WOOD PROPERTY VARIATION IN POPULUS

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The use of bigtooth aspen (*Populus grandidentata* Michx.), quaking aspen (*P. tremuloides* Michx.), and cottonwood (*P. deltoides* Bartr.) by the pulp and paper industry has increased greatly during the past decade. This expanded use has stimulated research on the genetic improvement of *Populus*. For the past 12 years an industry-sponsored aspen program has been underway at The Institute of Paper Chemistry (Einspahr and Benson 1964). One of its major goals has been the improvement of wood properties important to pulp and paper quality. During these 12 years a number of selected trees were evaluated and a number of studies have been completed in which wood, fiber, and pulp properties were obtained for individual trees.

This report summarizes wood property measurement data for several species of *Populus* and for both natural and artificially produced aspen hybrids. Although the nature of the data prevents any rigorous statistical treatment, comparable sampling and measurement techniques employed in the several studies permit useful comparisons between native species of *Populus* and the younger aged plantation-grown hybrids.

Materials and Methods

The older trees used in this comparison were growing in natural stands and either were selected for use as parent trees because of form and rate of growth or were randomly located trees that were being evaluated in studies of heritability or natural variation. Ten-millimeter, breast-high increment cores were used as a source of wood from the older trees. At least two cores were used in making the specific gravity and fiber length measurements, and additional cores were taken when micropulping information was determined.

The young trees used had been field planted as 1-0 stock and had grown in the test plantings for 5 to 6 years. These trees were cut, and disks or appropriate-sized wedges from disks were used in the evaluation work. The wood samples were located 16 to 32 inches above the ground and contained only those annual rings that developed after field planting.

Specific gravity determinations were run in duplicate, and the wood samples used for specific gravity were also the source of fibers for the fiber-length measurements. The fiber-length data reported for the 5- and 6-year-old trees were obtained on a ring-by-ring basis for the last three growth rings and were based on approximately 500 fibers from the fifth annual ring. All fibers 0.3 mm and longer including those cut, broken, and intact were measured.

The age-30 fiber-length measurements for the older trees were obtained by dividing the 10-mm increment cores into 5-year intervals, measuring 400 to 500 fibers per 5-year interval, plotting the fiber length-age curve, and taking the age-30 fiber-length value from the curve. For trees that were less than 30 years old, the fiber length for the last 10-year interval was determined and the fiber-length age information was adjusted to age 30, using a previously prepared fiber length-age curve. All fibers 0.3 mm and longer including those cut, broken, and intact were measured.

Information on pulp yield and fiber strength was obtained by micro-pulping small chip samples prepared from increment core or disk samples. Duplicate determinations were made upon the 5- and 6-year-old trees, and single determinations for all other trees. The micropulping procedure used employed a kraft pulping system and a multiunit digester (van Buijtenen et *al.* 1961). The techniques and the cooking conditions employed are reported in detail by Gardner and Einspahr (1964). The data on the percent yield of pulp are based on equivalent weights of wood in each digester. Zero-span tensile strength measurements were conducted on test handsheets, using the procedure described by Wink and Van Eperen (1962), and are interpreted as a measure of individual fiber strength. Alcohol benzene extractives and percent lignin were determined on wood samples using TAPPI standard methods T 6 M-54 and T 13 M-54.

Discussion of Results

Tables 1 and 2 summarize the results of the wood quality evaluation work with aspen and cottonwood carried on over the past 10 years. The greatest amount of evaluation work has been done with specific gravity, and the least number of

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Table 1. — Wood and fiber properties of Lake States-grown Populus *and* Populus *hybrids*

Species[1/]	Age, yr.	Specific gravity, g./cc.		Fiber length, mm.[2/]		Zero-span tensile, lb./in.	
		Average[3/]	Range	Average[3/]	Range	Average[3/]	Range
P. alba hybrids	18-30	0.392 (2)	0.389-0.394	1.10 (2)	1.00-1.21	--	--
	31+	.358 (4)	.334- .375	.99 (2)	.98-1.00	72.2 (1)	
P. deltoides	18-30	.363 (3)	.357- .372	1.10 (2)	1.05-1.15	--	--
	31+	.352 (10)	.336- .374	.95 (8)	.82-1.05	66.7 (5)	59.0-75.2
P. grandidentata	18-30	.363 (2)	.341- .385	.97 (3)	.94- .99	--	--
	31+	.378 (31)	.325- .433	.97 (40)	.77-1.18	72.9 (5)	67.7-81.8
P. tremuloides (3n)	31+	.391 (34)	.318- .447	1.23 (33)	1.02-1.37	56.9 (23)	48.6-65.9
P. tremuloides	18-30	.390 (123)	.310- .456	.97 (124)	.76-1.20	55.3 (5)	49.3-61.4
	31+	.390 (285)	.331- .476	.93 (283)	.62-1.19	60.5 (66)	49.4-76.7
P. tremuloides	5	.370 (554)	.311- .450	.67 (305)	.46- .94	65.5 (153)	56.2-75.4
P. tremuloides (3n)	5	.362 (72)	.342- .394	.65 (48)	.55- .76	61.8 (24)	56.6-66.5
P. tremuloides x P. tremula (3n)	5	.403 (70)	.347- .481	.75 (48)	.53- .88	61.0 (24)	46.9-77.2
P. tremuloides x P. sieboldii	6	.345 (9)	.318- .366	.72 (4)	.64- .85	61.2 (4)	57.2-64.2
P. tremuloides x P. davidiana	6	.340 (22)	.291- .374	.74 (8)	.70- .84	63.5 (9)	55.2-68.1
P. alba x P. grandidentata	6	.380 (5)	.344- .418	--	--	--	--
P. grandidentata x P. davidiana	6	.345 (12)	.312- .374	.76 (4)	.69- .81	63.7 (3)	60.8-67.2
P. grandidentata x P. alba	6	.373 (9)	.324- .441	.73 (4)	.67- .78	59.0 (4)	55.8-60.4

1/ The P. alba hybrids are naturally occurring hybrids in which the female parent is P. alba and the male parent is believed to be P. grandidentata. 3n indicates trees having three sets of chromosomes (triploids).

2/ Fiber length based on age 30 for mature, natural stand trees, and age 5 for plantation grown trees.

3/ Number in parentheses indicates number of individuals used to obtain the mean and range.

measurements involve lignin and extractive determinations. Comparison of data from wedges from young trees with increment-core data from older trees will tend to reduce slightly the differences between the two types of measurements. The reason is that the core samples weight the center of the tree more than the exterior portion so that the wood samples in this instance are more nearly alike (high in proportion of young wood) than usual.

Specific Gravity

Specific gravity, because of its influence on pulp yield and pulp properties and because it is influenced by cell wall thickness, relative proportion of latewood, proportion of thin-walled vessels, and the presence of reaction wood, is of interest from the tree improvement point of view. The specific gravity data were based on measurements of 1,245 trees. The majority of trees measured were either mature quaking aspen or 5-year-old plantation-grown quaking aspen. Because of the numbers of individuals involved, these data make reliable standards of comparison. Looking first at the mature trees, there appears to be no significant difference between the diploid quaking aspen "age groups" or between diploid and triploid quaking aspen. Bigtooth aspen specific gravity data, although based on fewer trees, seem to indicate that this species may have a slightly lower specific gravity than quaking aspen. It also appears

Table 2. — Pulp and chemical properties of Lake States-grown Populus and Populus *hybrids*

Species[1/]	Age, yr.	Pulp yield, percent: Average[2/]	Pulp yield, percent: Range	Lignin, percent: Average[2/]	Lignin, percent: Range	Extractives, percent: Average[2/]	Extractives, percent: Range
P. alba hybrids	18-30	--	--	--	--	--	--
	31+	51.5 (1)		20.4 (1)		3.8 (1)	
P. deltoides	18-30	--	--	--	--	--	--
	31+	51.2 (5)	50.5-52.7	22.4 (5)	22.0-22.9	2.1 (5)	2.0-2.2
P. grandidentata	18-30	--	--	--	--	--	--
	31+	51.2 (5)	50.0-52.8	20.3 (5)	20.0-20.6	3.0 (5)	2.7-3.3
P. tremuloides (3n)	31+	55.1 (24)	51.8-59.0	18.3 (24)	16.2-19.9	3.14 (24)	2.38-4.00
P. tremuloides	18-30	51.0 (3)	49.7-52.6	--	--	--	--
	31+	51.8 (61)	47.8-54.4	19.2 (1)		3.5 (1)	
P. tremuloides	5	48.8 (153)	43.6-52.4	18.1 (153)	15.7-20.4	4.64 (153)	2.70-16.7
P. tremuloides (3n)	5	48.2 (24)	46.6-50.2	17.2 (24)	16.6-17.9	6.32 (24)	4.98-7.90
P. tremuloides x P. tremula (3n)	5	48.8 (24)	46.8-50.4	17.2 (24)	16.3-18.2	5.38 (24)	4.76-6.37
P. tremuloides x P. sieboldii	6	48.0 (4)	47.2-48.9	19.3 (4)	18.4-19.8	4.56 (4)	4.30-4.93
P. tremuloides x P. davidiana	6	49.3 (9)	48.0-51.2	18.3 (8)	18.0-18.8	4.64 (8)	4.34-5.18
P. alba x P. grandidentata	6	--	--	--	--	--	--
P. grandidentata x P. davidiana	6	49.3 (3)	48.4-49.8	17.6 (4)	17.2-18.4	4.90 (4)	4.65-5.40
P. grandidentata x P. alba	6	50.1 (4)	49.2-50.7	18.0 (4)	16.9-19.2	4.45 (4)	3.93-4.94

[1/] The P. alba hybrids are naturally occurring hybrids in which the female parent is P. alba and the male parent is believed to be P. grandidentata. 3n indicates trees having three sets of chromosomes (triploids).

[2/] Number in parentheses indicates number of individuals used to obtain the mean and range.

that the specific gravity of cottonwood and the older *P. alba* hybrids is lower than quaking aspen. Comparison of the younger aged trees (5 and 6 years old) with the mature-tree specific gravity of 0.390 suggests only moderate decreases have resulted despite the relatively young age of the trees involved.

The young triploid hybrids (*P. tremuloides* x P. *tremula* triploid) had the highest average specific gravity of the trees evaluated, and the hybrids between *P. tremuloides* and *P. davidiana* had the lowest specific gravity. The fairly wide range in values reported suggests that the genetic improvement of specific gravity appears to be quite promising.[2]

[2] *Broad sense heritability for specific gravity in aspen has been estimated to be about 0.4 (Einspahr* et al. *1967a, and van Buijtenen* et al. *1962).*

Fiber Length

Fiber length influences a number of pulp strength characteristics and, particularly in the short-fiber hardwoods, longer average fiber length is generally accompanied by higher tear resistance and, to a lesser extent, increases in burst, tensile, and fold (Tappi 1960). Because of the importance of fiber length, parent trees and progeny groups have been evaluated and minimum standards established.

Using the fiber length of diploid quaking aspen (table 1) as a standard of comparison, it appears that bigtooth aspen, quaking aspen, and cottonwood have similar age-30 fiber lengths. Triploid quaking aspen has a fiber length approximately 28 percent longer than the native diploid species mentioned above. The data for *P. alba* hybrids are too limited to judge adequately the fiber length of this material, but preliminary measurements indicate it is at least as good as that of the native quaking aspen.

The age-5 fiber lengths are, as expected, less than the age-30 fiber measurements. The several aspen hybrids all had average fiber lengths exceeding that of the diploid quaking aspen.

An earlier reported comparison of the age-5 fiber length of the triploid hybrids confirmed its superiority over that of diploid quaking aspen (Einspahr *et al.* 1967b). Despite the restricted number of measurements on the other hybrids, the fifth-year fiber length of several of the materials suggests that these hybrids can be expected to have fiber lengths longer than those of the native aspen. It is also of interest that the fifth-year data reported are approximately equal to the fiber-length averages reported for mature maples. Pulping work with these young aspen and aspen hybrids indicates they will yield pulps satisfactory for the types of papers presently being made from quaking aspen.

Zero-Span Tensile Strength

Zero-span tensile strength is a difficult measurement to make but when properly handled gives an average fiber strength value. Zero-span tensile strength has been shown to be positively related to the more conventional paper tests of burst, tear, and tensile strength and has the advantage that it can be made on a very limited amount of pulp. Because the absolute values obtained are influenced by cooking conditions, sheet formation, and other processing variables, fairly large differences (8 to 10 lb/in.) must exist between the averages in order for the differences to be meaningful.

Based upon earlier experience (Gardner and Einspahr 1964) with this test it seems unlikely that the zero-span tensile strength differences for the 5- and 6-year-old trees are statistically significant. Comparing the fiber strength of the older trees, bigtooth aspen and possibly cottonwood appear to have fiber strength values greater than diploid quaking aspen. A comparison of the young trees with the older trees reveals that the 5- and 6-year-old trees have higher zero-span tensile strength values, although it is doubtful that the differences presented are statistically significant.

Lignin, Extractives, and Pulp Yield

Because of the interrelationships between levels of lignin, extractives, and yield of pulp, these factors are considered together (table 2). Differences between types of materials in the above properties were not large except for the older triploid quaking aspen, which had the highest average pulp yield and relatively low levels of lignin and extractives. The 5- and 6-year-old trees had 2 to 3 percent lower pulp yield than the older bigtooth and quaking aspen. This reduced yield apparently resulted from the higher extractive levels present in the younger aged trees. Lignin levels in the younger trees were 1 to 2 percent less than in the older trees, but despite this lower level of lignin the overall pulp yields were less. The pulp yield and extractive and lignin levels for the younger aged trees are surprisingy uniform considering the differing genetic parentage. The somewhat reduced overall natural variation in the above chemical properties of aspen suggest that only limited gains can be expected if these properties are emphasized in tree improvement work.

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