of the total tree, contained 26 percent of the N, 34 percent of the P, 43 percent of the K, 29 percent of the Ca, and 34 percent of the Mg. The concentrations of the five nutrients in root wood, root bark, and small roots are given in table 1. [As with their aboveground counterparts (bark and twigs), root bark and small roots generally have nutrient concentrations several times greater than the wood of large roots.] Lateral roots averaged 25-percent bark, and the thicker stump-taproot averaged 18-percent bark. By comparison, the aboveground portion of the tree averaged 24-percent bark.

In the second part of the investigation, the dry weights of the stump-taproots of 25 trees were determined. The average ratio of stump-taproot to total top was 1 :10, or the stump-taproots were about 10 percent as heavy as the aboveground portions of the tree. Although the sample trees ranged from 8 to 23 years old and represented a mixture of clones, variation was small (C.V. = 0.186). Four additional trees were sampled from a soil with somewhat lighter texture (Tunica series). Their stump-taproot to top ratio was also 1 :10.

The stump-taproot dry weight of pulpwood-size cottonwood growing on clayey soil may be predicted by the following relationships:

$Y = -17.386 + 1.328\ D^{1.7}$ $\quad r^2 = 0.964$

where D = d.b.h.

$Y = -0.168 + 0.0968\ T$ $\quad r^2 = 0.940$

where T = aboveground dry weight.

Tree height was not a good predictor of stump-taproot dry weight.

The root tissue most likely to be used eventually on a commercial basis is the stump-taproot because of its size, compactness, and wood quality. The technology for harvesting stumps is already available (Koch 1976), although cost of extraction could be a prohibitive factor. A lo-percent increase in harvested raw material would not be the only benefit of harvesting stumps. Site preparation for the next rotation would be easier if the stumps were gone.

The increase in length of lateral roots of trees in the three plantations began at similar rates (fig. 1). As root closure began to occur, root-length increase slowed, beginning first in the closer-spaced plantations. The 10- by IO-foot plantation suffered severe dieback of roots in about year 6. This was observed in all the roots excavated. It is interesting that in year 5, aboveground growth rate of the trees dropped sharply. (Root dieback is probably a result of competition-induced stress-possibly a shortage of carbohydrate to support an extensive and growing root system.) After the dieback in year 5, the roots began to branch and slowly grow out again. (Thinning before the onset of root dieback or using a wider initial spacing are suggested as preventive measures.) At year 9, the lateral roots of the plantation spaced at 10 by 20 feet were extending very slowly and suffering some minor dieback. Roots in the 40- by 40-foot plantation had closed between rows, yet the spacing was so great that roots were still widely dispersed. There was no sign of dieback of roots in this plantation.

Table 1.-*Concentrations of five essential nutrients in three root tissues of &?-year-old cottonwoods in plantations*

Tissue	N	P	K	Ca	Mg
	percent of dry weight				
Root wood	0.12	0.06	0.27	0.16	0.04
Root bark	0.48	0.09	0.79	1.65	0.14
Small roots[1]	0.43	0.14	0.75	1.32	0.20

[1] <7 mm thick.

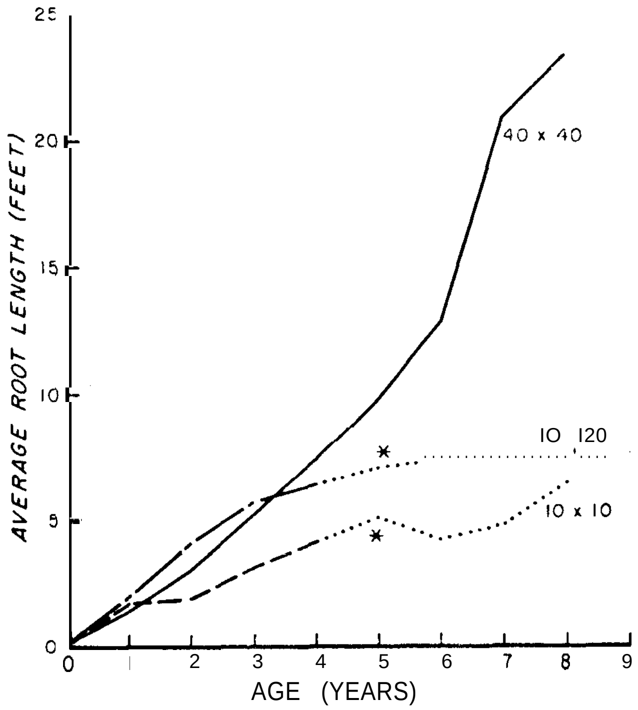

Figure 1.—*Root length by year of cottonwood plantations at three spacings. * Estimated period; exact root length could not be measured because of root dieback.*

It appears that root length tends toward a quasi-equilibrium at a little more than half the plantation spacing. Root extension, the distance between tree trunk and root tip, is slightly shorter than, but highly correlated with, root length. Thus root extension is ultimately controlled by spacing. There were several weak correlations (r = approximately 0.5) of d.b.h. or crown radius with root length or root extent. Although pruning in the 40- by 40-foot plantation had reduced diameter growth, it had no significant effect on root length or root extension.

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