Corrections were made to Table II and Figure 2 of this paper on February 17th, 2004.

*Potential of mimosa (*Albizia julibrissin*) for papermaking*

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ABSTRACT: Mimosa (*Albizia julibrissin*) is a fast-growing perennial plant that can be grown on plantations at high yields. For mimosa to be a viable substitute for hardwood fibers in fine paper manufacturing, papermakers need to know how mimosa responds to different pulping conditions and to different bleaching sequences. Experiments are being carried out at Auburn University's Pulp and Paper Research and Education Center to determine the anatomic characteristics of fibers, the various aspects of cooking and the pulp qualities of mimosa, and the strength properties of paper made from mimosa pulp. In terms of strength, pulp made from the mimosa is comparable to pulp obtained from typical southern hardwood (sweet gum). Pulp processing experiments indicate the potential for cost savings associated with the ease of pulping, bleaching, and refining of the mimosa fibers.

Application: Mimosa could become a viable substitute for hardwood in the manufacture of writing and printing papers.

Quality writing and printing paper grades require a blend of long fibers from softwood and short fibers from hardwoods. The long fibers give the paper strength and durability, while the short fibers provide surfaces that are smooth and receptive to fast and clear application of inks. The forest products industry has done an excellent job in developing southern pine plantations. Hardwoods are not grown on plantations, however, making accessibility and proper reforestation difficult. Although several attempts have been made to identify a suitable and sustainable hardwood that can offer an acceptable source of short fiber for papermaking, there has been little success.

Mimosa (*Albizia julibrissin*) is a small to medium-sized tree in the pea family (*Fabaceae*) that can grow to 20–40 ft tall. Mimosa is also called "silk-tree." It can grow in various types of soils, and its wood is used in diverse ways, such as in constructional and cabinet works. Mimosa trees grow fast, and the species adapts well to different climatic conditions, principally in the tropics [1, 2]. Mimosa is a perennial, so it does not have to be replanted or reseeded: the wood is harvested, and new stems grow from established plants. It is similar to nonwood fiber sources in that it can be harvested on an annual basis. But since mimosa is a woody plant, it has fewer of the pulp processing drawbacks often associated with nonwoods [3–6]. In short, mimosa has great potential as a substitute for hardwood because it can be grown on plantations with high yields and it has most of the desirable attributes for pulp that hardwood species have.

The eventual goal of our work is to establish an optimum means of processing mimosa with existing pulp and paper technology and equipment. Mimosa has a better chance of being accepted as a direct substitute for hardwood if it can be pulped without additional equipment or capital expense. Therefore, the objective of our research program is to develop the new technologies needed in paper processing and agronomy to make mimosa a viable substitute for hardwoods in the manufacturing of fine papers.

AGRONOMIC AND AGRICULTURAL STUDIES

Mimosa forage and yield estimates

Auburn has been working with mimosa for a number of years to study it for use as a forage plant [7–9]. There are eight acres of established mimosa at the E. V. Smith Research Center near Montgomery and six acres at the Piedmont Station at Camp Hill, just north of Auburn. In addition, there are small-yield plots at the Wiregrass Station near Dothan in southeast Alabama and at the Tennessee Valley Station near Huntsville in north Alabama. These acres and plots represent a range of soil conditions under which the crop is being evaluated. All stations are well equipped to plant and harvest mimosa, to measure yield, and to provide samples for chipping and pulping studies.

Herbicides for establishing plantations

One of the remaining barriers to the commercialization of mimosa for pulp and paper production is the initial establishment of mimosa plantations. Competition from weeds seriously retards the growth of mimosa seedlings after the seeds have germinated. To identify a commercially available herbicide that will control weeds with little or no damage to the mimosa, we evaluated several herbicides on the basis of how well the mimosa plants fared. These herbicides were applied to field-seeded mimosa at different rates, before and after the emergence of the mimosa seedlings from the soil.

First we seeded four-row plots with mimosa. Control plots were those for which we carried out no weeding and those plots that were weeded by hand. With several herbicides applied at different rates, there were twenty-two different treatments. With four replicate plots for each of 22 treatments with herbicide applied before the plants emerged and 22 treatments with herbicide applied after the plants emerged, we had 16 control plots and a total of 192 plots in the experiment.

Each plot was 3 m × 3 m, and rows were 76 cm apart. On May 23, 2000, plots were seeded with a cone planter that placed about 15 seeds per meter in the row. Herbicide was applied before emergence on May 31 and after emergence on

Mimosa	TEMP., °C	EA, %	TIME, min	L/W	KAPPA No.	YIELD, %
1 yr	170	18	60	4.0	20.5	42.0
2 yr	165	18	100	4.0	17.1	43.6
2 yr	170	18	50	4.0	17.8	42.8
2 yr	165	20	70	4.0	18.6	41.4
2 yr	170	20	40	4.0	17.9	41.0
Sweet gum	170	20	100	5.3	19.6	44.4

I. Selected pulping conditions and results.

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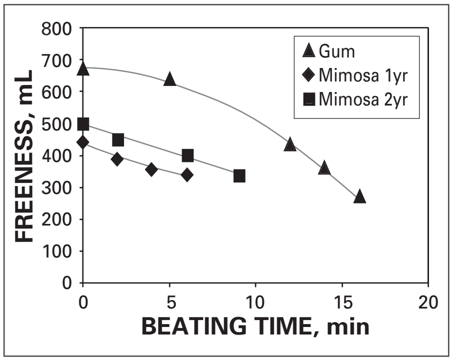
	MIMOSA		SWEET
	1 YEAR	2 YEARS	GUM
Fiber length, mm	0.51	0.65	1.4
Fiber width, µm	18.1	18.4	27.7
Wall thickness, µm	4.7	5.0	8.8
Coarseness, mg/m	0.09	0.095	0.187

II. Results of Kajaani analyses.



1. Beater curves.

June 12, when mimosa seedlings were between the 1st and 2nd true leaf stages. The number of plants per plot was determined on August 9. We recorded plant height on September 1 and stem diameter on October 26.

A comparison between plots weeded by hand and plots that were not weeded showed that weed competition reduced the number of plants by 47%, plant height by 73%, and stem diameter by 44%. Clearly, weed control is important for successful establishment of a mimosa plantation. A number of herbicides tested killed weeds but also inflicted severe damage on mimosa seedlings and should not be used for this purpose. Of the herbicides tested, Pursuit®[1] and Strongarm®[2] were effective in controlling weeds with minimal damage to the mimosa seedlings. Applied at the highest rate before the plants emerged, Strongarm reduced weed competition enough that the number of mimosa plants increased by 20%, the average plant height increased by 225%, and the average stem diameter increased by 28%, compared to the plants in control plots that were not weeded.

Mimosa harvest yield estimates

Our studies at the E. V. Smith Research Center show that mimosa can be grown successfully in the southeastern United States with yields of more than 25 metric tons of dry matter per hectare. The research plantation plots have 10 year old plants that are generally harvested each fall to a stump height of 0.3 m. Mimosa foliage is highly nutritious for cattle and deer. In fact, a one-year-old coppice of mimosa planted in rows 1.8 m apart showed little damage after cattle had removed all the foliage. The stems were 4 m tall. In a two-year-old coppice, the stems were up to 6 m tall, and most are 10–30 mm in diameter at the base. Consequently, the mimosa plantation can be managed to provide valuable feed for livestock and wildlife as well as wood chips for the pulp and paper industry.

During the 1999 and 2000 harvests, the yields of wood measured for one-, two-, and three-year-old stems were 12.6, 35.5, and 54.6 metric tons/ha, respectively. On an annual basis, then, the wood yield for mimosa is 12–18 metric tons/ha. This yield is greater than an annual yield of 8–12 metric tons/ha for natural growth hardwoods. (Details of the mimosa stands and harvesting are in Bransby *et al.* [7].)

PULPING AND PAPERMAKING STUDIES

Pulping and papermaking experiments

Studies on pulping and papermaking properties are underway on one-, two-, three-, and four-year-old mimosa plants, but the results presented here are for one-year-old and two-year-old mimosa stems. Samples of the mimosa chips were pulped under different conditions to get an idea of the best range of pulping conditions for the raw material. These pulping experiments were conducted in the Auburn University Pulp and Paper Processing Laboratories.

One-year-old and two-year-old mimosa stems (including the thin layer of bark) were chipped and screened to obtain thicknesses between 3 mm and 7 mm. Cooking sequences were carried out in laboratory digesters according to the regular kraft pulping process to obtain pulps with kappa numbers between 18 and 20. A number of cooks were carried out, each with 500 g of chips at 30% sulfidity, with liquor-to-wood ratios of 4.0–5.3, at under various charges of effective alkali, and over different temperatures and cooking times. After cooking, the pulps were processed in a pulper and washed. Resulting pulps were evaluated for kappa number and unscreened yield. Selected pulps were screened for bleaching and pulp evaluation.

For refining, we used a Valley beater, and a beater curve was developed to show the pulp response to mechanical treatment. TAPPI handsheets were prepared at different freeness levels. Sheets were conditioned under constant temperature and humidity and were tested for selected strength properties. The sheets were compared to sheets made from sweet gum (*Liquidambar styraciflua L.*) under similar conditions. (The handsheets made in this manner are referred to in some of the figures as "unbleached and unblended.")

The response of mimosa to bleaching sequences is important. Not only are brightness and opacity key qualities of fine papers, but we need to be able to compare the mimosa pulp to typical hardwood pulp in terms of the ease of bleachability. We used a DED bleaching sequence, consisting of chlorine dioxide followed by caustic extraction followed by chlorine dioxide. Chlorine dioxide was applied based on kappa number, with 60% of the total charge applied in the first stage and 40% applied in the second stage. For pulps with a kappa number of 19, we applied 1.7% ClO_2 for 45 min at 25°C in the first D stage, 2.4% NaOH for 1.5 h at 65.5°C in the E stage, and 1.1% ClO_2 for 3 h at 71°C in the

[1]DG(Ammonium salt of imazethapyr(±-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecaeboxylic acid).

[2](Diclosulam N-(2,6-dichlorophenyl)-5-ethoxy-7-fluoro[1,2,4]triazolo[1,5-c]pyrimidine-2-sulfonamide).

second D stage. After each stage, the pulp was washed thoroughly over a fine-mesh screen.

Response of mimosa to pulping, bleaching, and papermaking conditions

Several laboratory digester cooks were performed to determine the conditions for achieving the target kappa number for a maximum cook temperature of 170°C. **Table I** shows conditions and resulting kappa numbers and screened yield percentages for cooks for one-year-old mimosa and two-year-old mimosa. Generally, mimosa required 20–40 min less cooking time than sweet gum required under similar conditions. Screened yields for mimosa ranged from 41% to just over 43%, which is a few percent lower than for sweet gum. Pulps from cooks at an effective alkali (EA) of 18% were used for paper handsheets, bleaching, and property tests.

Figure 1 shows the beater curves for one-year-old mimosa, two-year-old mimosa, and sweet gum cooked at 170°C. Mimosa had a lower initial freeness of 500 mL CSF or less. The freeness dropped quickly in response to beating. The time required to reach 450 mL CSF, which is a useful freeness level for bleachable grades of pulp, was 4 min or less as compared to more than 12 min for sweet gum.

Figure 2 shows bulk, tensile index, burst index, and porosity (Gurley densometer reading) for handsheets made from these pulps at different levels of freeness. Comparing mimosa with sweet gum at a freeness of 450 mL, we see that mimosa exhibited slightly lower bulk, tensile index, burst index, and porosity.

Figure 3 shows the response of these pulps to bleaching with the DED sequence. For similar chemical applications, mimosa pulps showed higher brightness levels. Mimosa pulps also showed higher opacity, as shown in **Fig. 4**. The viscosity values of bleached pulp samples for mimosa were similar to that of the sweet gum pulp.

Kajaani analyses of samples of the unbleached pulps are shown in **Table II**. The average length of mimosa fibers is about 0.6 mm as compared to 1.4 mm for sweet gum. The mimosa fibers are slender, with about half the cell wall thickness of gum. Mimosa fibers have a low fiber coarseness, indicating better collapsibility of the fibers. However, we

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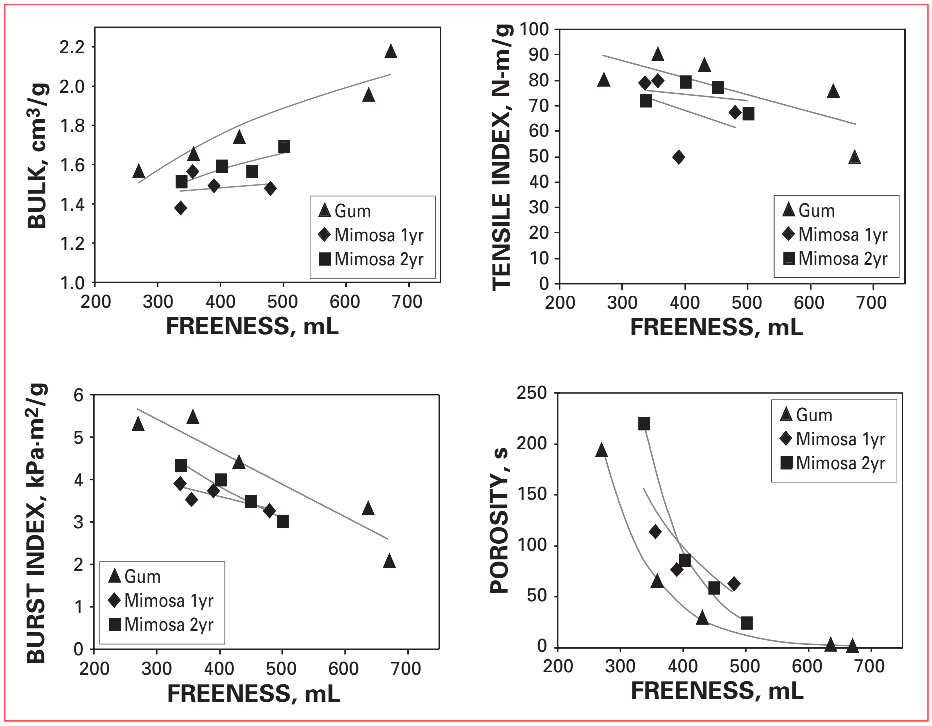
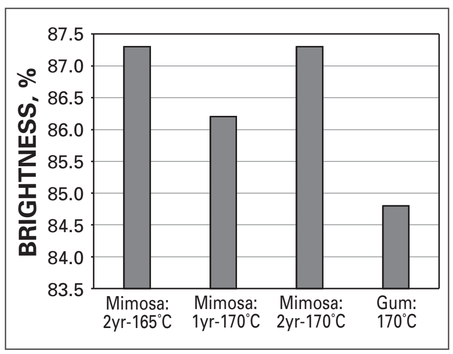
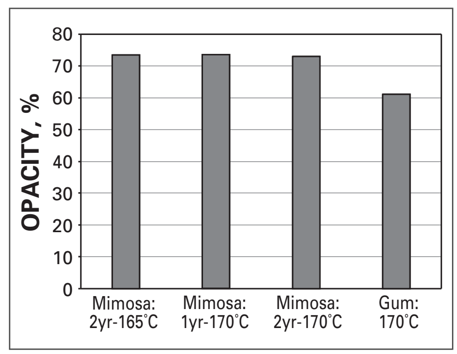


2. Bulk, tensile index, burst index, and porosity at different freeness levels.



3. Brightness response.



4. Opacity.

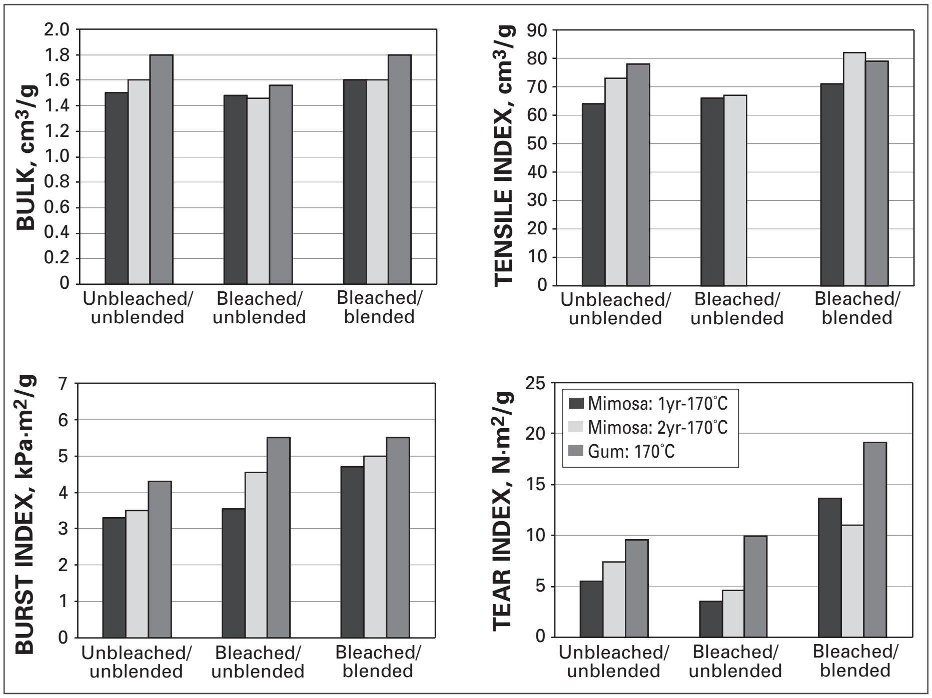
have used only one-year-old and two-year-old mimosa, and the fiber length would be expected to increase with age.

Figures 5 show property measurements for handsheets made with the unbleached pulps, bleached pulps, and bleached pulps in 50:50 blends with bleached softwood fibers. Comparisons are made at similar freeness levels (about 450 mL CSF). Unblended and blended sheets compare well with each other, indicating similar strength and physical properties. The porosity (not shown) of the bleached and blended mimosa pulp was similar to that of the bleached and blended sweet gum pulp.

CONCLUSIONS, FUTURE WORK

The pulping studies continue to support the notion that mimosa is easily pulped and that it has fiber and papermaking properties similar to those of hardwoods. The ease of pulping was displayed in laboratory digester runs in which kappa number targets were achieved with short cook times and low pulping chemical charges, even with the bark present. Mimosa pulp had a low initial freeness and an adequate response to beating, which usually translates into energy savings from reduced operation of refiners. Mimosa pulp samples were brighter than samples of sweet gum when they were given similar chemical bleaching treatment. Studies are now underway to see if the chemical usage can be reduced for mimosa.

Digester yields for mimosa are slightly lower than for gum (and other hardwoods), but we anticipate that studies with three- and four-year-old wood will show that the yields go up for older wood. Also, digester yield needs to be taken in the context of superior harvest yields and shorter growing cycles for the perennial mimosa. Strongarm and Pursuit appear to be effective herbicides for weed control when a mimosa plantation is being established. Seed collections and planting are underway in studies to identify superior genetic lines.



5. Bulk.

Two-year-old mimosa has slightly better pulp and paper properties than one-year-old mimosa when comparisons are made on unblended sheets. The pulp and paper properties are similar in 50% softwood blends for mimosa and gum, with 50% being a typical blend for manufacturing printable grades of paper. Studies in progress will compare the paper properties of blended and unblended sheets made with pulps derived from one-, two-, three-, and four-year-old wood. **TJ**

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INSIGHTS FROM THE AUTHORS

Mimosa has great potential as a substitute for hardwood fiber in papermaking. Since mimosa is a woody plant, it has few of the pulp processing drawbacks often associated with non-woods. Mimosa does not have to be replanted or reseeded: wood is harvested, and new stems grow from established plants.

The mimosa stem is too large in diameter for crop harvesters and too small for tree harvesters and pulp chippers. However, the harvest and pulp yields are surprisingly high and consistent. Our goal is to establish the means of processing mimosa efficiently and economically.

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