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ANATOMY AND DRY WEIGHT YIELDS OF TWO *POPULUS* CLONES GROWN UNDER INTENSIVE CULTURE

John B. Crist and David H. Dawson

Considerable interest has been generated in utilizing the total wood and perhaps the bark produced by young woody species grown under short rotations for pulp or particleboard production. Representatives of the industry feel that rotations must be shortened and yields of high-quality materials substantially increased if expenditures for woodland improvement are to be competitive with other investment alternatives. Extremely intensive silviculture, such as has been demonstrated with sycamore in the southeastern United States by using the corn-silage system (McAlpine *et al.* 1966), may very well be economically feasible (Dutrow 1971). Continuing research and development effort already has demonstrated that kenaf (*Hibiscus cannabinus* L.) can be grown as a high intensity, short rotation (annual) crop on high-quality land (White *et al.* 1970).

There is considerable biological evidence that growing large trees over long rotations may not be the most efficient system for capturing the solar energy available or quickly and completely occupying a site. For example, Leak (1970) pointed out that conventional timber production accounts for a very minute proportion--0.1 to 0.2 percent of the net solar energy that enters into a northern hardwood stand. Daniels (1956) in contrast, reported that photosynthesis in the laboratory may attain efficiencies of up to 35 percent under optimum conditions. Implied in these findings is that traditional forest management has been almost exclusively concerned with less than 1 percent of the solar energy entering the forests we manage. For maximum production

of woody fiber, it is apparent that foresters need to understand how to utilize more of the remaining 99+ percent.

Recently the USDA Forest Service's North Central Forest Experiment Station in Rhinelander, Wisconsin, launched Program Maximum Yield, in which a systems approach is being taken to develop the most efficient and economic method for producing fiber from woody plants. Basic research input is being collated from specialists in the fields of physiology, genetics, engineering, utilization, and economics under this program. As described by Dawson and Hutchinson (1972), it is hoped that the results will enable segments of the industry in the North Central Region to assume a more viable role in helping to meet the expanding need for pulpwood. An early study in Program Maximum Yield, reported here, was made to determine the dry weight yield and quality of material produced by two *Populus* hybrids grown in an agronomic mode for 2 yr under intensive cultivation near optimum moisture and nutrient levels at three plant spacing densities.

THE PLANT MATERIAL AND RESEARCH METHODS

The two clones chosen for the study were *Populus* "Tristis #1" (*Populus balsamifera* L. x *P. tristis* Fisch.) and "Northwest" poplar (*Populus deltoides* Marsh. var. *occidentalis* Rydb. x *P. balsamifera* L.). Both clones propagated easily and were known to be hardy in the North Central States as well as to have manifested different crown and

branch architecture in conventional spacings. Both were available in quantity from the Forest Nursery Station at Indian Head, Saskatchewan, where they have been selected and tested for years (Cram 1960).

Plantings were spaced at three relatively high densities (9 in. by 9 in., 12 in. by 12 in., and 24 in. by 24 in.) because density-clone interactions had to be determined early in the rotation period. Dominant cuttings of each of the two clones were planted during the summer of 1970 at each of these three densities in three 16 ft by 16 ft irrigated plots in three replications using a randomized block design. By the fall of 1970, most of the cuttings had rooted; where fail spots occurred, replacements were made using cuttings that had been rooted in adjacent beds.

Throughout the first full growing season--the spring and summer of 1971--nutrients were applied frequently to the soil to ensure that nutrients in the plants were maintained at slightly above the critical level (i.e., the concentration of an element in the leaves at which plant growth begins to decline). Moisture levels were maintained at 75 to 90 percent field capacity.

Near the end of the 1971 growing season, all aerial portions of trees from 2 by 6 ft subplots were harvested. This material was measured, separated by components, oven-dried at 70°C until equilibrium was reached, and then weighed.

Anatomical characteristics of the two clones were measured as part of a screening process to determine the relative suitability of various candidates for fiber production in a maximum yield system.

Three stems of harvested plants (replications) were taken from each of the three planting densities for each of the two clones and examined. Segments of each stem were removed from near the base, middle, and tip. Microtomed sections were cut from these segments and photomicrographed. The photomicrographs were projected onto a screen containing a grid from which countings were made to calculate the percent composition of vessels and of bark fibers. The diameters of the vessels and of the bark fiber bundles also were measured using the calibrated projections. Specific gravities of intact stem segments were determined using the water immersion method. The same method was used to determine individual specific gravities for the wood and for the bark after the segments had been dissected and the pith had been removed from the wood. Fiber, vessel, and bark-fiber lengths were obtained from calibrated microscopic projections of tissues that had been macerated using peracetic acid. Broken or cut cells were not measured. Data were analyzed using a 4-way analysis of variance for each of the 10 anatomical characteristics.

RESULTS AND DISCUSSION

Table 1 documents that considerable tonnage of wood and bark can be produced by

Table 1.--Dry weight by components of *Populus "Tristis #1"* and *Populus "Northwest"*¹

(In tons/acre)

POPULUS "TRISTIS #1"												
Planting:	Totals					Stems				Branches		
density : (in.) :	Tree :	Wood :	Bark :	Tips :	Leaves :	Total :	Wood :	Bark :	Total :	Wood :	Bark :	
9 by 9	12.25	6.29(51) ²	2.94(24)	0.11(1)	2.91(24)	6.61(53)	4.74(38)	1.86(15)	2.63(21)	1.55(12)	1.08(8)	
12 by 12	9.33	4.01(42)	2.45(26)	.12(2)	2.75(29)	4.71(50)	3.16(33)	1.54(17)	1.76(19)	.85(9)	.91(10)	
24 by 24	3.86	1.58(44)	.97(25)	.05(1)	1.26(32)	1.67(43)	1.11(28)	.56(14)	.89(23)	.47(12)	.41(11)	
POPULUS "NORTHWEST"												
9 by 9	6.38	2.79(44)	1.65(25)	0.15(2)	1.79(28)	3.98(62)	2.59(40)	1.39(21)	0.46(7)	0.20(3)	0.26(4)	
12 by 12	5.70	2.09(37)	1.76(31)	.11(1)	1.74(31)	2.72(48)	1.82(32)	.90(16)	1.13(19)	.27(4)	.86(15)	
24 by 24	2.02	.57(28)	.47(23)	.05(2)	.93(46)	.71(35)	.41(20)	.30(14)	.33(16)	.16(7)	.17(8)	

¹One-yr-old material from rooted cuttings.

²Percent of total tree weight in parenthesis.

very dense stands of young trees. Sprouts from the 2-yr-old rootstock of *Populus* "Tristis #1" planted at the 9 in. by 9 in. density produced the equivalent of over 6 tons of wood and almost 3 tons of bark/acre/year at 9 in. by 9 in. planting density. The *Populus* "Northwest" sprouts were only slightly better than half as productive.

However, sprouts from both clones yielded greater tonnages of wood and bark than did "total tree harvested" in natural aspen stands on good sites in the Lake States that yielded between 1 and 2 tons/acre/year (Einspahr and Benson 1970, Benson and Einspahr 1972).

Table 2 shows differences in the 10 measured anatomical characteristics between the 2 clones. The means presented were obtained by averaging data for all replications, planting densities, and stem sampling heights for each clone. Differences or patterns attributable to planting density or sampling height are included in the following discussion.

The specific gravity of *P.* "Tristis #1" wood (without pith) was much higher

than that of *P.* "Northwest" wood (Table 2); yet the values for both clones were within the wide range of specific gravities reported for *Populus* species (Isenberg 1951, Valentine 1962, Wilde and Paul 1959). The specific gravities of both clones increased as planting densities decreased. However, specific gravity progressively decreased as stem height increased in *P.* "Tristis #1;" just the opposite was found in *P.* "Northwest."

The fibers of *P.* "Tristis #1" were slightly shorter than those of *P.* "Northwest." Although fibers from both clones were short, their lengths are comparable to the fibers of other young *Populus* species and hybrids (Cech *et al.* 1960, Kennedy and Smith 1959). As would be expected, the fibers of both clones decreased in length as stem height increased.

Stems grown at the 12 in. by 12 in. density had slightly longer fibers than those grown at the 9 in. by 9 in. density. This observation might be attributed to differences in crown geometry and morphology, which enabled larger amounts of photosynthate to be distributed to the stem

Table 2.--Comparison of anatomical characteristics of two hybrid *Populus* clones

Measured characteristics	<i>Populus</i> "Tristis #1": mean ¹	<i>Populus</i> "Northwest": mean ¹	Difference between means ²
Wood (without pith)			
sp. gr.	0.402	0.338	** ³
Fiber length (mm)	.560	.574	* ⁴
Vessel length (mm)	.276	.247	**
Vessel diameter (mm)	.040	.039	--
Vessel composition of wood (percent)	19.33	30.12	**
Bark fiber length (mm)	1.066	1.010	**
Bark fiber composition of bark (percent)	9.42	11.52	**
Bark fiber bundle diameter (mm)	.146	.118	**
Bark sp. gr.	.397	.370	--
Intact stem segment sp. gr.	.367	.324	**

¹Averaged over all planting densities, replications, and stem sampling heights.

²Variation due to planting density, replications, and stem sampling heights removed by ANOVA.

³Denotes significant difference at the 99 percent confidence level.

⁴Denotes significant difference at the 95 percent confidence level.

for accelerating fiber growth in stems grown at the 12 in. by 12 in. planting density. However, sprouts grown at both the 9 in. by 9 in. and the 12 in. by 12 in. densities had fibers that were considerably longer than those grown at the 24 in. by 24 in. density.

The vessels of *P. "Tristis #1"* were considerably longer than those of *P. "Northwest,"* but the vessels of both clones were considerably shorter than vessels in older *Populus* (Panshin *et al.* 1964). Their lengths decreased as planting density decreased. The diameters of the vessels from both clones were similar. Generally, vessels near the top of the stem were considerably smaller in diameter than those from the middle or bottom of the stem.

The greatest difference in the wood anatomy of the two clones was in vessel

composition (fig. 1). Based on a percentage of cross sectional area, the wood of *P. "Tristis #1"* was composed of approximately 19 percent vessels as compared to 30 percent in the wood of *P. "Northwest."* This probably accounts for the lower specific gravity of *P. "Northwest"* wood.

Utilization of material produced on short rotations might include bark. Bark fibers would probably be the greatest contributors of all bark-cell types to pulp yields and properties. The bark fibers of the clone *P. "Tristis #1"* were longer than those of *P. "Northwest"* but fibers of both averaged slightly greater than 1 mm in length, which is almost the same as the length of bark fibers found in aspen (Chang 1954, Hossfeld and Kaufert 1957). If bark is included in pulp, the long fibers should enhance strength properties because the bark fibers from both

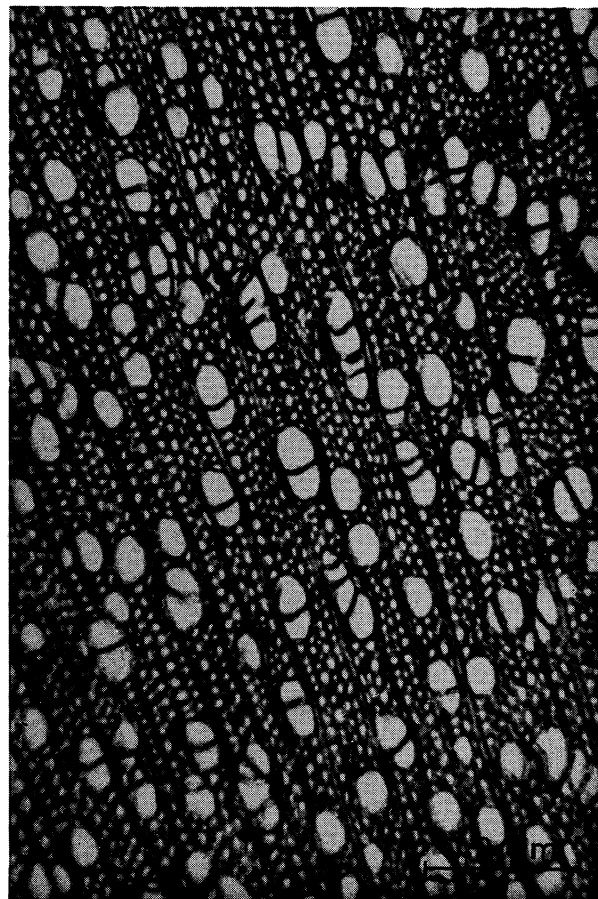
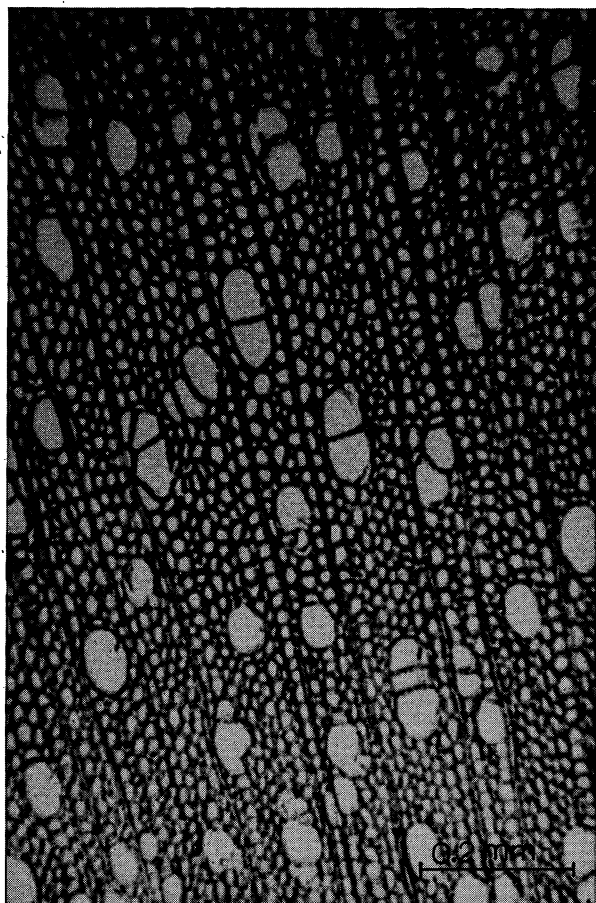


Figure 1.--Photomicrographs showing *Populus "Tristis #1"* (left) had a lower percentage of vessels than *P. "Northwest"* (right).

clones were nearly twice the length of the wood fibers.

The bark of *P. "Northwest"* had a significantly greater percentage of fiber than did that of *P. "Tristis #1,"* but both clones averaged approximately 10 percent fiber based on a percentage of cross sectional area. Bark fibers were arranged tangentially in bundles that had an approximate average diameter of 0.13 mm. No brachysclereids, commonly called "stone cells," were noticed in the bark of either clone. Apparently this cell type had not yet formed in these young stems as has been reported in other *Populus* species (Chang 1954). Difficulties in papermaking attributed to stone cells could be avoided if stems were harvested before stone cells formed.

In *P. "Tristis #1"* the specific gravity of the bark was only slightly lower than that of the wood. In *P. "Northwest"* the specific gravity of the bark was much greater than that of the wood but less than the specific gravity of the bark in *P. "Tristis #1."* The bark of both clones increased in specific gravity as stem height increased.

The specific gravities of undissected stem segments for both clones were lower than the specific gravities of their respective bark and wood. This pattern reflects the large amount and influence of pith in these small stems.

SUMMARY

Two selected *Populus* clones grown under short rotations and dense spacings produced yields averaging as much or more than recorded yields of aspen stands native to the North Central Region in the United States. The differences in yields between the two clones grown at three planting densities illustrate that the selection of genetic material and the cultured regime under which a species is grown are significant factors that must be determined in maximum yield systems specifically for the species used. Nearly all wood-quality characteristics (specific gravity, fiber length, vessel length, and vessel composition) varied significantly between clones, but most characteristics were well within the ranges reported for *Populus* pulpwood.

Of apparently great economic or practical significance is that the bark of both clones averaged approximately 10 percent fiber and that these fibers were considerably longer than the wood fibers. Moreover, no stone cells were observed in the bark of either clone. Because of the high proportion of bark weight to wood weight and additional costs of bark separation, these findings would imply that the possibilities of profitable bark usage were good. The conclusions derived should not be extrapolated to more extensive systems or immediate application on a large scale. However, they do point out that more comprehensive research on maximum fiber yield-short rotation research should be productive.

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