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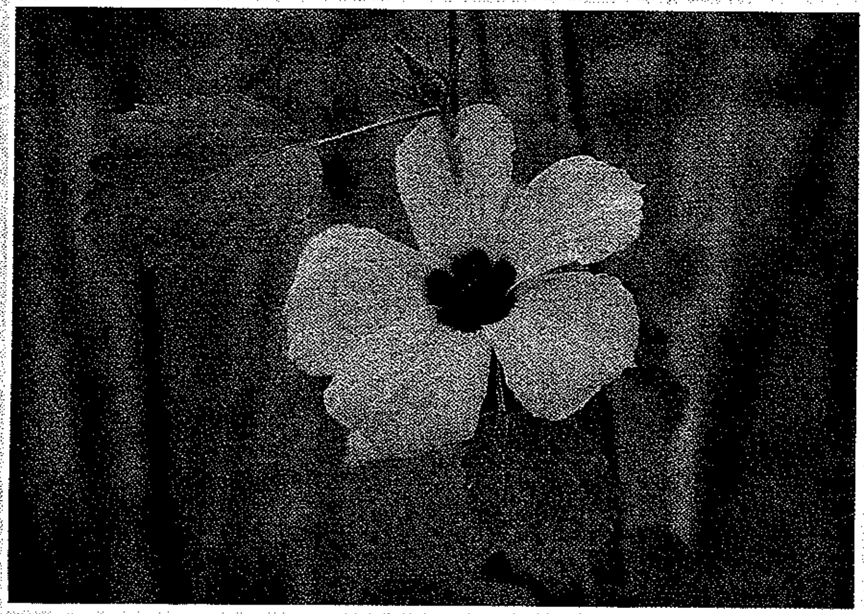

A Summary of Kenaf Production and Product Development Research 1989-1993

MAFES
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A Summary of Kenaf Production and Product Development Research

1989-1993

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This publication, except for the covers, is printed on 100 percent kenaf paper with Soy Ink.

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Foreword

With the funding aid of the United States Department of Agriculture's Agricultural Research Service, the Mississippi Agricultural and Forestry Experiment Station has focused on developing the potential of kenaf as an alternative crop. For the past 5 years, MAFES scientists have worked to improve efficiency in culture, harvesting, storage, transporting, and marketing, and to develop potential uses for kenaf in order to benefit and promote Mississippi agriculture.

This publication serves as a summary of this research of the Mississippi Agricultural and Forestry Experiment Station at Mississippi State University and several of its outlying branch stations. The topics discussed range from agronomic research to various aspects of product development.

The Mississippi Agricultural and Forestry Experiment Station is very proud of the work that has been accomplished on this project and the commercialization and economic development that have resulted. MAFES has realized the potential and importance of value-added products in industrial settings. For this reason, we will continue to strive toward developing all facets of kenaf production and product development.

On behalf of the Mississippi Agricultural and Forestry Experiment Station, I hope you both enjoy and benefit from the results presented in this publication.

Verner G. Hurt
Director

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Agronomic Research for Kenaf Crop Production in Mississippi

S.W. Neill and M.E. Kurtz

Variety Trials

1989. The availability of kenaf seed was limited, and quality was suspect as research got underway in 1989. Because of the latitudinal effect on kenaf growth, mid-maturing and late-maturing varieties were selected for the variety trial. These included both palmatified (deeply-lobed) and entire-leaf varieties:

Variety/Maturity	Leaf Structure
Mid-late C-108	Entire
Mid Cubano	Entire
Mid-late Everglades 41	Entire
Mid-late Tainung 1	Palmate
Mid-late Tainung 2	Palmate
Mid-late 45-9X	Palmate
Mid-late 78-18-RS-10	Palmate
Mid-late 78-18-GS-10	Palmate

Procurement of seed and adverse weather caused this trial to be planted late – June 21, 1989. A stand was not achieved until the last week of June. This trial was located at Leverette (near Charleston) in Tallahatchie County on a Cascilla silt loam soil. The crop was terminated by an early freeze October 20, 1989.

1990. There were three locations for variety trials in 1990: Leverette, Itta Bena (Leflore County), and Grenada (Grenada County). Plantings at these locations were accomplished by May 16. Variety 78-18-GS-10 was dropped because of lack of seed. Additional varieties included:

Variety/Maturity	Leaf Structure
Mid-late Everglades 71	Palmate
Mid-late 19-117-2	Palmate
Mid-late 15-2	Palmate

Grenada experienced severe drought conditions during the summer. This is thought to have reduced yields at that location.

1991. By June 3, 1991, plantings were accomplished at three locations: two sites at Stoneville and the one at Leverette.

1992. Plantings were limited to the two sites at Stoneville in 1992. Plantings were accomplished by May 1, but dry conditions delayed emergence until May 20.

Table 1 shows the combined averages across locations by year and the 3-year and 4-year averages. Kenaf varieties tested were all photoperiodic, which means that regardless of the date of planting, the plant will remain vegetative until the daylight period falls below 12 hours and 30 minutes. Therefore, the 1989 trial, with the late planting date, was short-seasoned and went reproductive prior to attaining its full vegetative height, resulting in yields lower than the potential.

Table 1 gives an indication of those varieties that produced the higher yields consistently at the locations.

Tables 2, 3, and 4 present the yield data at Leverette and Stoneville for the years and are indicative of the yield potential at those areas. These locations were selected because they reflect three different soil types – sandy (Leverette), mixed (Stoneville-Field 13), and clay (Stoneville-Field 16).

The evaluations of these 10 varieties should give a commercial producer an idea as to the yield poten-

Table 1. Averages by year of kenaf varietal dry stem yield across Mississippi locations.

Variety	Variety Averages 1989	1990	1991	1992	4-year average	3-year average*
	tons/acre					
Tainung 2	3.6	5.87	7.18	4.60	5.31	5.88
Everglades 71	- -	6.20	6.72	4.40	5.77	5.77
15-2	- -	5.55	6.43	4.70	5.56	5.56
19-117-2	- -	5.45	6.63	4.55	5.54	5.54
Tainung 1	4.0	5.90	6.50	4.20	5.15	5.53
Everglades 41	3.9	5.53	6.38	4.50	5.08	5.47
78-18-RS-10	3.5	5.63	6.38	4.35	4.97	5.45
45-9X	3.3	5.70	6.80	3.85	4.91	5.45
Cubano	3.8	4.97	6.73	4.50	5.00	5.40
C-108	3.6	5.30	6.55	3.90	4.84	5.25

*Drop 1989 average due to 120-day growing season (averaging 1990-92).

S.W. Neill, former Research Technician at the Delta Branch Experiment Station, Stoneville, is an Environmental Scientist I, YMD Joint Water Management District, Marigold, MS. M.E. Kurtz is a Plant Physiologist at the Delta Branch Experiment Station, Stoneville, MS.

Table 2. Average by year of kenaf varietal dry stem yield at Leverette, Mississippi.

Variety	Leverette 1989	1990	1991	3-year average	2-year average*
	tons/acre				
Tainung 2	3.6	6.5	9.0	6.37	7.75
Everglades 71	3.9	7.4	7.9	6.40	7.65
45-9X	3.3	6.5	7.8	5.87	7.15
78-18-RS-10	3.5	6.0	7.2	5.57	6.60
Tainung 1	4.0	6.5	6.6	5.70	6.55
Cubano	3.8	5.0	7.2	5.33	6.10
Everglades 41	3.9	5.6	6.6	5.37	6.10
C-108	3.6	5.7	6.4	5.23	6.05
19-117-2	- -	- -	7.1	- -	- -
15-2	- -	- -	7.6	- -	- -

*Drop 1989 average due to 120 day growing season (averaging 1990-91).

Table 3. Average by year of kenaf varietal dry stem yield at Field 13, Stoneville, Mississippi.*

Variety	Field 13 1991	1991	1992	2-year average
	tons/acre			
Tainung 2	6.3	8.1	5.1	6.50
Cubano	7.1	6.7	5.3	6.37
C-108	6.3	8.1	4.3	6.23
Tainung 1	6.4	7.0	5.0	6.13
Everglades 41	6.0	7.6	4.8	6.13
45-9X	6.7	6.8	4.8	6.10
Everglades 71	6.0	7.3	4.8	6.03
78-18-RS-10	6.4	6.1	5.1	5.87
19-117-2	6.7	- -	5.0	5.85
15-2	6.2	- -	5.2	5.70

*Field 13 is a Sharkey clay soil, but not heavy clay.

tial. Other variables that might affect a producer's choice would be availability of planting seed, bast ratio of the variety, and soil type.

Seed

The availability of kenaf planting seed is questionable for some of the varieties tested; however, there are several commercial ventures involved in seed production.

Kenaf seed germination in some varieties has been a problem if seeds are carried for longer than one year. The author recommends germination tests of seed lots approximately one month prior to planting in order to adjust seeding rates to ensure adequate stands.

Bast Ratio

Bast ratios of varieties were studied and are worthy of comment at this time. Past research has indicated bast ratios are affected by stem diameter. Stem diameter can be manipulated by row spacing; however, this could reduce yield and plant density. Drought conditions experienced in 1990 seemed to affect bast ratio. In some fertility trials, differing rates of fertilizer appeared to influence bast ratios.

There are noted differences in bast ratios among varieties, with the two Tainung selections producing low ratios and 45-9X producing high ratios. However, it is the author's opinion that too little is known in this area to make a recommendation of a variety solely on bast ratio.

Soils

Soils are seen to have an influence on kenaf yield (Tables 2, 3, 4). The Leverette location had a silt loam soil with a low cation exchange capacity (CEC). Stoneville Field 13 was a silty clay soil with a mid-range CEC, and Stoneville Field 16 contained a heavy clay soil with a high CEC rating. As indicated in the tables, the lower CEC soils produced almost 2 tons greater yield than soils with the high CEC ratings and a ton more than the soils with the mid-range CEC. This trend was also noted among varieties with almost the same graduations. More work in this area should be done before a specific recommendation of a variety for a soil type can be made. However, these tables may be used as a reference in that selection.

Table 4. Average by year of kenaf varietal dry stem yield at Field 16, Stoneville, Mississippi.*

Variety	1991 Field 16	1992 Field 16	2-year average
	tons/acre		
19-117-2	6.1	4.1	5.10
Everglades 71	5.7	4.0	4.85
15-2		5.5	4.85
Cubano	5.9	3.7	4.80
Everglades 41	5.3	4.2	4.75
Tainung 2	5.3	4.1	4.70
78-18-RS-10	5.8	3.6	4.70
Tainung 1	6.0	3.4	4.70
C-108	5.4	3.5	4.45
45-9X	5.9	2.9	4.40

*Field 16 is a Sharkey clay soil.

Kenaf Variety by Date of Planting in Misssissippi

Carl H. Hovermale

Information on crop varieties and planting dates is a basic requirement needed for producers. Previous work at the MAFES South Mississippi Branch showed that kenaf plantings from mid-April to early May produced good yields.

Four kenaf varieties were planted in four-row plots 20 feet long. Plantings began April 15 in 1990 and April 1 in 1991 and 1992, with later plantings every 2 weeks until June 15. A seeding rate of 10 pounds per acre was used in all trials. One pint of Treflan® per acre was incorporated before planting. One quart of MSMA was post-directed using a backpack sprayer for late-season weed control when the kenaf was 3 feet tall.

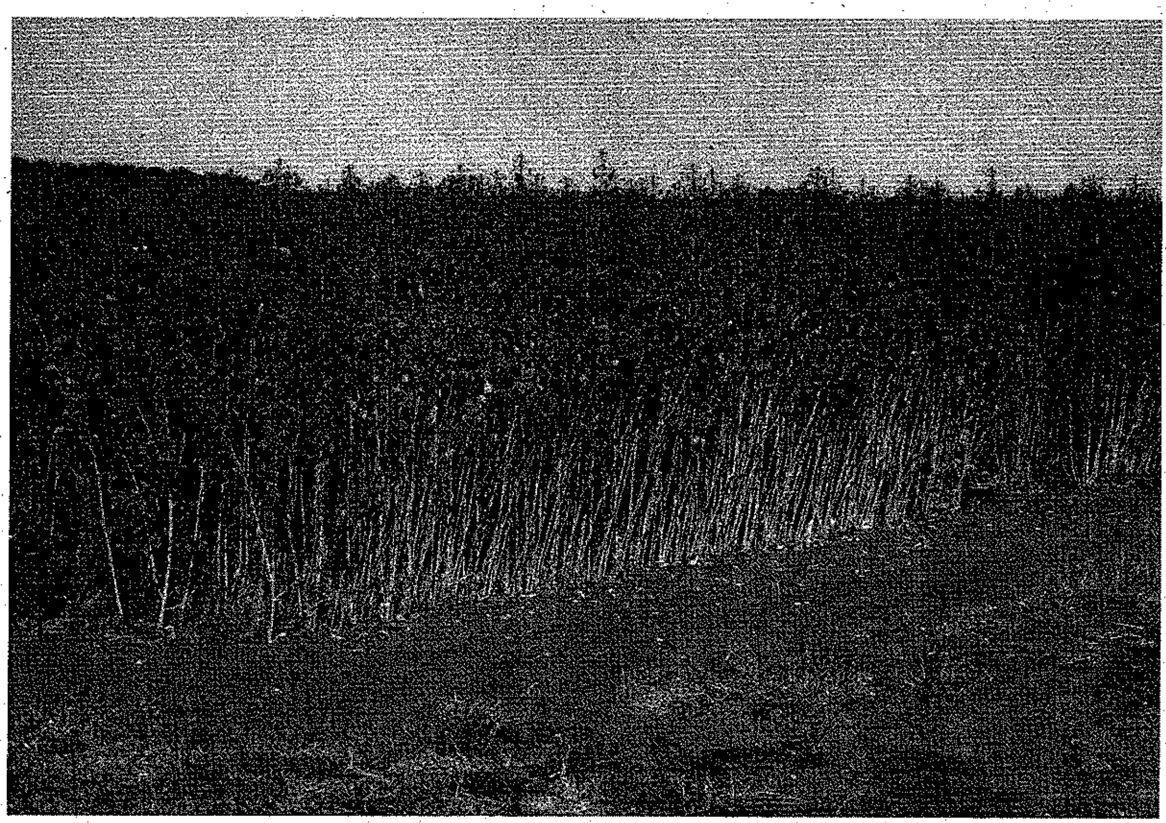
Two 13-foot sections of row in each plot were cut at ground level and weighed. Samples were taken for moisture determination and yields converted to dry matter per acre. Five plants were selected at random from harvested plants in each plot and measured for plant height. Plants were counted at harvest to determine standing plants per acre.

Carl H. Hovermale is Agronomist at the South Mississippi Branch Experiment Station, Poplarville, MS.

1990 Results

Plants lodged per plot, percent defoliation, disease incidence, and percent lodging were not affected by planting date. Kenaf planted May 30 or before yielded more than that planted June 15 (Table 1). Plant height was related to planting dates. The taller plants were found in the earlier plots. However, the highest number of plants per acre resulted from the May 15 and 30 plantings.

Averaged over all planting dates, Everglades 71 was



All varieties of kenaf tested at the South Mississippi Branch responded to early planting (April 15 or earlier) with higher yields. However, damping off disease can be a problem in early season.

shorter than other varieties tested and yielded less than Roselle or RS10 but was not different from Tainung 1 (Table 1). Roselle had the highest final plant stand (49,471 plants/acre). Taniung 1 had the lowest plant population (31,715 plants/acre). Disease and defoliation ratings for Roselle averaged around 10%, while other varieties were between 73% and 98%.

Table 1. Effect of variety and planting date on kenaf yield, MAFES South Mississippi Branch, 1990.

Date	RS10	Everglades 71	Tainung 1	Roselle	Average
	Variety				
	lb/acre				
April 15	7,230	4,485	4,890	9,037	6,402A[1]
April 30	5,275	5,780	3,253	9,857	6,401A
May 15	6,266	5,443	4,579	9,483	6,443A
May 30	6,567	5,145	4,880	7,431	6,006A
June 15	3,594	4,820	2,289	2,728	3,356B
Mean	5,786B	5,129C	3,976C	7,707A	

[1] Means within a column followed by the same letter are not different at the (p<.05) level of significance according to DMRT.

Table 2. Effect of variety and planting date on kenaf yield, MAFES South Mississippi Branch, 1991.

Date	RS10	Everglades 71	Tainung 1	Roselle	Average
	Variety				
	lb/acre				
April 1	14,027	15,635	14,647	11,082	13,853A[1]
April 15	12,322	12,477	13,562	9,222	11,896B
May 1	8,990	11,005	10,850	7,827	9,668C
May 15	9,377	9,765	9,920	7,517	9,145C
June 1	9,222	10,695	9,300	7,285	9,125C
June 15	7,052	4,052	6,897	5,192	6,549D
Mean	10,165A	11,108A	10,862A	8,021B	

[1] Means within a column followed by the same letter are not different at the (p<.05) level of significance according to DMRT.

Table 3. Effect of variety and planting date on kenaf final plant stand, MAFES South Mississippi Branch, 1992.

Date	RS10	Everglades 71	Tainung 1	Roselle	Average
	Variety				
	plants/acre				
April 1	17,820	49,950	15,390	46,440	32,400B[1]
April 15	28,080	33,210	12,960	49,680	30,983B
May 1	31,050	23,490	24,030	32,400	27,743B
May 15	88,560	56,700	73,980	88,020	76,816A
June 15	42,930	23,490	36,180	65,070	41,917B
Mean	41,688AB	37,368B	32,508B	56,322A	

[1] Means within a column followed by the same letter are not different at the (p<.05) level of significance according to DMRT.

There was an interaction between variety and planting date. The yield of RS10 and Tainung 1 decreased from the April 15 to April 30 planting, while the yield of Roselle and Everglades 71 increased for the same period.

Generally, with the planting dates imposed, Roselle was better adapted to this area than the other varieties. This year's data indicate that kenaf compensates very well for thin stands. One plant per 5 square feet yielded almost as much as 1 plant per 0.6 square foot. Early-season damping off diseases are a serious problem with kenaf production. April 15 and 30 plantings consistently had lower stands even though the same number of seeds were planted.

1991 Results

Kenaf planted April 1, 1991 was taller, had thicker stems, and yielded more than the other plantings (Table 2). Planting kenaf June 15 resulted in plants shorter than when planted May 15 or before and had the lowest yields. Planting after April 15 resulted in significantly lowered yields even though stem diameter and plant height were not significantly different. Planting April 15 resulted in significantly higher plant stands.

Averaged over all planting dates, there was no significant difference in height attributable to variety. RS10 and Everglades 71 had higher plant populations than Roselle, but Tainung 1 was not different from any variety. Roselle yielded less and had smaller stem diameters than the other varieties tested (Table 2). Roselle had the highest plant mortality. There was no interaction between variety and planting date for any variable studied.

Generally, with the planting dates imposed, Roselle was the least adapted to this area, which is a contradiction of the previous year's results. This difference is attributed to the lack of disease pressure. Some of the differences in plant stand are attributed

Table 4. Effect of variety and planting date on kenaf yield, MAFES South Mississippi Branch, 1992.

Date	RS10	Everglades 71	Tainung 1	Roselle	Average
	Variety				
	lb/acre				
April 1	10,462	15,810	11,625	19,142	14,260AB[1]
April 15	17,825	15,267	15,035	17,050	16,294A
May 1	16,042	15,112	15,267	12,245	14,667AB
May 15	11,005	14,492	14,260	12,090	12,962B
June 15	8,292	8,060	9,532	6,742	8,157C
Mean	12,725	13,748	13,144	12,725	

[1] Means within a column followed by the same letter are not different at the (p<.05) level of significance according to DMRT.

Table 5. Effect of variety on kenaf plant height, population, yield, and stem diameter, MAFES South Mississippi Branch, 1993.

Variety	Height	Plant population	Yield	Stem diameter
	in	plants/A	lb/A	mm
RS 10	114B[1]	42,000A	6,572A	7.40B
Everglades 71	109BC	23,211C	5,438AB	7.9AB
Tainung 1	128A	30,333BC	6,988A	9.00A
Roselle	102C	39,875AB	4,655B	5.70C
Mean	113	33,855	5,913	7.50

[1] Means within a column followed by the same letter are not different at the (p<.05) level of significance according to DMRT.

Table 6. Effect of planting date on kenaf plant height, population, yield, and stem diameter, MAFES South Mississippi Branch, 1993.

Variety	Height	Plant population	Yield	Stem diameter
	in	plants/A	lb/A	mm
April 1	128.40A[1]	24,083C	8,979A	10.0A
April 5	123.6AB	41,938AB	7,858A	8.4AB
May 1	118.4AB	21,533C	5,675B	9.7AB
May 5	98.4C	40,063AB	2,712C	3.6C
June 1	110.4BC	28,867BC	5,544B	7.6B
June 15	102.0C	45,938A	5,548B	5.7C
Mean	113.5	33,737	6,052	7.5

[1] Means within a column followed by the same letter are not different at the (p<.05) level of significance according to DMRT.

to trying to adjust seeding rate for the percent seed germination of each variety.

1992 Results

In 1992, kenaf planted June 15 was shorter, had thinner stems, and yielded less than the other plantings (Table 4). Planting April 15 resulted in significantly higher yields than planting May 15 or after even though plant height was not significantly different. Planting May 15 resulted in significantly higher plant stands (Table 3).

Averaged over all planting dates, there was no significant difference in height or yield attributable to variety. Roselle had higher plant populations than Tainung 1 and Everglades 71 but was not different from RS10 (Table 3). Roselle had smaller stem diameters and lower plant populations than the other varieties (Table 4). There was no difference in mortality attributable to variety. There was no interaction between variety and planting date for any variable studied.

1993 Results

Kenaf planted May 1, 1993 or earlier was taller, had greater stem diameters, and yielded more than the other plantings (Table 5). Plant stand was variable. Kenaf planted April 15, May 15, and June 15 had higher populations than kenaf planted April 1 or May 1 (Table 6). Kenaf planted May 15 had the lowest yield and smallest stem diameter. Tainung 1 was taller, had thicker stems, and yielded more than Roselle (Table 6). There was an interaction between variety and planting date for stem diameter, but it was relatively small and extremely variable.

The Effect of Plant Population on Kenaf Yield

S.W. Neill and M.E. Kurtz

Population trials were conducted with kenaf at several locations in the Mississippi Delta during 1989 through 1992 (Table 1). The results generally showed that the higher the plant population, the greater the yield. However, the data in Table 1 can be misleading at the lower populations because kenaf plants spaced widely apart tend to grow large trunks (3-4 inches in diameter) and branch excessively, and are therefore able to keep yields at a relatively high tonnage. This phenomenon has caused difficulty in the harvesting of research plots and is believed to present the same problems for commercial harvests. More input by end product users will determine if this is a desirable characteristic or one to be avoided.

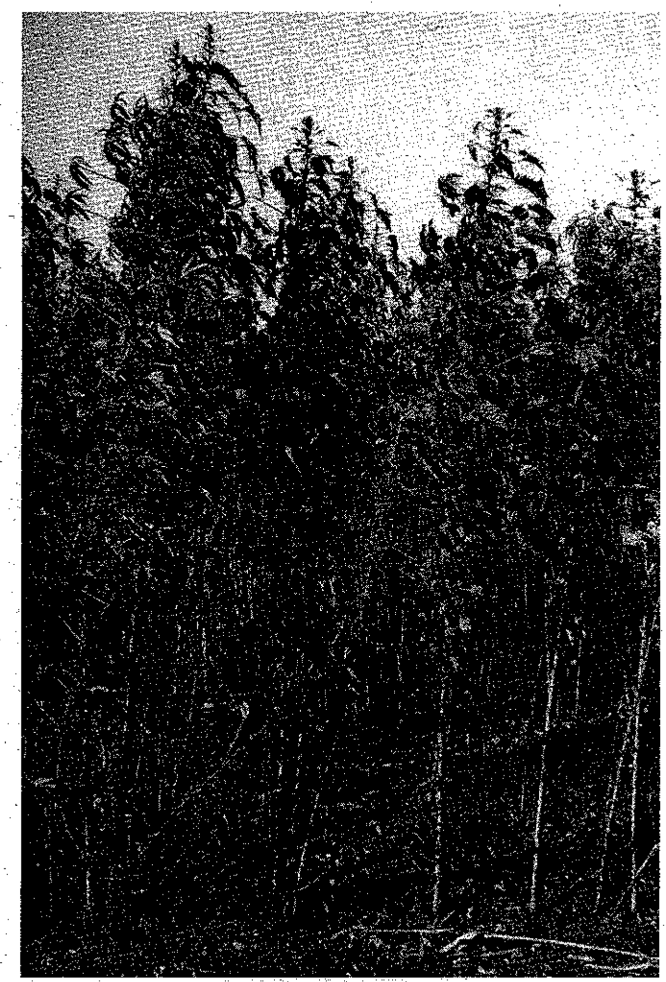
Another characteristic of kenaf that is somewhat worrisome is the self-thinning of the plant stand that takes place through the growing season. Final plant stand can often be as much as 20 percent less than that at a month after emergence. Some of the lower treatments in Table 1 are the result of this characteristic. The thinning is much more prevalent in the wider spacings than the narrow because of intraspecific crowding along the row. A mature kenaf stalk can have a base diameter of 1.5 to 2 inches at ground level and will usually thin down to about five plants per foot of row. The only way to increase plant population on a per acre basis is to narrow the row spacings. Literature review indicates a desired plant population of approximately 80,000-100,000 plants/acre.

Bast ratio is a component that can be directly manipulated by plant population. Bast ratio increased as the plant population increased, most likely because of competition for nutrients and sunlight. This crowding effect resulted in smaller stalk diameter. Stem diameter is considered a component of yield along with height, and higher populations tend to produce stalks shorter and smaller in diameter than plants at the lower population levels. End user specifics could have a role in the plant population levels selected.

S.W. Neill, former Research Technician at the Delta Branch Experiment Station, Stoneville, is an Environmental Scientist I, YMD Joint Water Management District, Marigold, MS. M.E. Kurtz is a Plant Physiologist at the Delta Branch Experiment Station, Stoneville, MS.

Table 1. Population trial results 1989 thru 1992 at all locations.

	Leverette			Stoneville		
Treatment	1989	1990	1990 Glendora	1991 Field 13	1992 Field 13	1992 Field 16
(plants/acre)	(tons/acre)					
17,000	--	--	--	4.9	1.6	--
35,000	--	--	--	5.3	1.9	2.5
52,000	2.9	--	--	6.3	2.3	--
70,000	3.2	5.3	4.7	6.0	2.2	3.3
87,000	3.0	5.2	5.1	--	--	--
104,000	--	5.9	5.6	--	--	3.8
280,000	--	--	--	--	--	4.3



Plant populations of 80,000-100,000 appear to be desirable for kenaf. The crop tends to thin itself through the growing season, but total yields are maintained as the plant increases trunk size and branching.

Fertility and Row Spacing for Kenaf Production

S.W. Neill, C.H. Hovermale, and M.E. Kurtz

Kenaf is a very vigorous plant under optimum conditions. Kenaf can reach canopy in as few as 5 weeks, so fertility applications need to be made with this factor in mind. Literature review indicates little yield is gained by split applications of nitrogen and that a recommended rate would be 150 to 200 pounds per acre of actual nitrogen.

Trials conducted at Leverette and Stoneville, Mississippi in 1990 and 1991 indicate that 150 pounds of nitrogen should be sufficient to ensure maximum yields. Increasing nitrogen has caused the plant to be greener and bushier, but has not increased yield correspondingly. Depending on the row spacing and management, a recommendation would be to apply 100 lb/acre N preplant, and another 50 lb/acre as a postemergent sidedress application.

Trials utilizing multiple rates of phosphorus and potassium with nitrogen have been conducted with unclear results as to the role of the phosphorus and potassium. The addition of these alternative fertilizers does not seem to have an effect on yield as does nitrogen; however, the effect on the individual plant (bast ratio) is being studied and will continue in future trials. Soil test results would be the best vehicle on which to plan phosphorus and potassium applications.

Row spacing has been investigated at numerous locations across the country and in other regions of the world. The effort in Mississippi has been towards a spacing compatible with equipment readily available at the production location. Spacings investigated ranged from 10 inches to 40 inches and included bedded rows (Table 1). The 2-year row spacing trial was done at Leverette, Mississippi on a silt loam soil.

The combined dry stem yield for the 2 years indicated that a 20-inch to 30-inch row spacing tended to produce higher yields than either the 10-inch or the 40-inch spacings. This trial also indicated that on soils with good external drainage there was not a need for bedding. The area of manipulation of plant stand by row spacing is apparent in the final stand counts and attrition rates. This trial was hand-thinned to approximately 110,000 plants per acre a month after emergence both years. The plants continued to thin in the wider spacings, possibly due to nutrient and sunlight competition and intraspecific crowding.

In the previous article on plant population, the point was made that as the number of plants per acre increased, so did yield. That was also the case in this trial except for the narrowest spacing, where the yield decreased. Plants in the 10-inch spacing were shorter and thinner than the other spacings, probably due to competition for nutrients.

Results of these trials indicate spacings for optimum yield would be between 20 inches and 30 inches. Further research is being done with different varieties and row spacings from 10 to 30 inches. Indications are that the varieties used show no effect of spacing, and that yields are higher at the 20-inch spacing. The authors believe higher numbers of plants per acre at harvest is a factor to be considered in the selection of row spacing.

Trials conducted at the MAFES South Mississippi Branch on Ruston fine sandy loam soil provided different results for row spacing than the Leverette trials. Planting dates were May 15, 1990, May 17, 1991, and May 1, 1992. Row spacing (8, 20, and 40 inches) was the main plot and nitrogen rate (0, 50, 100, 150, and 200 pounds per acre) was the subplot. A seeding rate of 10 lb/acre remained constant over row widths. One pint of Treflan® per acre was preplant incorporated before planting. One quart of MSMA was post-directed using a backpack sprayer for post-emergence weed control. Harvest was accomplished after frost defoliated the plants and converted to dry matter per acre.

Table 1. Row spacing effect on combined dry stem yield, Leverette, Mississippi, 1990-1991.

Treatment	Leverette 1990	Leverette 1991	Combined average
	—(tons/acre)—		
40-in double flat	7.6	6.6	7.10
30-in bedded	7.8	5.8	6.80
30-in flat	7.8	5.8	6.80
20-in flat	7.4	5.5	6.46
40-in flat	7.0	5.4	6.23
40-in double bedded	6.7	5.6	6.14
40-in bedded	6.4	5.6	6.00
10-in flat	7.3	4.7	5.99

S.W. Neill, former Research Technician at the Delta Branch Experiment Station, Stoneville, is an Environmental Scientist I, YMD Joint Water Management District, Marigold, MS. C.H. Hovermale is an Agronomist, South Mississippi Branch Experiment Station, Poplarville, MS. Mark E. Kurtz is a Plant Physiologist, Delta Branch Experiment Station, Stoneville, MS.

1990 Results

Nitrogen fertilization rate had no effect on plant height or population. One hundred-fifty and two hundred pounds of nitrogen per acre at planting resulted in kenaf yields of 11,328 and 19,888 lb dm/acre, respectively. This was higher than 0 nitrogen, which yielded 7,612 lb dm/acre. Applications of 50 and 100 lb/acre of nitrogen per acre resulted in yields of 9,657 and 9,724 pounds of kenaf per acre, respectively, which was not different from other nitrogen rates.

Row spacing had no effect on plant height. In 8-inch rows, kenaf yielded 12,170 lb dm/acre compared to 9,593 and 7,764 lb dm/acre for 20- and 40-inch rows, respectively. Kenaf in 8-inch and 20-inch rows had populations of 157,905 and 136,453 plants per acre, respectively. This was more than 40-inch rows with 84,398 plants per acre. The same amount of seed was planted in each plot, which leads to the assumption that attrition in thicker kenaf is higher.

1991 Results

Average kenaf yields ranged from 12,866 lb/acre with 0 nitrogen to 18,173 lb/acre with 150 lb/acre of nitrogen, but because of the wide variability within plots, differences in average yields between nitrogen fertilization rates (Table 2) were not statistically significant. Kenaf fertilized with 150 or 200 lb/acre of nitrogen was taller and had greater stem diameters than that fertilized with 50 lb/acre or less. Kenaf plots fertilized with more 150 lb/acre of nitrogen had lower plant populations than those with 0 nitrogen.

Kenaf planted in 8-inch rows was taller, had a higher plant population, and produced higher yields than kenaf planted in 20- or 40-inch rows (Table 2).

Table 2. Effect of nitrogen rate and row spacing on yield of kenaf, MAFES South Mississippi Branch Station, 1991.

	Row Spacing (inches)			
Nitrogen	8	20	40	Average
		lb/acre		
0	21,360	8,795	8,503	12,866
50	19,475	16,083	12,438	15,999
100	28,899	12,062	11,042	17,334
150	28,899	14,234	11,296	18,173
200	24,501	14,073	12,311	16,962
Mean	24,627A[1]	13,067B	11,118B	

[1] Means within a column followed by the same letter are not different at the (p<.05) level of significance according to DMRT.

The higher plant population may be responsible for the higher yield in the 8-inch rows. There was no interaction between row spacing and nitrogen rate.

1992 Results

Kenaf yields ranged from 21,711 lb/acre with 50 lb/acre N to 30,147 lb/acre with 100 lb/acre N, but yield differences attributable to nitrogen were not statistically significant. There was no difference in final plant height attributable to N rate. Kenaf plots fertilized with 150 lb/acre of nitrogen had lower plant populations.

Kenaf planted in 8-inch rows had a higher plant population and produced higher yields than kenaf planted in 20- or 40-inch rows. The higher plant population may be responsible for higher yield in the 8-inch rows. There was no interaction between row spacing and nitrogen rate.

1993 Results

Kenaf yields ranged from 13,993 lb/A with 0 lb/acre N to 26,368 lb/acre with 200 lb/acre N. Kenaf with 0 nitrogen was significantly shorter than all other treatments but over 50 lb/acre N, there was no difference in height. There was no difference in plant population attributable to nitrogen rates. Stem diameter of kenaf fertilized with 100 lb/acre or more of nitrogen was greater than when no nitrogen was applied.

Kenaf planted in 8-inch rows had greater stem diameters and produced higher yields than kenaf planted in 20- or 40-inch rows (Table 3). There was no difference in plant population or final plant height attributable to row width. There was no interaction between row spacing and nitrogen rate.

Table 3. Effect of nitrogen rate and row spacing on yield of kenaf, MAFES South Mississippi Branch Station, 1993.

	Row Spacing (inches)			
Nitrogen	8	20	40	Average
		lb/acre		
0	24,049	10,786	7,143	13,993C[1]
50	26,964	10,349	12,319	16,544BC
100	25,507	22,301	11,444	19,751AB
150	25,507	14,430	13,776	17,905BC
200	33,888	21,426	15,598	26,368A
Mean	27,183A	15,859B	12,056B	

[1] Means within a column followed by the same letter are not different at the (p<.05) level of significance according to DMRT.

Selection and Breeding of Kenaf for Mississsippi

Brian S. Baldwin

Most kenaf varieties grown in the United States have been developed in tropical regions of the world. Selection and improvement for varieties adapted to the unique growing conditions found in Mississippi have been minimal. Generally, tropical varieties are short-day types (bloom very late in summer). While these varieties tend to remain vegetative over a long period of time at nontropical latitudes (and therefore give maximum yield), they seldom produce seed before frost at temperate locations. Because of variable spring conditions, early spring planting cannot be guaranteed, therefore day-neutral (blooming after a given number of days) or longer short-day (blooming earlier in the summer) varieties would be desirable for Mississippi.

Like its relatives cotton and okra, kenaf's large showy flowers and nectaries attract a number of insects, which pollinate (and cross-pollinate) the flowers. Because of a moderate level of cross-pollination, seed obtained is frequently not true to type. This means that seed labelled as a single variety may contain plants with different leaf shapes, flower color, fiber quality, and date of maturity.

While this variation within a particular variety has caused problems, especially in testing for fiber quality, such variation is a plant breeder's dream. The variation allows plant breeders to pick and choose individual plants that will resist diseases, have stronger fiber, and bloom earlier than the rest of the population. Selection of individual plants from tropical cultivars has enabled Mississippi researchers at Poplarville and Starkville to generate plant lines that will bloom and produce seed in Mississippi. Once these plants are selected, a number of techniques can be used to keep insects from mixing pollen from different plant types. Controlled cross-pollination can then be used to incorporate two or more desirable characteristics into the same plant.

Kenaf seed takes roughly 45 days to ripen in northern Mississippi, making a flowering date of the first week in September necessary to obtain enough viable seed before the frost.

One characteristic that is important, but has little to do with adaptation, is leaf shape. Many cultivars currently used in the United States are of a leaf type that resembles marijuana (*Cannabus sativa*). While kenaf is not related to marijuana, the fact that some cultivars have leaves that look similar has led to occasional problems with local law enforcement officials.

The Mississippi kenaf project is currently selecting and increasing seed of plants that are best adapted to Mississippi's climate and harvesting techniques to maximize yield as well as fiber quality.

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Kenaf has two distinct leaf shapes. The palmatified shape (left) can create a problem because it closely resembles marijuana. The entire-leaf type (right) has leaves more closely resembling those of its relatives, okra and cotton.

Weed Control in Kenaf

Mark E. Kurtz

Moderate yield reductions in kenaf have been reported from weed competition (3, 10) without mention of species. Significant reductions in kenaf yields (75 to 85%) from common cocklebur (*Xanthium strumarium* L.) competition have also been reported (6, 7). Even though several studies have been conducted to evaluate chemical weed control in kenaf (1, 2, 3, 4, 5), information is still quite limited.

Research conducted using herbicides applied prior to emergence of kenaf and weeds demonstrated that trifluralin (Treflan®), chloramben (Amiben®), monuron (Monuron TCA®), diuron (Karmex®), and mecoprop (Vipex®) gave acceptable results in kenaf (1, 2, 3) unlike fluordifen (Preforan®) where kenaf injury was noted (2, 4). The herbicide oxadiazon (Ronstar®) tank-mixed with Karmex was not safe for use in kenaf nor was the high rate of nitrofen (TOK®) or EPTC (Eptam® (4). White et al. (9) reported that propachlor (Ramrod®) was safe for use in kenaf.

There is a need for the evaluation of newer classes of herbicides for use in kenaf. Kurtz and Neill (6) evaluated 14 herbicides registered for use in either cotton, soybeans, or milo for kenaf tolerance. Metribuzin (Sencor®), imazaquin (Scepter®), chlorimuron + metribuzin (Canopy®), atrazine (AAtrex®) and imazethapyr (Pursuit®) all reduced kenaf height below that of untreated kenaf and reduced yield significantly. In light of some of the early research, it is imperative that studies be conducted to elucidate the selectivity of herbicides (currently registered for use in the United States) to kenaf.

Results

Preemergence

An experiment with preemergence herbicides was conducted and the herbicides AAtrex, Canopy, Scepter, Command®, Karmex, Sencor, and Bladex® reduced kenaf population below that of the untreated. The same herbicides, in addition to Zorial® and Cotoran®, all caused kenaf phytotoxicity. However, not all of the treatments that reduced stand or increased phytotoxicity reduced yield.

Cotoran did not reduce stand, did increase phytotoxicity, and did reduce yield. Zorial increased phytotoxicity but didn't decrease stand or yield. Bladex and Scepter increased phytotoxicity and reduced stand but didn't reduce yield. Sonalan®, Pursuit, Prowl®, Dual®, and Lasso® did not reduce stand, increase phytotoxicity, or reduce yield. Sencor, Karmex, Command, Canopy, and AAtrex all increased phytotoxicity, reduced stand, and reduced yield.

How can an herbicide reduce stand and not reduce yield?

Kenaf has an ability to adjust its stalk size to accommodate the area available for its given population. If the population is high, kenaf produces slender stalks. If the population is low, kenaf produces stalks with a larger diameter. This effect will sometimes make up for the weight lost by the death of surrounding plants; however, one cannot depend on this happening in every case. At this point in kenaf research, if data suggest that a given herbicide causes kenaf phytotoxicity and stand reduction, this herbicide should not be considered for use until all aspects of herbicide rate, placement, and timing have been fully investigated. Of the preemergence herbicides tested, those used for grass control seem to be the safest to use in kenaf. However, until these herbicides are registered for use in kenaf in Mississippi, it is **not** legal to use any of these mentioned in this article.

Postemergence

In 1989 and 1990, experiments were conducted to evaluate cotylodonary kenaf tolerance to Bueno-6®, Basagran®, Scepter, Pursuit, Cadre®, Blazer®, Cobra®, Reflex®, Fusilade®, Poast®, Assure®, Select®, Classic®, Ally®, and Oust®. From these studies, only Bueno-6, Fusilade, Poast, Assure, and Select could be used without kenaf injury in both years. This injury was expressed as reduced height and dead tissue (necrosis) both years.

Bueno-6, Basagran, Scepter, Pursuit, Cadre, Blazer, Cobra, Reflex, and Classic were evaluated both years for their effects on 14-inch kenaf. In 1989, at the 7 DAT (days after treatment) rating, all herbicides caused injury. By 16 DAT, kenaf injury persisted for all treatments except Bueno-6 and Basagran. In 1990, only the Bueno-6 treatment was noninjurious at the early rating (8 DAT), but at 34 DAT, neither Bueno-6 or Basagran showed any signs of injury. All treatments, with the exception of Bueno-6, caused height reduction both years.

It is apparent that kenaf tolerates the selective herbicides (Bueno-6, Fusilade, Poast, Assure, and Select) in a similar fashion as other broadleaf crops.

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Basagran, Scepter, Pursuit, Cadre, Blazer, Cobra, Reflex, Classic, Ally and Oust applied broadcast postemergence-over-the-top (POT) are too injurious to be considered for use in kenaf. However, application as post-directed sprays should be considered.

From this work, Bueno-6 and Fusilade have been registered for use in kenaf in Mississippi under 24C special local needs registration.

In 1991, another experiment was conducted to evaluate Poast and Assure II at two rates and three timings. Timings were cotylodonary, 2-leaf kenaf, and two weeks later. Bueno-6 (2.0 lb/A) was applied to 3-inch kenaf over-the-top and separate treatment to 3-inch kenaf followed by another treatment 1-3 weeks later. We also looked at the insecticides Orthene® and Asana XL® on 1-2 leaf kenaf at two rates and then reapplied the treatments every 10 days until five applications were made at each rate. Initially, Bueno-6 caused some blotching but this disappeared rapidly. No treatment reduced stand, height, or yield.

This test led us to feel confident with the application of Poast, Assure II, Orthene, and Asana XL on kenaf. If these chemicals are registered in kenaf there will be a wide margin of safety.

Because of the need for herbicides to control broadleaf weeds in kenaf, we continued our efforts looking at Cobra, Goal®, Karmex, Lorox®, Bladex, Basagran, Scepter, Cadre, and Pursuit. Many of these herbicides have been proven to injure kenaf when applied POT.

Post-Directed

Two experiments were conducted in 1992 to evaluate the previously listed herbicides as post-directed sprays. Each was tank-mixed with Bueno-6 for a broader spectrum of weed control. Results concerning injury were somewhat variable; however, at no time was injury above 26%. At the Delta Branch Experiment Station, only Goal + Bueno-6 caused injury greater than the control.

At Vance, MS, Karmex, Lorox, Bladex, and Scepter all had some form of injury symptoms. Karmex and Bladex showed a whitening effect on the leaves. This was due to the herbicide being taken up from the soil by kenaf roots. These symptoms soon went away. Scepter injury was evidenced as pronounced shortening of kenaf plants and lasted season long. Lorox caused necrosis of leaf tissue preceded by chlorosis. Only Scepter resulted in yield reduction in both tests.

Bueno-6 is registered for use in Mississippi as a post-directed spray.

Cobra, Goal, Bladex, or Basagran each look promising for post-directed use in kenaf.

In 1993, the following herbicides were evaluated as post-directed sprays: Bladex (0.8, 1.06, 1.6 lb ai/A), Blazer (0.375, 0.5, 0.75 lb ai/A), Caparol (0.5, 0.65, 1.0 lb ai/A, Cobra (0.2, 0.26, 0.4 lb ai/A), Cotoran (1.0, 1.33, 2.0 lb ai/A, Karmex (0.6, 0.8, 1.2 lb ai/A), and Reflex (0.375, 0.5, 0.75 lb ai/A). All treatments were mixed with X-77 at 0.25% v/v, and sprays were directed toward the base of 8-inch kenaf. Minor plant injury symptoms were expressed as necrotic lesions on leaves. Yield was not affected.

Herbicide Carryover

Trials were conducted in 1991 and 1992 on a silty clay loam and a Sharkey clay soil to evaluate possible herbicide carryover problems to the kenaf crop. Results are shown in Tables 1 and 2. Zorial, Scepter, Pursuit, Command, Karmex, Cotoran, and Bladex were evaluated on each soil at two rates. Herbicides were applied in a fallowed area in 1991 on the silty clay loam soil and in soybeans on the Sharkey clay. Kenaf was planted in these areas in 1992.

The higher rate of Karmex reduced stand on the silty clay loam and the high rate of Command lowered stands on the Sharkey clay. The high rate of Zorial, Scepter, Pursuit, and Cotoran reduced kenaf height on the Sharkey clay. The high rates of Scepter reduced height on the silty clay loam.

In 1992, Scepter carryover damage was noted in a farmer's field at Vance, MS. Scepter had been used in soybeans the previous growing season. Kenaf emerged and grew to about 8-12 inches tall and stayed there for several weeks without growing. This type of

Table 1. Herbicide carryover in kenaf on a silty clay loam.

		Kenaf (1991-1992)			
Treatment	Rate lb/A	Stand plant/10ft	Phyto %	Height ft	Yield ton/A
Zorial	1.000	55	0	3.08	4.5
Zorial	2.000	53	0	3.35	4.9
Scepter	0.125	57	15	2.90	4.4
Scepter	0.250	45	45	2.20	4.0
Pursuit	0.094	50	21	3.10	4.8
Pursuit	0.188	46	3	2.80	4.9
Command	1.250	59	0	3.28	4.4
Command	2.500	58	0	3.55	5.2
Karmex	1.600	56	0	3.25	4.6
Karmex	3.200	41	0	3.67	5.4
Cotoran	1.500	55	0	3.63	5.3
Cotoran	3.000	55	0	3.65	4.4
Bladex	1.200	62	0	3.32	5.0
Bladex	2.400	54	0	3.08	4.6
Untreated		58	0	3.40	4.4
LSD (.05)[a]		17	22	0.77	1.0

[a] For comparison of any two means within a column.

Table 2. Herbicide carryover in kenaf on a Sharkey clay.

Treatment	Rate lb/A	Kenaf (1991-1992) Stand plant/A	Height ft	Yield
Zorial	1.000	38,224	3.0	1.9
Zorial	2.000	34,140	2.7	1.5
Scepter	0.125	39,531	3.2	2.1
Scepter	0.250	37,407	2.6	1.6
Pursuit	0.094	39,531	2.8	1.9
Pursuit	0.188	34,467	2.7	1.6
Command	1.250	36,427	3.5	3.1
Command	2.500	29,893	3.0	2.9
Karmex	1.600	41,491	3.0	1.6
Karmex	3.200	36,917	2.9	2.1
Cotoran	1.500	45,085	3.2	2.3
Cotoran	3.000	40,021	2.7	1.3
Bladex	1.200	32,997	2.9	2.0
Bladex	2.400	45,901	3.2	2.0
Untreated		46,065	3.4	2.1
LSD (0.05)[a]		17,157	0.7	1.1

[a] For comparison of any two means within a column.

injury is critical because of the early growth potential of kenaf that is lost. When rotating crops, one should be careful not to rotate kenaf into a field that has been treated with Scepter the previous growing season until this problem can be further investigated. No yield reductions occurred on either soil.

Control of Kenaf

Another experiment was set up to look at controlling kenaf when it becomes a weed in a soybean crop. This probably will not be a problem except under the following conditions. (1) If kenaf is planted in one field and unusually heavy rainfall occurs, kenaf seeds can be washed into adjacent fields carried by runoff water. (2) If planters are not cleaned out carefully, kenaf seed can be planted in fields where it is not supposed to be planted. Kenaf seed will probably not survive in the soil to a point of being a problem the following year. However, if kenaf is left standing in the field over winter, seed can be knocked to the ground during a spring harvest and there is a potential for a kenaf weed problem. Seed viability studies need to be conducted to shed more light on this problem.

The following preemergence herbicides were evaluated for kenaf control in soybeans: Canopy, Command, Sencor, Sceptor, and Zorial. When kenaf control was averaged across two soil types and two rating dates, only Canopy, Sencor, and Scepter proved to be effective. Canopy and Sencor treatments will do a good job at the recommended rate according to soil type, but if you feel like you are going to have kenaf as a problem weed, don't cut rates.

Postemergence studies were also conducted evaluating Basagran, Blazer, Classic, Cobra, Pursuit, Reflex, and Scepter at labeled rates for soybeans. Blazer, Reflex, and Cobra were the best treatments on the Sharkey clay followed by Classic, Scepter, and Pursuit. Basagran was the weakest but was the safest of these herbicides in the kenaf tolerance studies. Of the seven chemicals tested, Blazer, Cobra, and Reflex would be the best postemergence chemicals to control kenaf in soybeans.

Several herbicides tested have shown much promise for use in kenaf in a variety of use applications.

However, as we go to print with this article, only Treflan or Trilin are registered for use PPI, and Bueno-6 or Fusilade 2,000 are registered for use postemergence for weed control in kenaf in Mississippi.

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Plant-Parasitic Nematodes – Pests of Kenaf

Gary W. Lawrence

One of the most serious pests associated with kenaf production in Mississippi and practically every country where the crop has been produced is the plant-parasitic nematode. Plant-parasitic nematodes are multicellular, microscopic worm-like animals that feed primarily on the root systems of plants. These animals use a specialized mouth part (a stylet) to puncture the cells of the root and withdraw the cellular contents.

Typically, plant-parasitic nematodes feed either from the outside of the root as an ectoparasite or inside the root tissue as an endoparasite. The ectoparasitic nematodes will damage the plant by feeding on the epidermal root cells. The endoparasitic nematodes will enter the root and establish a permanent residency by altering the plant's physiology. The nematode will induce the plant to produce specialized nurse cells inside enlarged roots or root galls. The nurse cells act as a sink to divert the natural flow of nutrients produced by the plant to the feeding site of the nematode. The reduction in available nutrients for plant growth and development generally results in plants that may appear stunted, have yellow leaves, and have root systems that are galled, inefficient, and reduced in size.

Kenaf is parasitized by a number of species of plant-parasitic nematodes. Early research conducted in Florida identified nine species of nematodes associated with kenaf production. In Mississippi, 13 species of plant-parasitic nematodes are commonly found in the state's soils (Table 1). Six species may have the potential to reduce the growth and development of kenaf.

The root-knot nematodes are the most frequently associated species on kenaf. The southern root-knot nematode is the predominant root-knot species in Mississippi and the southern United States. The nematode is also pathogenic on soybeans and is the primary root-knot species affecting cotton. The nematode has the potential to become a serious problem to kenaf production in Mississippi since both soybean and cotton are widely grown.

The major research emphasis at Mississippi State University has been directed at the southern root-knot nematode. Preliminary research has shown that this nematode will significantly reduce kenaf growth and yield. When nematode numbers are high, plant death may result. In population studies, it was determined that an at-plant population density of 100 nematodes/cm^3 soil would reduce kenaf yield by 32%. If nematode numbers are as high as 500/cm^3 soil, a

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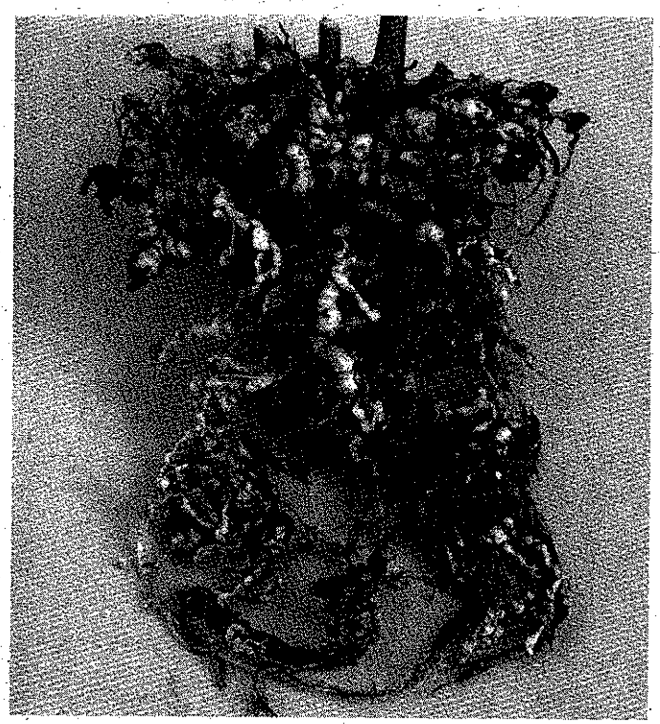
Table 1. Nematodes common to the Mississippi Delta.

Common Name	Scientific Name
*Southern root-knot	*Meloidogyne incognita* (Races 1-4)
*Javanese root-knot	*Meloidogyne javanica*
*Peanut root-knot	*Meloidogyne arenaria*
Stubby root	*Trichodorus* sp.
*Stunt	*Tylenchorhynchus* sp.
Stunt	*Quinisulcius* sp.
Ring	*Criconema* sp.
Spiral	*Helicotylenchus* sp.
Lesion	*Pratylenchus* sp.
Dagger	*Xiphinema* sp.
*Reniform	*Rotylenchulus reniformis*
*Lance	*Hoplolaimus magnistylus*
Soybean cyst	*Heterodera glycines*
Yam	*Scutellonema* sp.

*Nematode species considered to be a potential threat to kenaf.



This root galling on kenaf roots is typical of that resulting from infection by the root-knot nematode.

producer could expect reductions in yield as high as 67%. Therefore, it is recommended that a nematode analysis be conducted on all fields scheduled for use in kenaf production. If the root-knot nematode is present, options for nematode management include resistant varieties, crop rotation and the use of chemical nematicides.

We initiated a study to screen the available kenaf varieties for resistance to the root-knot nematode. Although we have not identified any varieties with resistance, the varieties do vary in the total number of nematodes that are produced. Nematode reproduction has consistently been lower on kenaf varieties Tainung 1 and Tainung 2. A lower nematode population at harvest will result in fewer nematodes the following year.

If kenaf must be grown in a field with a previous history of root-knot infestation, reductions in total yield should be expected. To reduce nematode populations at planting, chemical nematicides have been shown to reduce nematode populations and improve kenaf yields. Currently, the only nematicide that is labeled for use on kenaf is Telone II®.

The use of crop rotations is an effective means of managing root-knot nematode populations. Tests are currently in progress to determine the most economical rotation crop to reduce nematode populations. Both soybeans and cotton are susceptible to the root-knot nematode; therefore, care must be taken when a variety is selected to be included in the rotation.

Although plant-parasitic nematodes have the potential to reduce kenaf growth and yields, kenaf can be successfully cultivated as an alternative crop in Mississippi. This can be accomplished by developing a plan to manage the nematode populations. A knowledge of the nematode species and population numbers prior to planting will allow the kenaf producer to select a management tactic or a combination of tactics that will suit the particular needs at each location. This will ensure the production of a crop that will be profitable to the producer.

Photomicrograph shows the characteristic feeding habit of the root-knot nematode in kenaf roots. The female nematode is the spherical body in the lower center of the photomicrograph. The stylet is penetrating downward into the vascular system of the root; the large shape extending upward is the egg mass, often containing 1,000 or more eggs.

Kenaf Tissue Culture

Nancy A. Reichert

The science of plant tissue culture is based on the concept of totipotency, which is the ability of individual plant cells to grow into complete adult plants. The plant cells do this by responding to "cues" in the tissue culture media, most important of which are the plant growth regulators (PGR's). Other media components include all the nutrients (organic and inorganic) necessary for growth in culture (*in vitro*).

Explant choice (tissue or organ placed in culture) also aids in determination of outcome. If true-to-type plants are desired, shoot tips and axillary buds are usually employed for direct growth and regeneration. If the goal is plant improvement, plants of altered type are desired. Therefore, explants, such as leaf and internodal stem sections, would be utilized in adventitious (indirect) regeneration protocols.

In plant improvement strategies, tissues in culture can be manipulated in various ways, depending on the desired outcome. Regardless of desired end product, the first goal is to develop reliable adventitious regeneration protocols for the plant of interest.

With kenaf, *Hibiscus cannabinus*, our research group at Mississippi State University was the first to regenerate intact kenaf plants *in vitro* (McLean et al., 1992). Internodal stem explants of Tainung 1 were tested on media containing different combinations and concentrations auxins and cytokinins (PGR's).

Within 5 days, callus (growth of undifferentiated cells) formed around the periphery of the explants. Within 30 days, adventitious shoots developed from the callus on various media. The shoots were excised and placed on a different medium for root formation. Intact plants were then transferred to soil for continued growth.

Since the initial research, we have optimized adventitious regeneration protocols for kenaf, starting with internodal stem and leaf sections. We can reliably regenerate three new varieties: Everglades 41 (E41), Guatemala 45 (G45), and G48 (N.A. Reichert and D. Liu, 1994: manuscript in preparation).

In 1993, we field-tested 28 E41 tissue culture regenerants (R_0), and currently are in the process of analyzing their progeny (R_1). In 1994, we will be field testing hundreds of R_0 regenerants from each of these varieties.

Another explant type used in adventitious regeneration protocols are protoplasts, which are plant cells without cell walls. Hydrolytic enzymes (commercially available) are used to digest away the plant cell walls. Typical enzymes used for this purpose are a cellulase (digests cellulose) plus a pectinase (digests away pectins). Generally, millions of protoplasts can be harvested from each gram of leaf tissue (approximately 1/30 oz).

Once cell walls are removed, various manipulations can be performed on these "naked" cells. Manipulations include genetic engineering and cell fusion strategies (discussed below).

We have optimized protoplast isolation and culture protocols for six kenaf varieties (E41, E71, G4, G45, G51, and Tainung 1) and are currently modifying our adventitious regeneration protocols to fit into our protoplast protocol.

With the development of adventitious regeneration protocols, plant tissue culture can be used as a tool for use in crop improvement strategies. Three projects interrelated with kenaf tissue culture, plant breeding, and genetic engineering are briefly described below.

(1) Screen for improved traits resulting from somaclonal variation. Plant cells in tissue culture have mutation rates much higher than the rate that normally occurs in nature. Because of this, plants regenerated from these cells display a higher frequency of new or altered traits. These altered plants arising from culture are called somaclonal variants.

Many researchers have used the somaclonal variation phenomenon in the past to improve other plants. Some altered traits that have been observed include variations in pathogen/disease resistance, leaf shape, growth habit, maturity date and yield (Larkin and Scowcroft, 1981; Evans, 1989). Examples of plants improved in this manner include ornamental, vegetable, and agronomic crops. New carrot, celery, geranium, pepper, and tomato varieties have been developed in this manner.

We have, and will continue to screen our regenerants (R_0 and R_1) for new or altered traits. Superior plants will then be incorporated into the kenaf breeding project at Mississippi State University.

(2) Develop tetraploid kenaf via protoplast fusions (electrofusion) for trait assessment and breeding to related species. Normal kenaf has 36 chromosomes (diploid—two complete sets of chromosomes) in each cell. Protoplast fusions (combining two plant cells into one) are used to increase the total numbers of chromosomes in each cell. Two kenaf cells fused together would create a cell containing 72 chromosomes (tetraploid—four complete sets of

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chromosomes). Plants regenerated from this cell would contain 72 chromosomes in all cells. Tetraploid plants, in general, display more vigorous growth habits than their diploid counterparts.

We would like to perform electrofusions with kenaf protoplasts for two distinct reasons. Since kenaf is harvested for its fiber, we want to determine if tetraploid kenaf can generate greater amounts of fiber per plant. We also would determine any effects on fiber quality.

Tetraploid kenaf would also be incorporated into a breeding program to introduce resistance or tolerance to a devastating plant pathogen. Kenaf is extremely susceptible to root-knot nematode (*Meloidogyne incognita*) damage, which can greatly affect yield. Roselle, *Hibiscus sabdariffa* (tetraploid—72 chromosomes), a species related to kenaf, displays nematode tolerance (no yield reductions). Because of differences in chromosome numbers, sexual crosses between the two species are nearly impossible. With generation of tetraploid kenaf, sexual crosses to roselle should be possible for incorporation of nematode tolerance into kenaf.

We have developed reliable electrofusion protocols for kenaf protoplasts designed to be incorporated into our protoplast isolation and culture protocols for the eventual generation of tetraploid kenaf.

(3) Improve kenaf via genetic engineering. Previous research by others (Banks et al., 1993) proved that kenaf can be genetically engineered. Unfortunately, because of their experimental design, they were unable to regenerate transgenic (engineered) plants. Because of our regeneration protocols, we should be able to genetically engineer kenaf tissues **and** regenerate transgenic kenaf for field growth and analysis. In fact, plant transformation protocols are currently being developed to coincide with our defined regeneration protocols for immediate use once genes are identified for transfer into kenaf.

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Desiccation of Kenaf with Roundup

Mark E. Kurtz, Marty J. Fuller, and John G. Black

One method of harvesting kenaf in Mississippi is to mechanically cut the crop using a forage chopper and blowing chopped stalks into a cotton boll buggy for transfer into a module builder for in-field storage. In Mississippi, however, if harvest is delayed past late October, rainy weather often makes harvesting difficult if not impossible. To build a kenaf module, stalk moisture must be less than 30% or the module will go through a heat generated by microbial action. To avoid these problems, kenaf moisture must be reduced below 30% and harvested before late October.

In 1990 and 1991, Roundup® was evaluated as a preharvest aid in kenaf at 4.0 lb ai/A after kenaf had bloomed. In 1992, Roundup was evaluated at 6.4 lb/A at three timings; prior to first bloom (FB) August 24,1992, 2 weeks after FB (September 9), and 6 weeks after FB (October 6). In 1993, Roundup was evaluated at 6.4 and 3.2 lb ai/A at three timings prior to first bloom (September 2, 20, and October 4,1993). In 1993, kenaf did not bloom before the third application.

In 1990, 1991, and 1992, Agri-Dex® (0.625% v/v was added to all treatments. In 1993, X-77® was added at 1.0% v/v. In 1990, chemicals were applied with a hand-held CO_2-charged sprayer delivering 20 gpa. All other treatments were applied with a tractor-mounted compressed air system at 10 gpa.

In 1990 and 1991, Roundup failed to desiccate kenaf stalks at 1, 2, or 3 weeks after treatment (WAT). At 3 WAT, kenaf stalk moisture was higher in the Roundup treatment than in the untreated. In 1992, kenaf stalk moisture was reduced to 16% 3 WAT when Roundup was applied prior to FB. Kenaf stalk moisture was reduced to 31% and 19% with Roundup applied 2 weeks after FB by 4 and 5 WAT, respectively. Stalk moisture was not reduced at the latest timing. In 1993, when Roundup was applied at the first timing, kenaf stalk moisture was reduced to 18% and 27% with the high and low rate, respectively, by 3 WAT. With the second timing, it took 4 WAT to reduce stalk moisture to 27% and 42% with the high and low rates, respectively; and like 1992, the third timing did not reduce stalk moisture.

These data suggest that timing of Roundup application is very important and the rate of Roundup can be reduced to 3.2 lb ai/A and effectively dessicate kenaf below 30% stalk moisture in 3 weeks, if the chemical is applied prior to first bloom. Additional research is required to elucidate the effects of air temperature at time of application and flowering on kenaf stalk desiccation.

Economic Analysis

Desiccation of the kenaf crop offers the opportunity of a more timely fall harvest when field conditions are generally suitable in late October and early November.

From the middle of November through February, field conditions, or days suitable for field work, are limited to approximately one day per week on sandy soils in the Mississippi Delta. This time period provides little opportunity for harvesting, which can lead to kenaf harvesting activities in March and April.

The March/April timeframe can prove to be disadvantageous because this is a period when farmers would prefer to be focusing on soil preparation practices for the upcoming crop. If kenaf harvest is taking place during this time, delays or late planting of the crop following the kenaf are possible. This would especially be true if the kenaf was followed by cotton, kenaf, milo, or corn.

An economic analysis was conducted to evaluate the effects of alternative desiccation dates on the net returns of kenaf production versus a frost-killed scenario. The data in Table 1 display the assumptions employed.

Table 1. Assumptions used to project net returns from kenaf desiccated at different dates versus frost-killed kenaf.

Desiccation Date	Sep. 2	Sep. 20	Frost killed
Potential Harvest Date[1]	Sep. 23	Oct. 27	Dec. 10
Days Suitable for[2]			
Harvest Prior to Nov. 30	42.65	15.55	0
Direct Cost of Production[3] ($)	166	166	133
Yield (tons/acre)	3.06	4.20	5.0
Returns over Direct Costs ($)	2.19	65.10	141.80

[1] Date at which crop moisture is less than 30 percent.

[2] From "Days Suitable for Field Work" - Mississippi River Delta Cotton Area:, D.A.E. Research Report No. 384, Louisiana State University.

[3] From "Mississippi State Budget Generator," Direct costs are included through the harvesting phase; does not include module tarp or transport.

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For the assumptions employed in this paper, it appears that a significant cost premium is attached to desiccation, especially the early date (September 2). For the September 2 date, a farmer will experience approximately $139 in yield loss and chemical cost, assuming a $55 per ton value for the kenaf. For the September 20 date, the cost premium is approximately $77, utilizing the same assumptions.

A further point that must be noted is the economic feasibility of the desiccation scenarios. For the yields assumed in this work, kenaf production would not be economically feasible if desiccation were employed. However, if yields can be increased to about 5 tons per acre in the September timeframe, desiccation could be a feasible alternative. This may be possible with an earlier planting date or with better growing conditions.

In summary, it appears that the chemical cost and yield loss associated with desiccation are high prices to pay in order to accomplish a fall harvest of kenaf in the Mississippi Delta. Farmers who are growing kenaf will have to carefully formulate a farm plan that incorporates a late harvest of frost-killed kenaf in conjunction with a crop that is planted later, such as soybeans, or evaluate the potential farm program impacts of using this land as idle acres for the following year. As future research developments occur in the plant breeding and agronomic areas that might increase early yields, the potential of desiccation may be worthwhile.

In-field Separation of Kenaf

Lung-Hua Chen and Jonathan W. Pote

There are two disadvantages with forage harvesters currently being used for kenaf.

First, the harvester chops the kenaf into small pieces. The bark or bast fiber must be separated from the core, and the short bast fibers may limit the usage. Second, harvesting normally begins after frost kills the vegetation. Weather often prohibits prompt harvest. This delay in harvesting may affect other field operations the following year. In-field separation is an alternative harvest method that can eliminate these two problems.

It is easy to separate the bark or bast fiber from core by crushing the green kenaf. The separation machine described here is based on a prototype developed by Tainan Fiber Crops Experiment Station in Taiwan in 1975. The schematic diagram (Figure 1) shows the basic principle of the separation.

The whole kenaf stalk is fed into the machine. The first two crusher-rollers crush the stalk, which is then beaten by the beater-roller. This action separates the bast fiber from the core. The stalk is then fed into the third crusher-roller while the core falls downward. The crushing and beating process repeats through the third crusher-roller and the second beater-roller; the last crusher-roller removes the remaining core attached to the bast fiber. The whole-length bast fiber is the end product.

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The crusher-roller consists of a ¾-inch thick 5½-inch OD steel pipe with twelve 1¼-inch by ½-inch steel bars welded to the periphery of the pipe. The beater-roller consists of four 2-inch by ½-inch steel bars supported by four equally-spaced ⅜-inch thick steel plates welded to a 2-inch shaft. The outside diameter of the crusher-roller is 8 inches and that of the beater-roller is 13⅝ inches. With the crusher-roller operating at 267 rpm, the linear speed of the roller is 9.2 feet per second. Therefore, for a 10-foot long kenaf stalk, the separation time takes less than 2 seconds.

The speed of the crusher-roller affects the performance in bast and core separation. Our preliminary test indicates that the roller speed around 288 revolutions per minutes produced the best separation (Figure 2).

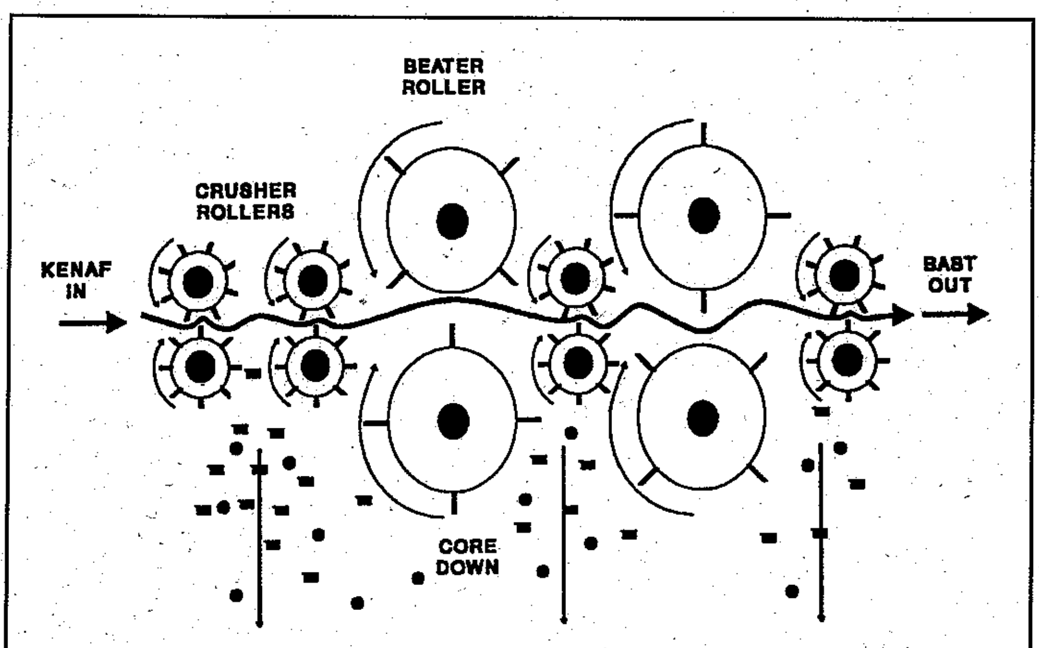

Figure 1. Schematic diagram of separation principle used in the prototype kenaf harvester.

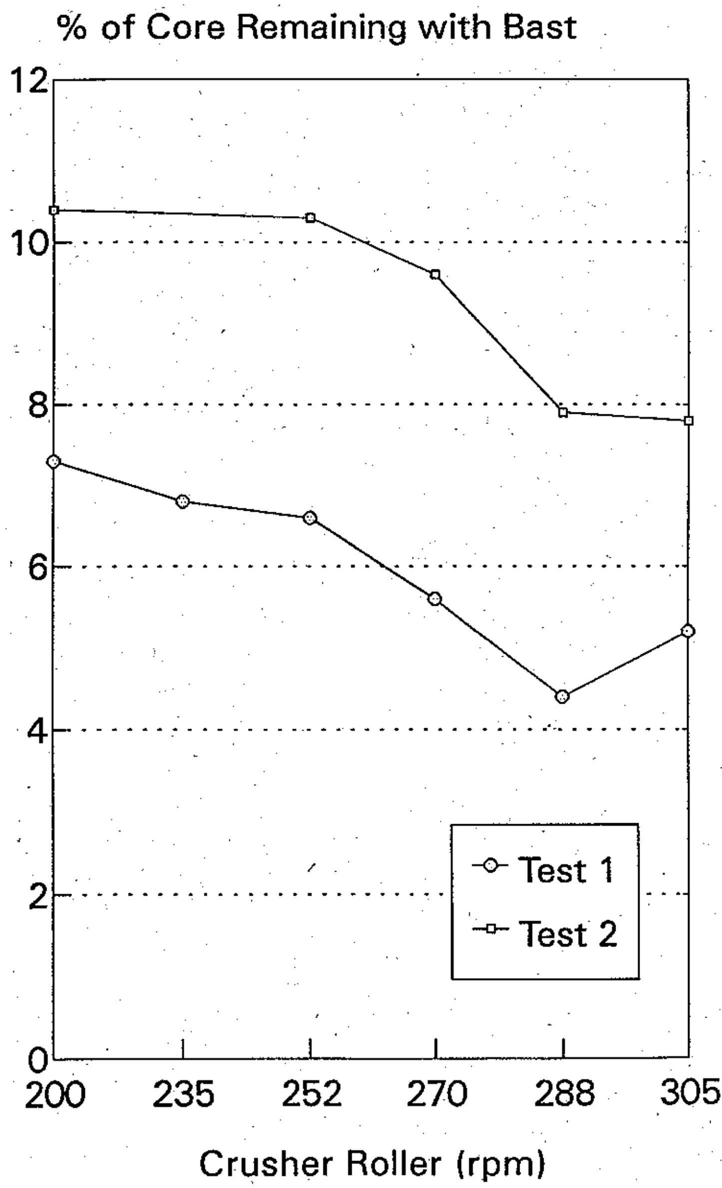

Figure 2. Preliminary tests indicated that a roller speed of about 288 revolutions per minute results in the best separation of kenaf bast fibers from the core.

The crusher-roller did damage the skin of the bast fiber. An Instron test showed that the tensile strength of the machine-separated bast was about 75% of that of the hand-stripped bast. Whether or not the separation process reduced the strength of retted kenaf fiber remains to be tested.

The ease of bast and core separation depends on the moisture content of the kenaf stalk. Green kenaf stalks have a moisture content around 70% wet basis. When the moisture content of kenaf is lower than 50%, the separation of bast from core becomes difficult. Whole stalk kenaf dries down very slowly after harvest. In our tests,it took at least 3 weeks for the kenaf to dry down from 70% to 50% moisture.

Some visualized advantages for in-field separation are:

(1) Because the resulting bast fibers are several feet in length, their use may be broadened.

(2) Bast fibers dry within a day, facilitating storage.

(3) Core can be more easily collected.

In order to fully utilize the machine capacity, it is necessary to have some means to harvest kenaf in large quantities and transport the stalks to a central location for separation. Another approach is to develop a machine that will harvest the kenaf stalk and separate the bast and core in the field just as the combine does for grain crops.

Our effort for the 1993 year was to build a once-over kenaf harvester. A used John Deere grain combine was used as the prime mover and power source. The separation unit was built to fit in the combine. A Kemper head and a feeder house of a forage harvester were attached to the front of the separation unit.

The self-propelled harvester worked satisfactorily most of the time when there was a continuous feeding of the kenaf. Occasionally, the intermittent feeding of kenaf from the Kemper head to the feeder house caused a large bundle of kenaf passing through the separation unit. This caused the breakage of the roller chain or the bearing housing. Further refinements are necessary to achieve a continuous field harvest with this unit.

An Economic Analysis of Kenaf Separation

Marty J. Fuller and Jeff C. Doler

Because of the desirable qualities displayed by the kenaf bark and core, fiber separation is necessary to utilize the full potential of the kenaf plant. Several alternative methods of separation are available.

The general objective of this study was to estimate the costs and returns of kenaf separation for the rotating drum concept marketed by The Lummus Development Corporation. The raw product form necessary for this system is that which has been chopped into short lengths and decorticated.

Methods and Procedures

The synthetic firm approach was used to estimate the capital requirements, annual ownership, and operating costs for the kenaf separation facility. Conventional economic principles were applied to estimate costs at three rates of processing 6, 9, and 12 tons per hour of raw material. Three rates of processing were evaluated because the true performance rate of the system is not known at present, but is expected to fall within the range identified. Utilizing assumed prices for the bark and core output of the kenaf separation facility, net returns were calculated for the three rates of processing.

Processing Plant Scenario

The processing facility evaluated has undergone a few minor modifications such as on-site bale storage and open-air core storage, but otherwise, the facility is arranged according to cotton gin standards. The kenaf fiber is packaged for transport at field-side using conventional cotton module builders, which are typically 8 feet by 32 feet and weigh approximately 6 tons. The modules are transported to the processing facility by a module truck that is equipped with a chain-driven, tilting bed to permit loading of the module. The modules may be processed upon arrival or stored for future use. Stored modules may be moved with yard movers, which function in the same manner as the module trucks but require a tractor for operation.

The modules are received into the processing plant by way of a stationary bed module feeder. The feeder allows modules to be unloaded from the truck or yard mover onto a moving conveyor. The conveyors carry the material through a disperser head, which breaks down the module, allowing the material to be moved by airflow through a dryer and into the separation process.

The material is moved through galvanized ductwork by air where it is discharged into a separation cylinder. The separation cylinder is a large rotating drum with a series of screens and baffles. The bark fiber is the lighter of the two fractions and, therefore, remains within the separation cylinder. The core material falls through openings in the screens onto a belt conveyor and is deposited into another system of galvanized ductwork for movement to core storage.

The bark fiber is discharged from the separation cylinder by gravity and moved by air to the hydraulic press for baling and weighing. The press, a universal density model common to the cotton industry, produces a bale measuring 21 inches by 54 inches with a bulk density of approximately 28 pounds per cubic foot. The baled bark can be stored on site in the bark warehouse or delivered to buyers. The bark warehouse is capable of storing up to one month of production and is based on cotton bale storage standards with appropriate fire and safety precautions.

Investment Costs

Estimated investment requirements for the synthesized facility totaled $1,983,101. The module feeder, separation unit, and bale press comprised a major portion of total investment, representing almost 56% of investment. Land, buildings, and improvements totaled approximately $404,000, or about 20% of total investment. The module truck was the next greatest cost item at $250,000 or 12.61% of total investment. No other single item accounted for more than approximately 2% of total investment.

Annual Ownership Costs

Annual ownership costs are incurred regardless of whether the facility operates or not. Those items representing ownership costs include depreciation, interest on investment, taxes, and insurance. Depreciation was calculated using the straight-line method assuming a zero salvage value. Interest on investment was charged at a rate of 9% on one-half of investment

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for all depreciable items and 8% on the full value of land. Insurance estimates were provided by a firm that underwrites the separation facility owned by Mississippi Delta Fiber Co-op (A.A.L.).

The standard assessment for property tax in Mississippi is based on 15% of the appraised value of land, buildings, equipment, and inventory on January 1 of each year. The appraised value of land was assumed to be original cost and the appraised value of buildings and equipment was assumed to be average investment. The millage rate, 85.21, was an average rate used in Tallahatchie County, Mississippi. Estimated annual ownership costs totaled $258,980.

Annual Operating Costs

Annual operating costs, also referred to as variable costs, may be defined as the cost of operating the facility. The variable resources include labor, utilities, repairs and maintenance, supplies, general office overhead, and interest on operating capital.

Labor requirements were based on the level of output. The wage rate was assumed to be $5.25 per hour, which included fringe benefits at 15%. Salaried labor included fringe benefits assumed at 20%. Total labor costs varied according to the rate of output.

Electricity requirements for the facility were estimated based on an assumed efficiency of 60%. The water requirements for the facility are minimal, with the two uses being normal household type use in the office building, and, in the case of fire, in the processing area. For these conditions, it was assumed that monthly water consumption would be 3,000 gallons.

The telephone requirements and costs were estimated based on the number of salaried personnel and the average call duration. For the assumptions employed, it was estimated that monthly telephone charges would average $360.

Repairs and maintenance for the facility were calculated based on estimates of average repairs over the useful life of the equipment, expressed as a percentage of initial investment. Estimated life and estimated repairs and maintenance were based on manufacturers' specifications, dealer estimates, and personal interviews with gin engineers.

Supplies and services include parts, bale bagging, bale ties (both wire and rope), fuel and lubricants, general office overhead, and miscellaneous supplies. Spare parts for the separation facility are a major portion of supplies and services. However, the stock of parts must be maintained to minimize down time.

Interest on operating capital was estimated assuming an annual rate of 9%. It was further assumed that operating capital would be necessary on a quarterly basis, or the time period required for inventory turnover.

Total Annual Cost

Total annual cost for the kenaf separation facility operating at 6, 9, and 12 tons per hour was $726,496, $762,043, and $797,591, respectively. As would be expected, annual ownership costs represented a smaller percentage of total annual cost as processing rate increased, ranging from 35.6% at 6 tons per hour to 32.5% at 12 tons per hour.

Labor cost represented the single largest component of total annual cost. Estimated labor costs were $223,000, $233,500, and $244,000 for the 6, 9, and 12 tons per hour processing rates, respectively.

On a per unit basis, annual cost of processing based on incoming raw material was $75.68 per ton at 6 tons per hour, $52.92 per ton at 9 tons per hour, and $41.54 per ton at 12 tons per hour. Estimates of costs based solely on output of bark fiber were $227.02, $158.76, and $124.62 per ton at 6, 9, and 12 tons per hour, respectively.

Estimated Net Returns

To analyze the potential profitability of the synthesized facility at the alternative processing rates, total returns were estimated assuming a bark price of $250 per ton and a core price of $40 per ton. A raw material price of $56 per ton was also assumed.

Analysis of the estimated net returns reveals that a processing rate of 9 tons per hour or greater must be maintained to cover total annual costs. All levels of processing above 9 tons per hour appear to be economically feasible based on the asusmptions of this study. However, the 6 tons per hour rate does not prove to be an economically feasible alternative.

Conclusions

The major conclusion that can be drawn from this study is that the processing or performance rate is critical to the economic feasibility of the described system. As soon as adjustments in the process are made and an actual performance rate is proven, much can be determined as to feasibility.

Another important factor that should be noted pertains to the assumed prices of the bark and core material. Obviously, any changes in this price structure can have a significant impact on profitability.

A more thorough and complete analysis can be found in "An Economic and Cash Flow Analysis of Kenaf Separation," an unpublished M.S. Thesis by Jeff C. Doler, Department of Agricultural Economics, Mississippi State University.

The Use of Kenaf as Bedding for Horses and Laboratory Animals

Roy Watkins

Two separate studies were conducted at the Mississippi State University College of Veterinary Medicine to determine the potential use of kenaf as animal bedding.

For a 2-week period, two horse stalls were bedded using kenaf. Daily observations were made from the time the stalls were chosen. General observations concluded that absorption was excellent. The kenaf produced less dust than softwood shavings produced. For this reason, kenaf was determined to make an excellent large animal bedding.

The second trial involved using kenaf that had been hammermilled to approximately 3/8-inch cubes to be used as a bedding for rodents. In conjunction with this trial, a sample of kenaf was sent to the State Chemical Laboratory for analysis. No residual chemicals were found in this sample.

The laboratory animal trials were done in two stages. First, one group consisting of six animals was bedded on kenaf. The animals were observed for 2 weeks for any adverse reactions. The animals did not seem to consume any significant amount of the bedding, which was a concern because of the protein content of kenaf. After this, approximately 40 cages of mice and rats were housed on kenaf bedding for a total of one month. As with the horse bedding, dust was low and absorption high.

Overall, according to the trials we have conducted, kenaf is a high-performance animal bedding material. Further testing would determine ammonia levels within the cage. Based on the findings, cage changes could be done less frequently leading to substantial savings. If the ammonia studies prove that cage changes can be done half as often, a large potential market would exist for laboratory animal bedding.

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Kenaf can be utilized as a high-performance bedding for animals. It has excellent absorption and produces less dust than commonly-used wood shavings.

Kenaf for Broiler Litter

J.D. Brake, M.J. Fuller, C.R. Boyle,
D.E. Link, E.D. Peebles, and M.A. Latour

Pine shavings and sawdust (PS) is probably the most popular broiler litter material in use. It is considered the benchmark by which all other prospective litter materials are compared. However, the growing scarcity of pine byproducts because of their use in particle board manufacture necessitates the search for alternative litter materials.

Some byproducts that are suitable as litter materials are not always economically available to the poultry industry because of transportation costs. Therefore, kenaf presents the opportunity for poultry producers to raise their own litter in their "backyard." Two successive broiler growout trials were conducted to evaluate PS, kenaf core (KC), and whole chopped kenaf (WCK). The KC was the spongy center portion of the kenaf plant. This material contained very little of the fibrous bark material. The WCK was the whole kenaf plant that had been cut and processed through a silage chopper.

In Trial 1, each litter material was placed into 12 experimental broiler growout pens at a depth of approximately 10 cm (4 inches). Broilers were reared to 42 days of age according to industry standards. Litter samples were taken at 1, 21, and 42 days during growout to evaluate litter moisture, nitrogen, pH, and ash content. Body weight and feed conversion were determined for all broilers at 42 days of age. Carcass grade was determined at 43 days of age during processing. Litter caking was scored after all broilers were processed.

As expected, litter moisture (M), nitrogen (N), pH, and ash content increased in all litter materials during Trial 1. This was due mainly to the accumulation of manure as the broilers grew. The PS exhibited lower moisture, nitrogen, pH, and ash contents throughout Trial 1 than did the kenaf products. The PS was approximately twice as dense as the kenaf products. Therefore, the differences observed in the chemistry of the litter material thoughout Trial 1 were probably due to a weight dilution effect.

Litter caking mirrored these results. The PS exhibited significantly less caking then the kenaf products. The WCK exhibited the worst caking because of the fibrous bark, which acted to form a mat with manure. This characteristic was undesirable. However, the differences that we noted in the physical and chemical properties of the litter materials did not significantly influence broiler body weight, feed conversion, or carcass grade.

All litter was turned and mixed prior to Trial 2 in an effort to break up the cake that formed in Trial 1. The pens containing KC and WCK were top-dressed in an attempt to attain equivalent litter weights in each pen. All other procedures were conducted as in Trial 1. The chemical differences between litter materials that were noted in Trial 1 were not as evident in Trial 2. However, WCK still exhibited the highest caking values at the end of the trial. Broiler body weight, feed conversion, and carcass grade were not affected by litter type.

In conclusion, the chemical differences between litter materials in Trial 1 were due to the dilution effect of the denser PS. When litter weights were equilibrated in Trial 2, the differences were not as apparent. Broiler performance was not affected by litter material in either trial. However, the caking that occurred in the WCK pens was a major concern. The form in which WCK was used in these trials caused several handling problems. These characteristics make WCK undesirable for use in an industry setting.

If a process for on-farm kenaf harvesting could be perfected where bark and core could be separated, poultry farmers could foreseeably grow their own litter material and produce a sellable fiber. Considering the size and density of the poultry industry, the fiber could be produced in quantities that may justify a fiber market in poultry producing areas.

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The Evaluation of Kenaf as an Oil Sorbent

Catherine E. Goforth

Research has determined that kenaf plant fines, milled fines, and milled core have exceptional absorption properties. For this reason, kenaf may possibly be used as oil sorbents in industrial socks, pillows, booms, or floor sweeps.

Researchers at the Milsaps Sorbent and Environmental Laboratory in Jackson, Mississippi, compared the absorption performances of kitty litter, peat moss, and various types of polypropylene fabrics to kenaf materials. To determine the level of sorbency, these materials were tested in diesel fuel, light-weight crude petroleum, and heavy-duty crude petroleum.

The results indicate that the most efficient kenaf materials are the kenaf plant fines, which are essentially the particles from the separation process, and milled fines, which are the core that has been hammermilled. The two polypropylene fabrics used in this study had the highest sorption rates of the materials tested. However, in the light crude test, the sorbency of the kenaf plant fines (11.98 g) was greater than the poorer polypropylene fabric (9.81 g) and is within the same range as the better polypropylene fabric (16.61 g). This is an important discovery since polypropylene has become a standard in industrial situations. The kenaf plant fines performed better than all other kenaf materials in the diesel, light crude, and heavy crude tests (Tables 1, 2, and 3). Both the kenaf plant fines and milled fines performed better than peat moss and kitty litter in all tests. The greatest difference was found in the light crude test (Table 2).

Kenaf plant fines consist of pores that not only sorb oil but also prevent the oil from leaking after absorption. This property will be very important to industries because of great concerns regarding waste minimization in industrial settings.

Milled core kenaf was compared to extruded kenaf. The milled core was determined to perform better than extruded kenaf in all three tests (Tables 1, 2, and 3). Extruded kenaf does not sorb as well as other kenaf materials because of reduced porosity. The extrusion process compacts the pores; therefore, the pores are unable to sorb oil easily.

The results of the study conclude that kenaf plant fines and kenaf milled fines are excellent sorbent materials, both of which are comparable to sorbent materials that are currently used in industrial settings. Also, milled core is very comparable to currently used floor sweep products.

Kenaf shows definite potential for use in socks, booms, and pillows because of its absorption and retention properties. These properties will be beneficial in helping to manage the handling of industrial waste.

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Reference

Millsaps Sorbent and Environmental Laboratory. Research Report: Kenaf Project, Mississippi State University. December 30, 1992.

Table 1. Comparison of sorbents in #2 Diesel.

Product	Medium adsorbed per gram of sorbent
Milled Core 1	2.11 g
Milled Core 2	4.39 g
Milled Fines	5.54 g
Fines	7.02 g
Screened Ext. Core	.77 g
Screened Ext. Fines	1.82 g
Peat Moss	3.50 g
Kitty Litter	.44 g
Polypropylene +	13.16 g
Polypropylene –	9.22 g

Table 2. Comparison of sorbents in T-102 Light Crude.

Product	Medium adsorbed per gram of sorbent
Milled Core 1	2.44 g
Milled Core 2	5.87 g
Milled Fines	6.92 g
Fines	11.98 g
Screened Ext. Core	1.08 g
Screened Ext. Fines	2.23 g
Peat Moss	3.48 g
Kitty Litter	.451 g
Polypropylene +	16.61 g
Polypropylene –	9.81 g

Table 3. Comparison of sorbents in T-201 Heavy Crude.

Product	Medium adsorbed per gram of sorbent
Milled Core 1	1.87 g
Milled Core 2	2.90 g
Milled Fines	1.64 g
Fines	5.00 g
Screened Ext. Core	1.50 g
Screened Ext. Fines	1.19 g
Peat Moss	1.23 g
Kitty Litter	.312 g
Polypropylene +	15.21 g
Polypropylene –	9.81 g

Kenaf Core as an Enhancer of Bioremediation

A. Borazjani and Susan Diehl

The wood treatment industries have been in operation in the United States for more than 100 years. Two of the more potent and most commonly used wood preservatives are pentachlorophenol (PCP) and creosote. These preservatives are used to treat wood products such as crossties, utility poles, marine piles, and structural lumber.

Before federal and state laws regulated the use of these preservatives, misuse in the handling, accidental spillage, and improper disposal of creosote and PCP led to large areas of contaminated soils and water. Industrial sites contaminated by past use of PCP and creosote are being cleaned up by nature's own bacteria and fungi.

Research by the Environmental Biotechnology Group of the Mississippi Forest Products Laboratory (MFPL) is identifying microorganisms and methods of carrying out this process, which is called bioremediation. During this process, contaminants (such as PCP, creosote, and petroleum products) can be converted to harmless byproducts (such as carbon dioxide and water). Bioremediation is far less expensive when compared to other cleanup methods, and it does not require transport of hazardous wastes through cities and communities. The soil itself is not destroyed, and, unlike incineration, bioremediation does not produce hazardous ashes. Bioremediation has been approved by the Environmental Protection Agency (EPA) as the cleanup method for more than 20 abandoned wood-treatment facilities.

One problem encountered when using bioremediation on contaminated soil is the soil environment often does not encourage the bacteria and fungi to degrade the pollutants. Pollutants often absorb to soil particles in such a way that the microorganisms cannot come in contact with them. This makes the pollutants unavailable for breakdown. Other environmental factors that greatly influence breakdown rates include temperature, oxygen, nutrient availability, pH, moisture content, light intensity, and organic matter. Many of these environmental factors can be controlled

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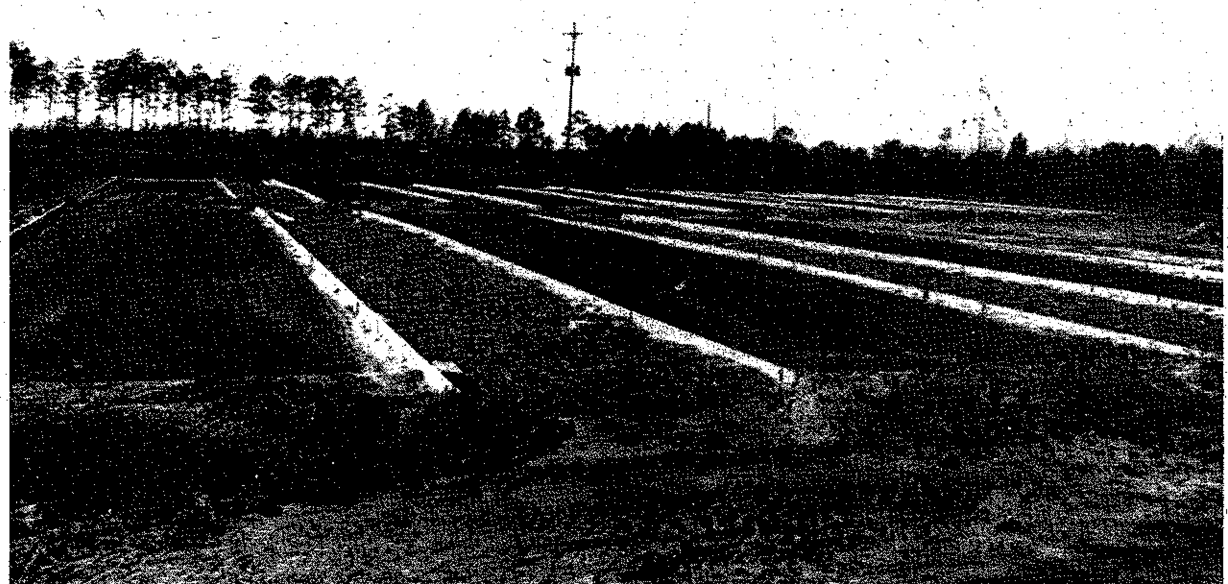

Because of its absorbency, kenaf core is being tested to enhance bioremediation of contaminated soil in land-farming experiments. This process uses conventional soil management techniques to enhance degradation of pollutants by soil microorganisms.

by a process called land-farming. Land-farming is the treatment of contaminated soil using conventional soil management techniques such as tilling, irrigation, and fertilization to enhance microbial degradation of pollutants.

Researchers at the MFPL have been looking at different ways to speed bioremediation of contaminated soil by altering the soil environment. One way to alter the soil environment, and hopefully enhance pollutant breakdown, is through the addition of organic matter. Kenaf has been shown to have an excellent ability to absorb oil, equal to the best synthetic organic products. Kenaf fines also contain many pores, which will not only absorb the oil but also allow for less leakage or release of oil once absorbed. These pores will also allow much greater contact between the oil and the microorganisms. Kenaf is also biodegradable, is high in protein, and contains very large numbers of natural microorganisms.

Preliminary studies at the MFPL have found that kenaf absorbed more than 55% of the oil from oil-contaminated soil. Removal of pollutants from soil particles by the kenaf should make the pollutants more available to the microorganisms, thus enhancing pollutant breakdown. In addition, the leaching potential of kenaf appears to be low, with only 0.02% of the oil leaching from contaminated kenaf. This means that, once the pollutant is absorbed to the kenaf, only a very small amount will leach from the kenaf into the groundwater.

Microorganisms native to kenaf were able to biodegrade 55% of the oil from contaminated kenaf. Thus, the kenaf itself may provide more microorganisms to assist in the bioremediation. We believe that kenaf has a great potential as an effective enhancer of bioremediation of organic wood-treating wastes because of its biodegradability, excellent sorbency, cost, size, and environmental friendliness. Because of these capabilities, researchers at the MFPL are exploring the use of kenaf to enhance microbial degradation of soil contaminated with PCP and creosote.

Kenaf Core as a Board Raw Material

Terry Sellers, Jr., George D. Miller, and Marty J. Fuller

In the United States, more than 60% of all timber harvested is manufactured into pulp and paper products (1). Increasing costs and decreasing quantities of desired species have led to some pulp fiber importation into the United States. For example, the United States now imports more than 50% of its newsprint paper stock, particularly from Canada (5). Kenaf fiber has been suggested as a supplemental fiber source for newsprint pulp as well as a potential raw material for board manufacture (2, 4, 6).

As a raw material in test runs by several newspapers, the whole-stalk kenaf fiber is reportedly as sturdy as wood pulp paper, but is generally brighter, requires less ink and has less ink rub-off (2). More recently, it was determined that separation of the bast and core fractions would be necessary for kenaf to become commercially viable as wood pulp (3). This separation allows the development of markets, primarily specialty pulp, which was not possible with the unseparated product. As a result of the separation process, a considerable amount of core material is generated.

The objective of this work was to evaluate kenaf core material in low-density composites. Such use in a value-added product would also enhance the overall success of kenaf as a viable agricultural crop.

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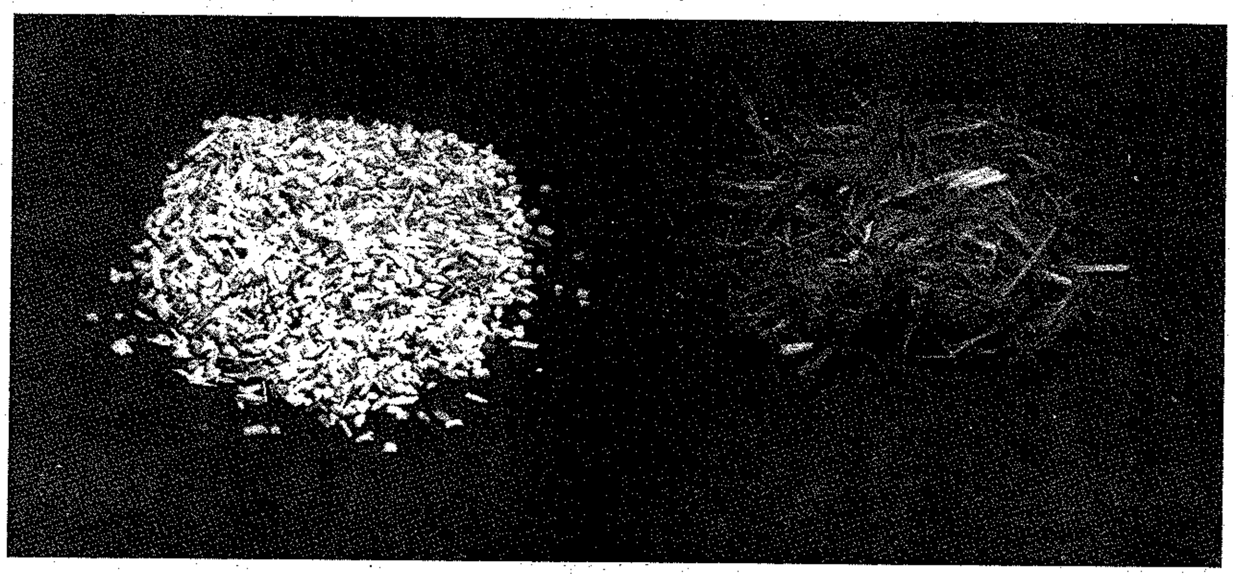
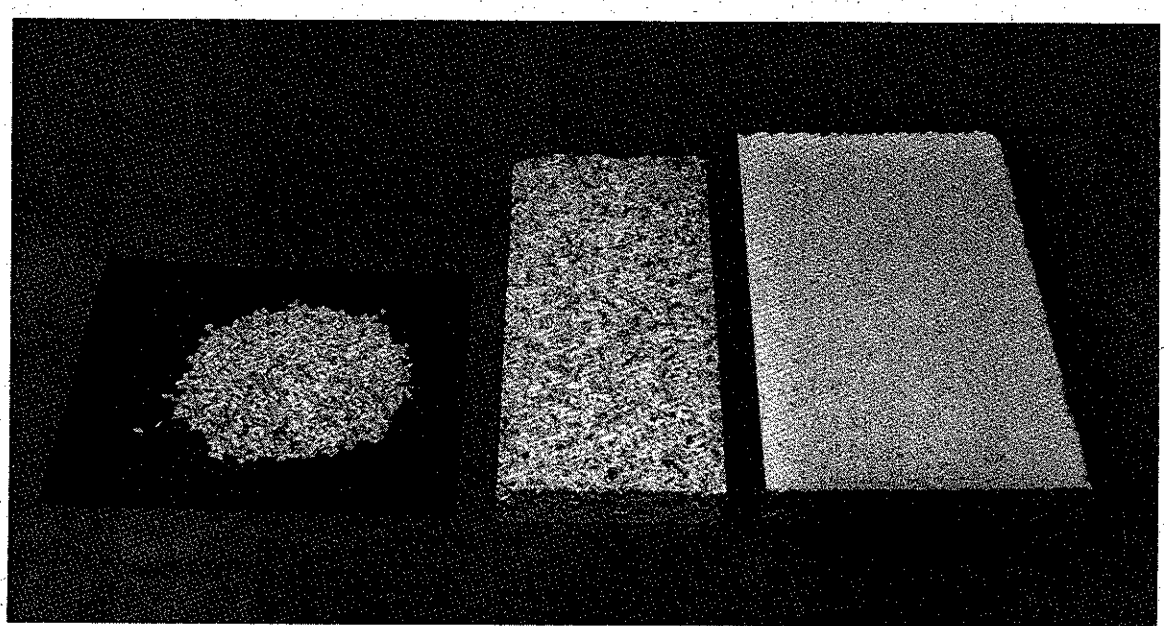
Kenaf core material was secured, dried, and made into 16-lb/ft^3 panels. No problems in processing (adhesive application, felting, or pressing) were encountered. Panels were made at two press times (7.4 and 5.7 minutes) for comparison. The assembly time (time from resin application to panel full hot-press pressure) was 20 to 30 minutes. Two panels per press cycle were made for a total of four. Two boards, one from each press cycle, were cut into specimens suitable for testing strength properties, dimensional stability, and water absorption properties and acoustical properties. One panel (long press-time type) held in reserve as a display panel was later tested for compression strength and modulus of elasticity.

The panel internal bonds were stronger in the panel with the longer press time. Such results sometimes indicate improved resin curing with longer press cycles. For a panel of this density, the internal bonds were apparently quite good.

The water absorption after a 2-hour soaking was about 120% and after a 24-hour soaking, nearly 250% for the panel with the longer press time. Water absorption by the panel pressed at the short press cycle was greater. The water absorption after 2 hours was 220% and water absorption after 24 hours was 325%.



New products are being developed from different parts of the kenaf plant, including core particles (left) and kenaf bast or bark fibers (right).



Kenaf core particles (left) have proven excellent raw materials for manufacture of low-density insulation board panels similar to acoustic ceiling tiles. An unpainted panel is in the center, a painted paned is on the right.

The kenaf core appears to be a potential raw material for low-density panels suitable for sound absorption type products. More research is needed for definitive judgments on its efficacy for construction panels and other uses. Further work is needed to explore blends of the core and bast fibers for these interior-type products. Since some insulation/acoustical tiles are made with cold press curing, work is needed to explore the use of kenaf in these processes.

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Kenaf Core as a Container Media Component for Woody Landscape Plants and Greenhouse Bedding Plants

Adolph J. Laiche, Jr. and Steven E. Newman

The selection of media components to successfully produce plants in containers is based upon freedom from soil pests and harmful chemicals, cost, shipping weight, availability, water-holding capacity, cation exchange capacity, and pH. Current organic and inorganic materials used to formulate container plant growth media include pine bark, peat moss, composted rice hulls, sawdust, mushroom compost, sand, vermiculite, and perlite (Bunt, 1984; Nelson, 1991; Whitcomb, 1984).

Studies were conducted at the South Mississippi Branch Experiment Station and at Mississippi State University to evaluate the potential use of kenaf core as a substitute for pine bark for producing woody landscape plants and as a substitute for vermiculite in peat moss-based plant growth media for growing bedding plants.

Excellent growth of *Ilex* 'Cherokee' and azalea 'Wakaebisu' was obtained when kenaf core was used as an organic component of container media. Growth of plants in media containing kenaf, especially with composted kenaf, compared very favorably with the growth of plants in pine bark, the most commonly used organic component to grow woody landscape plants in containers.

Results after only one growing season indicate that composting kenaf is beneficial for plant growth and may produce a more stable media. Plants grown in composted kenaf were slightly larger, weighed more, and had better root systems than plants grown in kenaf not composted. Plants grown in composted kenaf were similar in size and weight compared to plants grown in pine bark. Better root systems were obtained with pine bark compared to composted kenaf, however. Poorest root systems were obtained with the kenaf medium that was not composted. Growth of plants of azalea 'Wakaebisu' grown in pine bark, kenaf that was not composted, and kenaf that was composted were only slightly different in height, width, fresh weight, and root ratings.

Crops that are grown over one or more years to produce marketable plants require the use of organic components that are relatively stable and do not decompose at an excessive rate. Composting kenaf for periods of time longer than 3 months, as was used in this study, is needed to further explore composting as a possible method to improve the stability of kenaf core.

Preliminary results using kenaf core of several particle sizes, with and without short-term composting, at four dolomitic limestone rates and two rates of complete fertilizers, indicate that kenaf core can be used as a growth medium component to produce woody landscape plants in containers.

Additional nutrition and composting studies with kenaf core are needed on a wide assortment of varieties of woody ornamental plants to determine the reliablity of this material for or use in growth media for the nursery industry.

Plugs of *Celosia argentea* (celosia), *Viola x wittrockiana* (pansy), and *Impatiens wallerana* (impatiens) were transplanted into 10-cm pots containing five different peat moss-based media modified with core of kenaf and/or vermiculite. The maximum height, width, shoot weight, and root weight for all three bedding plant species were found in the media containing no kenaf. The pH increased linearly as the proportion of kenaf increased in the media.

Freshly-milled core of kenaf will not replace vermiculite in peatlite medium. Plants were stunted and chlorotic, indicating traditional nitrogen deprivation in spite of the fertility regime. In its raw form, kenaf core apparently does not have a satisfactory carbon:nitrogen ratio for plant growth; therefore, prior to its use as an amendment, it must be composted.

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Kenaf as a Textile Fiber: Processing, Fiber Quality, and Product Development

Gita N. Ramaswamy and Catherine R. Boyd

Kenaf is a bast fiber crop that has been used for a long time as cordage, ropes, etc. in other countries. Studies with kenaf in the United States have been mostly concerned with production. While some of the research of the 1970's and 1980's related to use of kenaf in newsprint, the commercialization of kenaf into various products has become the main focus in more recent projects, especially since 1986.

The possibility of extracting fibers from kenaf was investigated using established retting methods. The kenaf stalk, when decorticated, offers the opportunity to extract fibers that may be used in various textile end-products. The fiber extraction process affects fiber properties that are important for the making of textiles, both woven and nonwoven structures. Fibers can be extracted by either bacterial or chemical retting processes.

Bacterial retting experiments were conducted with decorticated stalks being placed in water at room temperature. Staggered retting was done with the bases of stalks being immersed initially and then the whole stalks. This method was used to prevent overretting of the upper stalk portion. Following the retting, which can take from 7 to 10 days, stalks were washed in hot water to remove the remaining green residue. Air drying and brushing or combing were done as final steps in obtaining the fiber.

Chemical retting was done using an established procedure with some modification to suit kenaf processing. The decorticated stalks were boiled for one hour in a weak alkali solution. Fibers were washed in hot water upon removal and then immediately neutralized. The material was then washed in hot water again. Air drying was followed by combing to obtain the fibers.

Although the natural retting process is lengthy, the resulting fibers have many desirable characteristics. The chemical retting process is quick but affects several properties, including a loss in tenacity, color, and luster when compared to the bacterially-retted fibers. It was found that the retting time could be reduced by a combination of the methods without affecting fiber quality.

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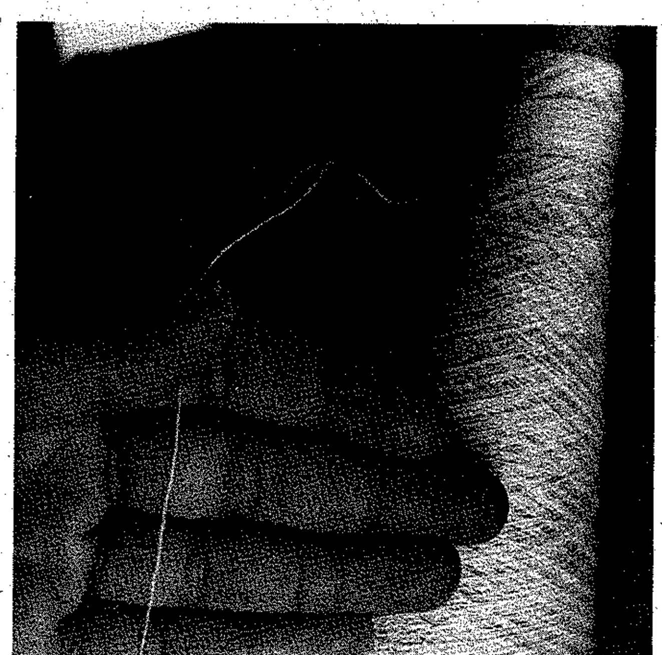
Data were collected on the following characteristics to examine differences in the fibers extracted by the two retting methods: reed length, bundle-breaking tenacity, elongation at break, color, luster, and residual gum content. Comparisons were also made to determine if varietal differences affected fiber characteristics.

Reed length is the total length from base to tip of the decorticated kenaf stalk before and after processing. This criteria may be important for fiber yield, and when intended use is for products such as ropes and cordage.

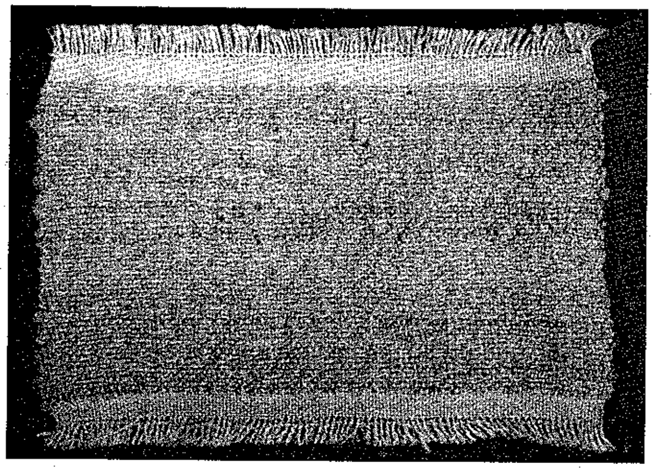
Bundle-breaking tenacity is defined as the load required to break a fiber bundle of fixed length and weight. The flat bundle method is believed to be a good indicator of yarn strength and has a high correlation to yarn quality index.

Elongation at break is the amount of stretch of a fiber bundle at break and it is an important measure to indicate the ability to stretch.

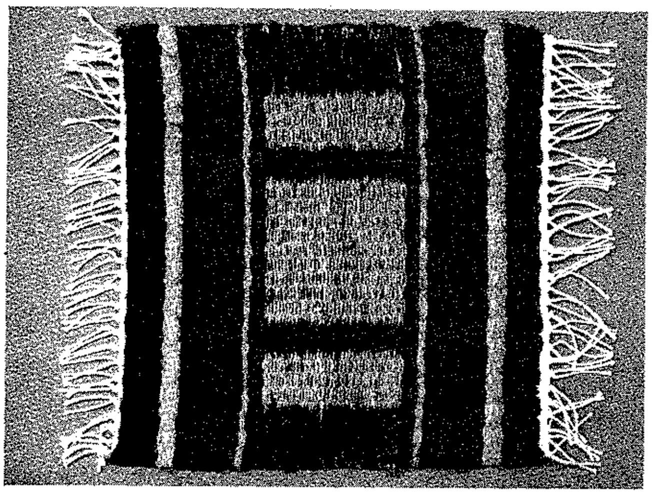
Color and luster are important properties, depend-



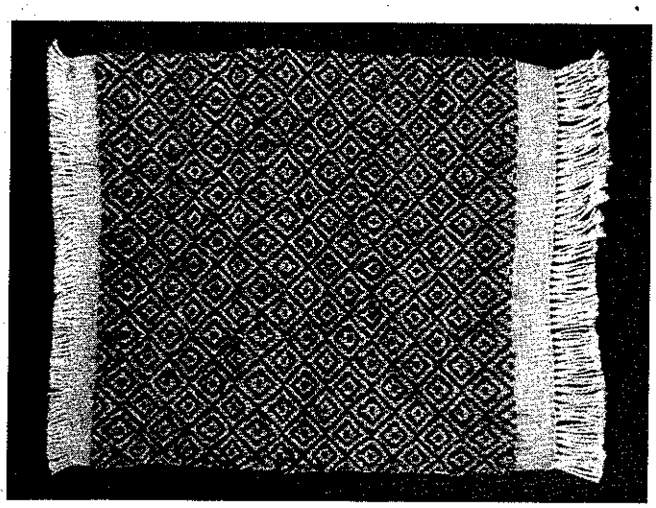
Kenaf fibers were processed and used to make a 20% kenaf/80% cotton blend yarn for use in woven textile products.



A jacket-weight fabric was handwoven with kenaf in the weft (filling) and cotton in the warp.



Cotton and kenaf fibers were handspun and then handwoven into a rug.



A placemat was handwoven with kenaf in the weft (filling) and cotton/linen in the warp.

ing on the fiber end use; luster has a positive correlation with strength.

Gum content refers to the total wax, oil, lignin, and other hemicellulosic material. Residual gum content, the amount of gum left after processing, affects the fineness of fibers, which ultimately determines the success of using these fibers in a fine, woven textile structure.

The fiber processing and characterization research has significant implications. It establishes criteria for selection and improvement of kenaf varieties for breeders and growers because breeders usually need to establish quality with a single plant.

Bundle-breaking tenacity as a measure of fiber quality would provide quick, accurate results depending on linear density of the bundle. It establishes the possibility of extracting fibers for large scale production of fibers.

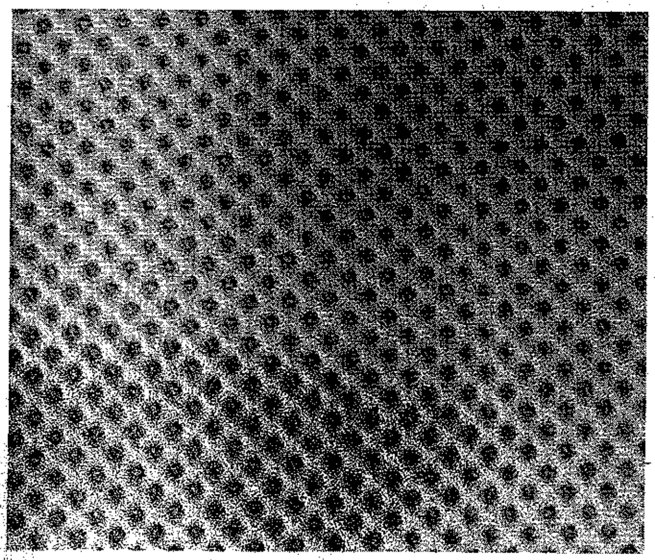
Modified bacterial retting is recommended as it produces fibers with better characteristics; time required for bacterial retting can be reduced by natural and synthetic activators.

The fiber characteristics indicate the feasibility of incorporating the retted fibers into nonwoven structures that have multiple end uses, such as in erosion mats, tea bags, pillow covers, mattress liners, etc. The trials with fiber processing are being done to reduce the residual gum content, which will enable extraction of finer quality fibers that may be incorporated into blended woven fabrics for domestic and apparel use.

Studies were also undertaken to evaluate the effect of residual gum on the quality of fibers extracted from the base to the tip of the plant. Fiber uniformity was studied using fiber characteristics and scanning electron microscopy (SEM). Since fiber quality also depends on the molecular structure, the effect of gum on crystallinity of fibers, extracted by the two methods was also evaluated.

The three textile product lines of interest to the researchers are (1) nonwovens for uses such as medical and chemical protection, furniture underlays, linings, and interlinings; (2) wovens for apparel, domestic, and medical uses (wound dressings); and (3) hand spun and woven yarns for use in rugs, placemats, and decorative items.

To make the textile products, fibers were processed, degummed, combed, and sometimes softened. The fibers for nonwoven products were taken to TANDEC (Textiles and Nonwoven Development Center) Knoxville, Tennessee where preliminary trials were done to make a melt-blown laminate (polypropylene, kenaf). The nonwoven laminate made resulted in uniform distribution of kenaf, which made up 70% of the laminate by weight. The laminate will be point-bonded and finished to obtain nonwoven fabric that



Kenaf nonwoven fabric is being tested for a variety of end uses.

will be tested for barrier effectiveness against blood, body fluids, and pesticide formulations; moisture absorbency; abrasion, tear, and tensile strength. Kenaf laminates will be compared with cotton laminates for the same characteristics.

Trials with 100% kenaf webs laminated by either melt-blown polypropylene (MB PP) or spunbonded polypropylene (SB PP) have also been done. These nonwovens are also being characterized and tested for barrier effectiveness. Kenaf webs were also needle punched to make nonwovens suitable for automobile and air conditioning filters.

Nonwovens were also made at SRRC, USDA, New Orleans, Louisiana, where kenaf was blended with polypropylene and calendered. This product may be used in furniture underlays and wallpaper backings.

Fibers processed in four different ways to obtain pliable fibers were used for making yarns and fabrics. The different kinds of chemical processes were aimed at preserving strength while reducing the residual gum content, thus increasing pliability. Fibers from all four processes were stapled (1 inch) and blended (80 cotton/20 kenaf) with cotton and spun and knitted at SRRC, USDA, New Orleans, Louisiana.

Fibers were opened, hand-blended with cotton, and carded to obtain the card lap. The card lap was put on a drawing machine to form the drawing sliver and then sent for spinning. Spinning resulted in 900 yards of yarn of 16s size, z-twist and 15.5 twists per inch. These yarns were then knitted into fabric tubes. Of the four processes, fibers processed bacterially and then chemically treated resulted in the best characteristics; fibers were the strongest, had the least residual gum content, and exhibited the best stretch property. The same experiment will be repeated to confirm the findings and also to make more yarns so tests on yarn quality index can be determined.

Hand spun/woven kenaf fibers

Plain and softened fibers were hand-spun and woven for experimentation. Results of this work are very encouraging and resulted in:

(1) A rug made of cotton warp and kenaf weft (or filling);

(2) Fine hand-woven placemats made of cotton/linen in warp and kenaf in weft;

(3) Jacket weight fabric made of cotton in warp and carded kenaf in weft; and

(4) Single and plied yarns were spun.

These preliminary trials with nonwoven and woven textile product lines illustrate the possibility of kenaf being used as a textile fiber similar to jute, ramie, and/or linen. Major obstacles may be the process to soften and processing costs. Preliminary experiments with fabric finishes may take care of the softening problem. So far, tests have been made only with cotton blends for the wovens and polypropylene for the nonwovens. In the future, trials may be conducted to blend kenaf with other manmade or natural fibers to enhance the natural luster and texture.

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