TECHNICAL NOTE

Moisture Content, Specific Gravity, and Percent Foliage Weight of Cottonwood Biomass

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Abstract

This study looked at three properties of cottonwood trees: moisture content, specific gravity, and foliage as a percentage of limb weight. There was an irrigated plot and an unirrigated plot. The study included six southern clones and one hybrid from the northwestern United States. There was no significant difference in moisture content among the southern clones, but the hybrid moisture content was significantly higher in both plots. The specific gravity values of two clones were significantly higher than the hybrid in the irrigated plot, while in the unirrigated plot, the values of three clones were higher than the value of two clones, and the hybrid value was close to the lower clones. The percent foliage values were higher in the irrigated plot, and the hybrid values were significantly lower in both plots compared with the six clones.

One of the fastest growing hardwood species in the United States is cottonwood (*Populus deltoides* Bartr. ex Marsh.). Wood products such as furniture stock, crates and boxes, and high quality paper are derived from cottonwood (Dutrow et al. 1970). The best growing sites for cottonwoods are sandy loam or silty loam soils near creek bottoms (McKnight 1970). The species can be easily propagated vegetatively by cuttings (Farmer and Wilcox 1964, Land et al. 2001). Because the species has a wide genetic diversity, the performance of select clones usually varies by geographic origin (Land et al. 1996). Therefore, planting clones adapted to a given area can significantly improve biomass production.

Zabek and Prescott (2006) studied a hybrid poplar (*Populus deltoides* × *Populus trichocarpa*) in British Columbia to develop biomass equations and carbon sink values with 12- to 14-year-old trees. Books have been published presenting the properties of poplars in North America (Dickman et al. 2001) and around the world (Isebrands and Richardson 2014).

Study Background

A forest products company started a field study of cottonwood clones to determine the effects of irrigation on growth. Their desire was to develop a fast-growing source of white pulp. After 5 years and disappointing results, the company abandoned the project, but the Arkansas Agriculture Experiment Station continued the project for 5 more years with growth measurements taken (Stuhlinger et al. 2010). At that time an additional study was conducted with some of the trees being weighed in order to develop equations for predicting pulpwood weight and total tree biomass weight from tree size (Hartley 2011). This study is the analysis of additional data collected during the weighing process.

The study site was in east central Arkansas at the University of Arkansas Pine Tree Research Station. The land had been used for crop rotation using soybeans, wheat, and grain sorghum, and the soil type is a Calloway silt loam. The study design was a split plot with two whole plots—unirrigated and irrigated—with a wide buffer between them. Well water was used to irrigate whenever a current rainfall deficit of 2 inches was reached, resulting in 8 to 10 acre-inches of irrigation water per year. Cottonwood clone was the split plot. Each clone was replicated six times within each irrigation plot (randomly assigned). Each plot contained 56 trees, which were hand planted at 10 by 10-foot spacing in a 7 by 8-tree layout. Nine cottonwood clones

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were planted, but only seven were used in the Hartley study (2011) and this study. Of the two clones that were discarded, one was a mixture of four clones and the other was a hybrid that performed very poorly. Two clones from Texas (S7C15 and S13C20), four from Stoneville, Mississippi (ST72, ST124, ST148, and ST163), and a hybrid (*P. deltoides* × *P. trichocarpa*) from the northwestern United States (49-177) were used in this study. The cottonwood clones used in this study were selections from various tree improvement programs conducted in the US South and Pacific Northwest, starting in the 1960s and 1970s. Clones S7C15 and S13C20 originated from eastern Texas (Western Gulf Forest Tree Improvement Program and Texas Forest Service). Stoneville clones ST72, ST124, ST148, and ST163 were collected in western Mississippi and selected at the USDA Forest Service Southern Hardwoods Laboratory. Clone 49-177 is a hybrid (*P. deltoides* × *P. trichocarpa*) developed by the University of Washington/Washington State University Poplar Research Program (Land et al. 1996).

Of the seven clones studied, the hybrid (49-177) performed the worst in the irrigated plot (for bole weight) but performed the best in the unirrigated plot. The average bole weight for 49-177 in the irrigated plot was 306 pounds, and the average bole weight for the other six clones was 459 pounds. In the unirrigated plot, the average bole weights were 273 pounds for 49-177 and 100 pounds for the other clones. (1 lb = 0.454 kg)

For his study, Hartley (2011) used two trees from each of six plots of each of the seven clones in each irrigation treatment, resulting in 168 trees. He used a random number generator to select the trees in each plot and attached a metal tag with a number from 1 to 168 to each selected tree. The trees were felled with a chain saw and skidded to a forklift, which had a crane-type digital scale attached to its forks. The whole tree was weighed. After delimbing and topping at 3 inches (7.6 cm) diameter outside bark (d.o.b.), the bole was weighed.

Some trees were felled between 6:00 and 7:00 a.m. and processed between 7:00 and 10:30 a.m. Another group of trees were felled between 12:00 and 1:00 p.m. and processed between 1:00 and 2:30 p.m. The trees were left in the plots in the shade until each was to be processed, thus reducing the effects of transpiration.

Study Procedures

At the weighing site, extra data were collected for this study. A limb was removed from above the 3-inch d.o.b. top (upper limb), and one was removed from below the 3-inch d.o.b. top (lower limb). These limbs were weighed together (digital scale with a 0.05-lb [23-g] accuracy) and the foliage was removed and reweighed. The percentage of the limb weight that was foliage was calculated for each tree, resulting in a sample size of 12 for each clone at each irrigation treatment.

To keep the moisture content and specific gravity workload manageable, it was decided (coin toss) to collect data from only even-numbered trees. This resulted in a sample size of 6 for each clone at each irrigation treatment. With each even-numbered tree, each limb that was weighed had a section cut out and placed in a preweighed plastic bag to retain moisture. Cross sections were cut from the butt of the bole, at a point 40 percent of the length of the bole from the butt (approximate center of volume) and at the 3-inch d.o.b. These cross sections were placed in individual preweighed plastic bags. Each bag was marked with the tree number and position in the tree of the enclosed sample. In total, 420 samples were collected.

At the laboratory, each bag with a sample was weighed. The sample was removed, tree number and position were transferred to it, and it was placed in an oven to be oven-dried at a temperature of 103°C. After drying, the sample was weighed and coated with a very thin layer of paraffin and immersed in water to obtain its volume. With this information, the moisture content was determined using the dry basis, and the ovendry specific gravity was calculated. Statistical analyses were conducted using Tukey's honestly significant difference.

Results and Discussion

Patterson and Doruska (2005) determined that the moisture content of southern pine pulpwood was the highest in the spring followed closely by the fall. Moisture content was the lowest in the winter, while summer moisture content was equal to the average for the year. Trees in this study were harvested in midsummer. Because they were harvested in the temperate zone, one would assume that moisture movements in diffuse porous hardwoods are similar to those in pine; if so, the moisture contents determined in this study should be about average for the year.

Generally speaking, the results show that moisture content decreased with increase in tree height (Table 1). This is contrary to results reported for southern pine in which moisture content increased with tree height (Patterson et al. 1983, Patterson and Doruska 2005). With the exception of 49-177, the upper limbs had higher moisture content than the lower limbs.

As stated previously, the hybrid 49-177 performed poorly in the irrigated plot and excelled in the unirrigated plot. The moisture content results would indicate that this clone can pull moisture out of dry ground, and that too much moisture can greatly stifle its growth. In both plots, the moisture content of 49-177 was statistically higher than that of the other clones.

The specific gravity values indicated a decrease in value from the butt to the midpoint and then an increase in value to the top (Table 1). Koch et al. (1968) found similar results with young yellow-poplar (*Liriodendron tulipifera*) trees. They determined the highest specific gravity was at the butt, and it decreased to a point above the first 16-foot (5-m) log. From there, the specific gravity increased slowly as height increased.

In the irrigated plot, clones S13C20 and S7C15 had a significantly higher average specific gravity value than 49-177, and the remaining clones were nonsignificant in the middle. In the unirrigated plot, clones S13C20, ST72, and ST163 had a significantly higher average specific gravity value than S7C15 and ST124, while the other two were nonsignificantly in the middle.

The limb wood had a higher specific gravity than the bole wood. This is to be expected. In lumber, the knots have a higher density than the wood surrounding them, and knots are overgrown limb sections (Bowyer et al. 2003).

There appears to be a slight trend in a higher specific gravity with irrigation. This could be due to the irrigation extending the growing season into the hot, dry summer months. Cells produced in the latter part of the growing season (latewood) have thicker cell walls, which add more mass to the tree.

Table 1.—Dry basis moisture content (MC) and ovendry specific gravity (SG) of cottonwood trees by clone, irrigation treatment, and position in tree (n = 6), and foliage as a percentage of the limb weight by clone and irrigation treatment (n = 12).

		Clones:						
	Parameter	49-177	S7C15	S13C20	ST72	ST124	ST148	ST163
Irrigated								
Butt	MC (%)	129	100	88	108	99	91	94
	SG	0.37	0.46	0.45	0.42	0.42	0.40	0.42
Middle	MC (%)	124	103	84	106	97	89	95
	SG	0.37	0.45	0.44	0.42	0.40	0.39	0.42
Top	MC (%)	107	95	90	98	94	88	90
	SG	0.43	0.47	0.48	0.45	0.44	0.43	0.45
Lower limb	MC (%)	104	95	95	96	94	97	99
	SG	0.44	0.51	0.52	0.48	0.50	0.47	0.47
Upper limb	MC (%)	102	99	103	100	101	101	106
	SG	0.45	0.52	0.52	0.49	0.50	0.47	0.50
Unirrigated								
Butt	MC (%)	156	84	86	86	101	95	87
	SG	1.40	0.39	0.41	0.44	0.38	0.41	0.44
Middle	MC (%)	145	91	95	88	89	90	96
	SG	0.36	0.36	0.40	0.43	0.36	0.38	0.42
Top	MC (%)	113	83	87	86	82	79	85
	SG	0.43	0.38	0.43	0.43	0.38	0.41	0.43
Lower limb	MC (%)	103	102	105	100	102	96	112
	SG	0.47	0.41	0.47	0.47	0.44	0.44	0.44
Upper limb	MC (%)	101	109	113	106	115	111	117
	SG	0.46	0.44	0.47	0.46	0.42	0.45	0.44
Foliage (% of limb wt)								
Irrigated		14.4	26.0	27.2	28.2	26.9	29.2	29.6
Unirrigated		9.3	21.6	17.6	18.8	16.3	23.3	16.4

Foliage presents the main avenue for moisture lost in trees. Therefore, it is not surprising that the unirrigated trees had less foliage (Table 1). In the unirrigated plot, the hybrid (49-177) had by far the largest growth, but it had the smallest percent foliage. The hybrid had almost twice as much foliage in the irrigated plot as the unirrigated plot but almost did not survive under irrigation.

Conclusions

The goal of the original study was to see whether a clone of cottonwood could be grown on marginal cropland in Arkansas without irrigation and produce a fast-growing supply of white pulp. According to Stuhlinger et al. (2010), only a hybrid (not included in this study) came close to meeting this goal, but in the irrigated plot the clones did very well. As previously mentioned, the natural habitat for cottonwood is in river bottoms, where the trees are naturally irrigated.

In this study, the southern clones had some significant differences in the properties studied, but they were not large quantitative differences. The hybrid from the northwestern United States (49-177) had large differences in moisture content and percent foliage from the other six clones and somewhat lower specific gravity. The differences in studied properties between irrigated and unirrigated varied by clone.

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