Deterioration Rates of . . .

Willow and Cottonwood

during Storage in Georgia

By

P. J. Bois[1]
Southeastern Forest Experiment Station
Asheville, N. C.

W. E. Eslyn
U.S. Forest Products Laboratory
Madison, Wis.

PULP COMPANIES HAVE become interested in the rapid growth and high fiber yield of cottonwood (*Populus deltoides*) and willow (*Salix nigra*), but both species are low in decay resistance, and thus there is concern about deterioration during outdoor storage.

Studies of deterioration in other tree species commonly used for pulp have provided considerable information on stain, decay, and loss of wood substance during outdoor storage in the South. In southern yellow pine, yearly specific gravity losses of 11 to 15 percent have been reported by Lindgren and Eslyn (7). Large decreases in specific gravity occurred in small oak and gum pulpwood, but overall decreases in oak specific gravity were less, possibly because of the higher percentages of heartwood (4). Since decrease in specific gravity is correlated closely with loss of wood fiber and pulp yield, it is an important indicator of storage loss in wood (6).

Occurring largely in low, wet areas, cottonwood and willow are difficult to harvest except in the summer and fall, when such sites are relatively dry. Hence, it is necessary to stockpile these two species for 6 months and longer to insure an adequate supply of wood. Evidence of decreases in specific gravity and subsequent wood pulp yield during this storage period prompted the present study of willow and cottonwood.' Objectives were to determine the deterioration rate of cottonwood and willow bolts as indicated by decreases in specific gravity after storage periods of 8, 17, and 48 weeks; to determine what decay organisms were causing deterioration; and to evaluate pulp quality after storage.

Figure 1. - Study pile No. 1, illustrating the open end from which sample zones and sample bolts could be recovered progressively.

[1]This study was conducted while working in cooperation with the Georgia Forestry Commission.

[2]This was a cooperative study with the Armstrong Cork Co. at Macon, Ga., with the assistance of Armstrong chemist J. C. Layden, Jr.

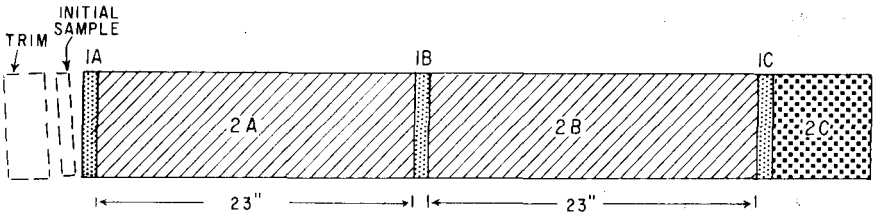

Figure 2. - Bolts were sampled as shown: 1a, 1b, and 1c were specific gravity-moisture content sections; 2a and 2b were pulping sections. Section 2c was discarded.

Procedure

Experimental Piles

In June and July 1963, two piles of unbarked roundwood were constructed on the Armstrong Cork Co. woodyard in Macon, Ga. Each pile was a mixture of willow and cottonwood, one pile of approximately 181 cords at the north end of the yard and another of approximately 121 cords at the south end. They duplicated as nearly as possible the pile-building practices of this mill; side walls were hand built, and the center wood of each pile was straw piled, leaving one end open for wood removal (Figure 1). The wood came mostly from the Piedmont of Alabama, with a small amount from the South Carolina Piedmont. Diameters of willow and cottonwood bolts to be sampled ranged from 3 to 10 inches (small end inside bark). The north pile location was a high, dry site, while the south pile location was lower and wetter. Hereafter, the north pile will be referred to as pile No. 1 and the south pile as pile No. 2.

Specific Gravity and Moisture Determinations

The piles were of fresh, green wood. Before they were built, bolts were selected and removed in a random manner. A 1-inch disk was removed from each bolt at a point 2 inches from the end, and its specific gravity and moisture content determined (Figure 2). Specific gravity based on green volume and ovendry weight was determined on complete disks by the sink-float method described by Heinrichs (5). Knots and tensionwood areas were removed from the sample disks before specific gravity was determined.

All moisture content values were expressed as a percentage of the ovendry weight. A triple beam balance was used in the field to determine the weight of each disk immediately after it had been sawed from the bolt. The bolt was then tagged on the opposite end with an identifying number, and a spiral of paint was applied around the center of the bolt. As the piles were being built, these tagged bolts were placed in the piles at definite intervals of pile construction so as to form zones of tagged wood across each pile. Three sample zones were built into pile No. 1 and two sample zones across pile No. 2. Each sample zone contained 50 cottonwood bolts and 50 willow bolts, a total of 250 bolts for each species.

After 8 weeks of storage, 42 bolts of cottonwood and 47 bolts of willow were removed from zone 1 in pile No. 1 without disturbing the remainder of the pile. (The identification of 8 cottonwood and 3 willow bolts was lost). Each study bolt was debarked by hand, and three 1-inch disks (1a, 1b, and 1c) were cut from each bolt (Figure 2).

Sample 1a was removed from the end of the bolt adjacent to the original specific gravity-moisture content section, and samples 1b and 1c were taken at 23-inch intervals, leaving these intermediate sections for pulping tests. The pulping sections were ground at the Macon plant and tests were made of green freeness and fiber classification. This procedure was repeated in each of the two piles after 17 and 48 weeks.

Appraisals of Decay and Blue Stain

At the 17- and 48-week samplings, the disks were visually appraised for blue (fungal) stain, decay, and insect activity. Estimates were made of the percentages of each disk area infected by white rot, brown rot, and blue stain, utilizing pathological indicators such as zone lines and discolorations. Since the presence of decay could only be estimated visually, no attempt to interpret stages of decay was made.

A sample disk from each bolt was sent to the U.S. Forest Products Laboratory for identification of the decay fungi. Isolations were made from both the sapwood and heartwood areas of each disk. In addition, an isolation was made from the blue-stained area of each disk to obtain some idea of the fungi involved in the staining of these bolts. The decay fungi isolated were plated on malt agar, where their macroscopical and microscopical growth characteristics were observed, and upon gallic acid and tannic acid medium, where their growth rate and oxidase reactions were noted in the manner described by Davidson *et al.* (1). From such data, and following the methods of Nobles (8) and Davidson *et al.* (2), cultural descriptions and key patterns were established for each isolate. Based upon their cultural appearance and their key patterns, the isolates were placed into similar groups and identifications attempted. Representative cultures from each group were forwarded to the Forest Disease Laboratory at Laurel, Md., for identification or verification of identity. These identifications have not been fully completed at this time and will be the subject of a later publication.

Table 1. - SPECIFIC GRAVITY AND MOISTURE CONTENT VALUES OF WILLOW BOLTS STORED OUTSIDE FOR 8 to 48 WEEKS

Storage times	No. of samples	Specific gravity: Initial average	Specific gravity: Standard deviation	Specific gravity: Bolt average at test	Specific gravity: Standard deviation	Decrease in specific gravity	Moisture content: Initial average	Moisture content: Standard deviation	Moisture content: Bolt average at test	Moisture content: Standard deviation
Weeks						Percent	Percent		Percent	
					Pile No. 1					
8	47	0.387	0.03	0.380	0.03	1.8	105	16	77	23
17	51	.373	.03	.369	.06	1.1	87	20	55	25
48	48	.361	.02	.345	.03	4.4	91	29	29	14
					Pile No. 2					
17	45	.399	.03	.387	.03	3.0	88	18	56	18
48	43	.387	.03	.368	.03	4.9	93	18	28	12

Results and Discussion

The initial specific gravity mean of the willow bolts was 0.38, with a range from 0.31 to 0.46. Cottonwood bolts also had an average specific gravity of 0.38, with a range from 0.30 to 0.48. The cottonwood specific gravity agrees with that reported by Farmer and Wilcox (3) for cottonwood grown in the lower Mississippi Valley. The average initial moisture content of cottonwood going into storage was 96 percent and ranged from 51 to 180 percent. Willow bolts averaged 93 percent moisture content, with a range from 31 to 190 percent. The average specific gravity and moisture content values of the two species before and after various periods of storage are shown in Tables 1 and 2. The specific gravity values of the bolts shown are the arithmetic mean of the specific gravities of the three disks taken from each bolt. The standard deviation of specific gravity and moisture content determinations at each sampling period are also shown. Since pile No. 2 had only two sample zones, these were only sampled at the 17- and 48-week periods.

Specific Gravity of Willow

The willow bolts decreased very little in specific gravity after 8 and 17 weeks. After 48 weeks, specific gravity values had decreased 4.4 percent in pile No. 1 and 4.9 percent in pile No. 2.

Specific Gravity of Cottonwood

In pile No. 1, specific gravity decreases were similar to those noted in the willow bolts. In pile No. 2, however, specific gravity values of the cottonwood bolts dropped 5.1 and 8.2 percent after 17 and 48 weeks, respectively - which was considerably more than willow loss.

Table 2. - SPECIFIC GRAVITY AND MOISTURE CONTENT VALUES OF COTTONWOOD BOLTS STORED OUTSIDE FOR 8 to 48 WEEKS

Storage times	No. of samples	Specific gravity: Initial average	Specific gravity: Standard deviation	Specific gravity: Bolt average at test	Specific gravity: Standard deviation	Decrease in specific gravity	Moisture content: Initial average	Moisture content: Standard deviation	Moisture content: Bolt average at test	Moisture content: Standard deviation
Weeks						Percent	Percent		Percent	
					Pile No. 1					
8	42	0.404	0.04	0.399	0.04	1.2	99	17	83	17
17	52	.394	.05	.384	.05	2.5	95	24	64	20
48	51	.364	.02	.343	.02	5.8	96	22	45	13
					Pile No. 2					
17	45	.389	.04	.369	.04	5.1	93	14	54	19
48	38	.380	.03	.349	.03	8.2	98	23	44	18

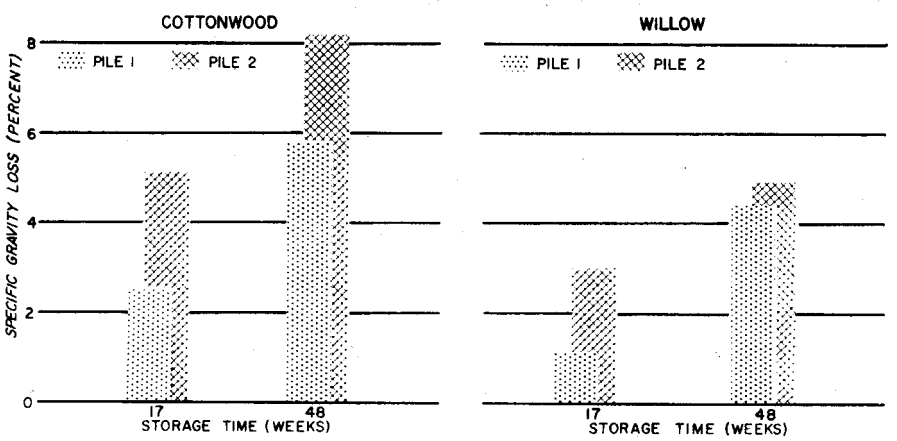

Figure 3. - The effect of pile site and species on specific gravity changes.

The Student "t" test of the specific gravity values after each period of storage indicated that the differences were statistically different at or above the 99 percent probability level (Table 3).

The decreases in specific gravity, though real, were very small after 8 and 17 weeks of storage. Larger and more meaningful decreases in specific gravity occurred after 48 weeks of storage. Further analyses of the 17- and 48-week data disclosed the effect of storage site and species on specific gravity changes (Figure 3), with cottonwood bolt losses in pile No. 2 almost twice those in pile No. 1. Because pile No. 2 site had previously been used for willow-cottonwood storage, remnants of decayed wood covered the ground.

Moisture Contents of Willow and Cottonwood

The initial moisture content values of the bolts had a rather wide range, as indicated by the standard deviations in Tables 1 and 2. This wide variation was found throughout 'the storage periods. In both piles, after 48 weeks, however, the willow bolt moisture content values had dropped to about 29 percent, while the cottonwood bolts dropped to only 44 percent. Initial moisture content values in these bolts stored for 48 weeks were about the same, and all had wide standard deviations.

Pulping Results

Pulping test results of green wood and samples after 8, 17, and 48 weeks of storage are presented in Table 4. Freeness values were erratic and showed little correlation with the fiber classifications. Cottonwood freeness measurements from piles No. 1 and 2 were, as a group, somewhat slower than the willow pulps. The lowest freeness values were observed in both species and both piles after 17 weeks of storage. The highest freeness values were obtained after 48 weeks of storage in three of the four treatment combinations.

Fiber classifications varied little throughout the study periods. The cottonwood samples had higher retentions on screen classifications, with correspondingly lower amounts of fines than the willow.

Fungus Damage Observed During Storage

Cottonwood

A total of 102 cottonwood bolts was examined after 17 weeks' storage; all of the bolts were blue stained.

White rot was present to some degree in all but two cottonwood bolts after 17 weeks' storage. After 48 weeks, white rot was present throughout every bolt examined. Zone lines, indicative of advanced decay, were present in 25 percent of the bolts at the end of 17 weeks and in 27 percent at the end of 48 weeks.

Table 3. - "T" VALUES FOR SPECIFIC GRAVITY VALUES AFTER VARIOUS STORAGE TIMES FOR WILLOW AND COTTONWOOD BOLTS

Storage times	No. of samples	Average initial specific gravity	Average bolt specific gravity at test	"t" values[1]
Weeks				
		Willow in Pile No. 1		
8	47	0.387	0.380	4.15
17	51	.373	.369	3.12
48	48	.361	.345	7.02
		Willow in Pile No. 2		
17	45	.399	.387	7.19
48	43	.387	.368	6.16
		Cottonwood in Pile No. 1		
8	42	.404	.399	2.83
17	52	.394	.384	4.52
48	51	.364	.343	12.85
		Cottonwood in Pile No. 2		
17	45	.389	.369	9.71
48	38	.380	.349	14.76

[1]All values were statistically significant at or above the 99 percent probability level.

Thirty-three percent of the cottonwood bolts contained brown rot after *17* weeks, but at *48* weeks only *13* percent of the bolts examined contained visible brown rot. A dark brown discoloration and high moisture content often accompanied brown rot when it occurred in the heartwood.

After *17* and *48* weeks, evidence of insect activity was noted in only two of the cottonwood bolts examined.

Willow

Ninety-eight willow bolts were examined after 17 weeks and 93 were examined after 48 weeks. After 17 weeks, 94 percent of the bolts had some blue stain; over one-half of these were completely stained. After 48 weeks, all bolts contained some blue stain and 90 percent were completely stained.

White rot was present in all but one willow bolt after 17 weeks, and in every bolt at the final sampling. Zone lines were present in only 3 percent of the bolts after 17 weeks, but they had developed in 29 percent of the bolts sampled after 48 weeks. A yellow discoloration accompanied white rot in approximately 12 percent of the bolts.

Brown rot was present following 17 weeks' storage in 42 percent of the willow bolts. As in cottonwood, the number of bolts containing brown rot was appreciably less at the end of 48 weeks of storage, at which time only 14 percent of the willow bolts examined contained visible brown rot.

No insect damage was noted in any of the willow bolts examined.

Table 4.- GREEN FREENESS AND FIBER CLASSIFICATIONS FOR WILLOW AND COTTONWOOD STORED OUTSIDE FOR UP TO 48 WEEKS

Pile No.	Weeks in storage	Green freeness	Bauer-McNett fiber classification				
			10 mesh	20 mesh	35 mesh	65 mesh	fines
			Percent				
			Willow				
1	0	599	15.6	12.2	13.9	14.0	44.3
1	8	626	15.8	11.4	15.4	12.3	45.1
1	17	465	13.4	13.2	14.8	15.6	43.0
1	48	575	15.2	13.0	13.1	15.2	43.4
Average			15.0	12.5	14.3	14.3	43.9
2	17	455	13.1	12.8	14.6	15.6	43.8
2	48	620	15.0	15.8	14.2	16.8	38.2
Average			14.0	14.3	14.4	16.2	41.0
			Cottonwood				
1	0	628	17.2	14.6	16.3	17.2	34.7
1	8	668	14.3	13.2	16.0	13.2	43.3
1	17	598	13.7	12.6	14.8	15.3	43.6
1	48	680	17.9	13.6	14.1	16.5	37.9
Average			15.8	13.2	15.3	15.5	39.9
2	17	517	19.7	12.9	15.9	15.4	35.7
2	48	620	15.0	15.8	14.2	16.8	38.2
Average			17.4	14.3	15.0	16.1	36.9

Fungi Isolated by Laboratory Techniques

No attempts have been made to identify the blue stain fungi found in the willow and cottonwood, but various mold fungi such as *Fusarium* sp., *Trichoderma* sp., *Cephalosporium* sp., and *Spicaria* sp. were isolated from every disk sampled. In addition, bacteria were often isolated from the decayed or discolored portions of the bolts.

Typical wood decay fungi (basidiomycetes j were obtained from 45 of the cottonwood and 40 of the willow bolts after 17 weeks' storage. In addition, two different basidiomycetes were isolated from each of three of the cottonwoods and from each of five of the willows. Almost the same total number of basidiomycetes were isolated from cottonwood and willow bolts after 48 weeks (Table 5). Eight of the cottonwood and two of the willow bolts yielded more than one wood-rot fungus.

At the end of 17 and 48 weeks, white rot fungi predominated in both wood species even though the number of these isolates decreased in number between the sampling periods. The corresponding increase in the percentage of brown rot fungi obtained at 48 weeks was not unexpected, as white rot fungi are often primary invaders of raw hardwood products, being followed in many instances by brown rot fungi. This increase was not apparent, however, during visual inspection of the disks.

The principal white rot fungi found associated with cottonwood and willow degradation included *Schizophyllum commune* Fr., *Polyporus adustus* Willd. ex. Fr., and *Peniophora flavido-alba* Cke. *S. commune* was the most common species in willow bolts after storage for 17 and 48 weeks, but occurred infrequently in cottonwood (Table 5). *P. adustus* was the most common white rot isolate obtained from cottonwood during both storage periods and was also of some importance in terms of frequency in willow. *P. flavido-alba* occurred with almost equal frequency in both woods during *17* weeks of storage. After *48* weeks of storage, however, it was found less frequently in cottonwood and more frequently in willow.

Coprinus radians (Desm.) Fr. was the most common fungus found on cottonwood during both sampling periods. Based on the generally negative reaction of this fungus on gallic and tannic acid medium, it has been tentatively included in the brown rot category (Table 5). Although of high incidence in cottonwood, *C. radians* was not found in the willow disks. This may have been due,

Table 5. - FUNGI AND TYPE OF DECAY ASSOCIATED WITH COTTONWOOD AND WILLOW BOLTS AFTER 17 AND 48 WEEKS OF OUTSIDE STORAGE

Storage period	Basidiomycetes isolated			Major basidiomycetes and occurrence (percent of total number)			
				White rot fungi			Brown rot fungi
	Total No.	Causing white rot[1]	Causing brown rot[1]	Schizophyllum commune	Polyporus adustus	Peniophera flavido-alba	Coprinus radians
Weeks		Percent	Percent	Percent	Percent	Percent	Percent
				Cottonwood			
17	48	73	27	4	21	10	23
48	51	55	45	0	14	6	22
				Willow			
17	45	93	7	22	9	11	0
48	41	85	15	15	5	15	0

[1]Determination of rot type based in part on ability of isolate to discolor gallic and tannic acid medium and, in part, on knowledge of rot type produced by a known isolate.

possibly, to an inability of the fungus to compete successfully with other organisms in the decomposition of willow.

Although the bulk of the basidiomycetes isolated from both woods has not been identified to date, they have been placed in groups of similar isolates. While these groupings indicate that no other single fungus will attain the numerical importance of the four already described, still it is planned to complete the identifications in progress and to include such information in a future publication.

Summary

After 8 weeks of outdoor storage, beginning in June, willow and cottonwood showed very little decrease in specific gravity. After 17 weeks, decreases in specific gravity were still small; one sampling of cottonwood showed a 5.1 percent drop, the largest recorded for that period. Although changes in specific gravity were small after 8 and 17 weeks of storage, these changes were statistically significant at the 99 percent probability level.

After 48 weeks, cottonwood bolts dropped a maximum of 8.2 percent in specific gravity, whereas willow bolts dropped a maximum of 4.9 percent. The pile storage site affected specific gravity; the lower, wetter site that had previously been used for roundwood storage produced greater decreases in specific gravity than the drier site.

Blue stain and decay were present in the majority of both the cottonwood and willow bolts at 17 weeks and in all the bolts of both species after 48 weeks. In isolations made at the end of 17- and 48-week storage periods, white rot fungi were more frequently obtained from both wood species than were brown rot fungi. The fungi apparently responsible for the bulk of the decay were *Schizophyllum commune, Polyporus adustus, Peniophera flavido-alba,* and *Coprinus radians.*

Little change was found in fiber classifications of pulp made from these woods after the various times of storage. Cottonwood green freeness values were somewhat slower than those from the willow pulps.

Literature Cited

1. Davidson, R. W., W. A. Campbell, and D. J. Blaisdell. 1938. Differentiation of wood-decaying fungi by their reaction on gallic or tannic acid medium. Jour. Agr. Res. 57(9): 683-695.
2. ———, W. A. Campbell, and D. B. Vaughn. 1942. Fungi causing decay of living oaks in the eastern United States and their cultural identification. U.S. Dept. Agr. Tech. Bull. 785, 65 pp.
3. Farmer, R. E., and J. R. Wilcox. 1966. Specific gravity variation in a lower Mississippi valley cottonwood population. TAPPI 49(5): 210-211.
4. Ference, G. M., and T. L. Gillis. 1956. The deterioration of straw-piled pulpwood. TAPPI 39(6): 406-415.
5. Heinrichs, J. F. 1954. Rapid specific gravity determinations. For. Prod. Jour. 4(1): 68.
6. Lindgren, R. M. 1951. Deterioration of southern pine pulpwood during storage. Proceedings, For. Prod. Res. Soc. 5: 169-180.
7. ———, and W. E. Eslyn. 1961. Biological deterioration of pulpwood and pulp chips during storage. TAPPI 44(6): 419-429.
8. Nobles, M. K. 1948. Studies in forest pathology. 6. Identification of cultures of wood-rotting fungi. Can. Jour. Res. 26: 281-431.