Influence of cultivars, years, environment, and stem location on kenaf fiber properties

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ABSTRACT

Kenaf contains two distinct fiber components, the long-bast fibers from the bark and the short-core fibers from the inner portion of the stem. Since the products that can be manufactured from kenaf as well as the product quality are influenced by the specific fiber properties, field studies were conducted in 1994 and 1995 to examine the fiber properties of four kenaf cultivars grown in four different environments. The four cultivars were Everglades 71, Tainung 2, SF459, and 7N; the four experimental sites were Weslaco and Overton, TX, and Dixon Spring and Urbana, IL.

Results indicated that the fiber lengths, widths, and length-to-width ratios of the four cultivars were not significantly different. What appeared to contribute most to differences in fiber properties were the years, environments, and the sources of fibers along the stem length and within the plants. Bark fibers from the middle section of stems were significantly longer than those from the lower stem sections; however, there were no significant differences observed among core fibers along the stem length. Bast and core fiber widths remained uniform throughout the entire stem. Several interactions existed between cultivars, years, environments, and stem location, indicating the numerous and compounding factors that may influence fiber properties, processing, and end use.

Application:

Kenaf can be used as a nonwood source of fiber and in manufacturing several wood-based products. This study showed the significant influence of years, environments, and stem location on bast and core fiber dimensions.

Kenaf (*Hibiscus cannabinus* L.) has been identified in many previous reports as a viable nonwood plant source of industrial fiber for pulp and paper *(1–5)*. More recent work has also indicated the potential of kenaf for the manufacture of composition boards for a variety of uses *(6–8)*. While it has been demonstrated that it is technically feasible to produce marketable products, there is a need to identify the best kenaf cultivar and growing condition for a specific end use.

Different cultivars of kenaf can be grown in different places. The differences in growing conditions and other factors may lead to variances in fiber-dimension properties. In a previous study, kenaf harvested from two different environments and several stages of maturity were evaluated *(9)*. It was determined that there was a decrease in length and width of fibers from 90 to 120 days after planting, but fiber dimensions remained constant thereafter. Kenaf grown in northern Florida was also found to produce longer but narrower fiber than that grown in central Illinois *(9)*. The desire to grow the appropriate kenaf cultivar has led to the development of improved germplasm. In 1992, the component yields of five kenaf cultivars were evaluated *(10)*. It was shown that yield component differences are associated with different kenaf cultivars.

Little information is available on the effects of cultivar and planting sites on the fiber-dimension properties of kenaf. In this study, we provide the fiber-dimension properties of four kenaf cultivars grown in Texas and Illinois.

The materials examined were harvested in 1994 and 1995. The objective of the study was to determine the effects of four kenaf cultivars, four planting locations, stem section or location (lower and middle portions of stem lengths), and fiber type (bast and core sections) on fiber length, fiber width, and fiber length-to-width ratio.

MATERIALS AND METHODS

The studies were conducted in 1994 and 1995. The four kenaf cultivars included in the studies were Everglades 71, Tainung 2, SF459, and 7N. Four environments were used for the evaluations. The two sites in Texas were Overton, which is in northeast Texas, and Weslaco, which is in the southern part of the state. Overton is characterized by an acidic type of soil, while that of Weslaco is alkaline. Studies in Illinois were conducted at Dixon Spring, which is in southern Illinois, and at Urbana, which is located in the central portion of the state. The Urbana South farm is characterized by loam soil, while that of Dixon Spring is the Gransburg silt loam type. The experiments were grown for 120–140 days prior to harvesting.

The samples for fiber maceration and fiber measurements were obtained from the bottom and middle sections of the plants; each section was 1 in. long. The bottom sections were obtained 2 in. from the point of harvest. The middle sections consist of materials obtained halfway along the length of each whole stem. The bark and core materials were manually separated

Cultivar	Fiber	Length, mm	Width, mm	Length/width ratio
Everglades 71	Bark	2.599	0.017	119.7
	Core	0.749	0.022	25.4
Tainung 2	Bark	2.581	0.016	116.5
	Core	0.715	0.024	23.0
SF459	Bark	2.620	0.016	118.7
	Core	0.723	0.023	23.6
7N	Bark	2.615	0.017	117.6
	Core	0.727	0.023	25.8

I. Mean fiber dimensions and length-to-width ratios of kenaf cultivars

Sources of variation[b]	Length	Width	Length/width ratio
Cultivar	NS[c]	NS	NS
Environment	S[c]	S	S
Fiber type	S	S	S
Stem location	S	NS	S
Year	S	S	S

[a]Tested at the significance level $\alpha = 0.05$
[b]Cultivar = Everglades 71, Tainung No. 2, SF459, 7N
Environment = Urbana, IL; Dixon Springs, IL; Overton, TX; Weslaco, TX
Fiber type = bark, core
Stem location = bottom, middle
Year = 1994, 1995
[c]S = significant; NS = not significant

II. Main factor effects on kenaf fiber properties[a]

Length	Width	Length/width ratio
Cultivar × location	Cultivar × type	Location × type
Location × type	Cultivar × height	Location × year
Location × year	Location × type	Type × height
Location × height	Location × year	Type × year
Type × height	Location × height	Location × type × height × year
Type × year	Type × year	Cultivar × location × type × year
Height × year	Type × height	-
Cultivar × location × type	Cultivar × location × type	-
Cultivar × location × type × year	Cultivar × location × type × year	-
Location × type × height × year	-	-
Cultivar × location × type × height × year	-	-

[*]Tested at the significance level $\alpha = 0.05$

III. Significant interaction effects on kenaf fiber properties[*]

by slicing and were macerated separately. For fiber length measurement, the referenced TAPPI Test Method was used *(11)*. Fiber widths were determined using the direct-measuring method.

For each year's experiments, the factors summed to four kenaf varieties, four planting locations, two stem positions (middle and bottom), and two types (bark and core fibers). There were six replications per treatment combination, resulting in 384 slides/year. More than 60 fibers were measured in each slide. An analysis of variance (ANOVA) was conducted to determine the effects of the main factors and their interactions. Mean comparisons of main factors were conducted using the least significant difference (LSD) at a significance level of $\alpha = 0.05$.

RESULTS

Table I presents a summary of fiber characteristics of each of the kenaf cultivars. The results the ANOVA conducted on the effects of the different factors and their interactions are summarized in **Tables II and III.** Variance analysis was conducted at a level of significance of $\alpha = 0.05$. Table III identifies the interaction effects that significantly contributed to variations in fiber quality. The fiber properties are significantly affected by the interaction of the indicated variables.

Note that cultivar or variety was similar with respect to length, width, and length-to-width ratio of fibers. What contributed to differences were the environment and the sources of fiber within (bark or core) and along the length of stems (bottom and middle sections). Similarly, there were differences in fiber properties among kenaf cultivars grown in 1994 and 1995 (**Tables IV–VII**). Cultivars planted in 1995 exhibited longer bast fibers than those from 1994. Variation in core fiber lengths was inconclusive. Fiber width, and consequently length-to-width ratio, exhibited significant differences between the two growing seasons. At this juncture, we note that there was a difference in growing conditions between 1994 and 1995. In 1995, a much lower yield was harvested in Illinois due to abnormal weather conditions.

Fiber lengths

There was a significant difference in lengths of fibers obtained from the bark and core sections of the plants, as previously reported *(1)*. In general, bark fibers of the four cultivars averaged 2.60 mm in length, while core fibers averaged 0.73 mm. Similarly, significant variation exists in length of fibers obtained from the middle and bottom sections of plants, with the former yielding the longer fiber. This trend holds for both the bark and core fibers, as shown in Tables IV–VII. For bark fibers, those coming from the bottom sections averaged 2.44 mm in length compared to 2.76 mm from the middle. Core fibers averaged 0.72 mm at the bottom and 0.75 mm at the middle. The lengths of bast fibers were comparable to those published earlier for Illinois *(1, 9)*. An earlier published report *(1)* showed an average bast fiber length of 2.6 mm and a core fiber length of 0.50 mm. The core fibers examined in our study were also longer.

Cultivar	Year	Urbana, IL, mm	Dixon Spring, IL, mm	Overton, TX, mm	Weslaco, TX, mm
Everglades 71	1994	2.19	2.19	2.53	2.47
	1995	2.61	2.50	2.30	2.58
Tainung 2	1994	2.32	2.41	2.34	2.57
	1995	2.50	2.53	2.39	2.62
SF459	1994	2.34	2.48	2.48	2.50
	1995	2.43	2.47	2.39	2.54
7N	1994	2.38	2.28	2.51	2.52
	1995	2.33	2.45	2.50	2.59

IV. Mean bark fiber lengths (bottom) of kenaf cultivars in 1995 and 1996

Cultivar	Year	Urbana, IL, mm	Dixon Spring, IL, mm	Overton, TX, mm	Weslaco, TX, mm
Everglades 71	1994	2.54	2.66	3.29	2.96
	1995	2.87	2.75	2.54	2.62
Tainung 2	1994	2.59	2.77	2.79	2.74
	1995	2.75	2.86	2.46	2.66
SF459	1994	2.55	3.00	2.98	2.77
	1995	2.90	2.97	2.44	2.68
7N	1994	2.43	2.94	3.14	3.02
	1995	2.79	2.68	2.56	2.71

V. Mean bark fiber lengths (middle) of kenaf cultivars in 1995 and 1996

Tables VIII and IX summarize the mean fiber lengths of kenaf components harvested in 1994 and 1995, respectively. The mean comparisons were performed using the LSD test at a significance level of $\alpha = 0.05$. We noted that the bark fibers of cultivars from the middle sections are statistically similar in length. Analysis of the length of core fibers from the middle sections also showed that the average lengths remained uniform among the cultivars. The bottom fibers, however, exhibited variations among the four cultivars. The effects of environment on fiber properties are very evident. In 1994, the kenaf plants grown in Overton, TX, yielded the longest bast fibers compared to those grown in other environments. However, in 1995, bark fibers of cultivars grown in Illinois were longer than those grown in Texas. The variation was most noticeable in fibers taken from the middle sections.

Fiber width

The mean fiber width for all the cultivars is statistically similar. As shown in Table III, the factors that contribute most to variation were the interactions of environment and fiber location and fiber type. Core fibers were much wider (0.023 mm) than bark fibers (0.016 mm). Along the stem length, there was no significant difference in fiber widths between those obtained from the bottom and middle sections. Environment does not significantly contribute to the width of bark fibers. However, core fiber width was significantly affected by the environment. Kenaf plants grown in Illinois exhibited wider fibers than those grown in Texas. The core fiber widths in this study are comparable to those examined earlier for Illinois *(1, 9)*, which averaged 0.022 mm. The current bast fibers were narrower compared to the 0.018-mm dimension published in a previous study *(1)*.

Another significant contributing factor to variations in fiber width was the year of growth. Bark fibers were consistently wider in 1994 than in 1995 for both the bottom and middle stem sections. Core sections were also wider in 1994.

Length-to-width ratio

As the length-to-width ratio would imply, its value depends on the resulting trends in width and length of fibers. This ratio is not dependent on

Cultivar	Year	Urbana, IL, mm	Dixon Spring, IL, mm	Overton, TX, mm	Weslaco, TX, mm
Everglades 71	1994	0.69	0.71	0.72	0.71
	1995	0.85	0.77	0.77	0.76
Tainung 2	1994	0.69	0.70	0.68	0.72
	1995	0.69	0.74	0.69	0.74
SF459	1994	0.67	0.68	0.70	0.67
	1995	0.69	0.75	0.71	0.74
7N	1994	0.67	0.70	0.68	0.71
	1995	0.76	0.73	0.75	0.79

VI. Mean core fiber lengths (bottom) of kenaf cultivars in 1995 and 1996

Cultivar	Year	Urbana, IL, mm	Dixon Spring, IL, mm	Overton, TX, mm	Weslaco, TX, mm
Everglades 71	1994	0.73	0.72	0.82	0.71
	1995	0.75	0.76	0.73	0.77
Tainung 2	1994	0.72	0.68	0.76	0.74
	1995	0.72	0.73	0.73	0.72
SF459	1994	0.75	0.71	0.81	0.70
	1995	0.71	0.78	0.76	0.76
7N	1994	0.75	0.68	0.73	0.69
	1995	0.72	1.00	0.78	0.79

VII. Mean core fiber lengths (middle) of kenaf cultivars in 1995 and 1996

the cultivar (Table II) but is more of a function of the other factors. However, the environment, fiber location, and fiber type contributed significant effects. The length-to-width ratio of core fibers grown in Urbana, IL, yielded the lowest values, while those from Overton, TX, exhibited the highest. In general, bark fibers from the bottom and middle stem locations or sections have ratios of 110 and 125, respectively. For cores, the differences between the two locations are not significant. These differences were 23 and 26 for the bottom and middle sections, respectively.

DISCUSSION

Kenaf has been cultivated in the past for its long-bast fiber, which is an alternative source of material for industries like pulp and paper. The growing interest in kenaf bast and core fiber has resulted in the development of new cultivars with improved resistance to pests, while maintaining or improving the yield potential and fiber quality of these cultivars. Fiber properties are good indicators of the properties of end products that could be derived. In some cases, the fiber properties can also affect the production process.

The four cultivars investigated in this study showed similarity with respect to fiber-dimension properties; there was an improvement in fiber geometry compared to other varieties grown in the past three decades. The middle stem section or sampled location exhibited longer bast fiber than did samples taken from the bottom of the stems. This property could affect the economics of harvesting the plant or the design of harvesting equipment. The study did not include an investigation of the whole-stem property, including the top section of plants. This should be an interesting study that could determine the overall variation in fiber property along the stem length.

Fiber properties were not consistent in the two years that the plants were grown. Fibers in 1995 were longer; however, there was a lower fiber yield in this year. The differing year of growth resulted in different properties of bast and core fibers along the stem length. Similarly, the environment has an effect among the cultivars, showing variations between the two growing years. This could indicate that one variety will produce better fiber properties if grown in the appropriate environment.

SUMMARY AND CONCLUSIONS

This study examined the fiber properties of four kenaf cultivars: Everglades 71, Tainung 2, SF 459, and 7N. The plants were grown under four environments in Illinois and Texas and were 120–140 days old at harvest. The sampled fiber materials were obtained from plants grown in 1994 and 1995. The results of statistical analyses indicated that:

- There were no significant differences in fiber length, width, and fiber length-to-width ratio among the four cultivars.
- Bast fibers obtained from the middle stem sections were significantly longer than those from the bottom section.

Cultivar	Section	Urbana, IL	Dixon Spring, IL	Overton, TX	Weslaco, TX	Bark,[b] Mid.	Bark, Bot.	Core, Mid.	Core, Bot.
Everglades 71	Bark	2.36	2.42	2.91	2.72	A	B	-	-
	Core	0.71	0.72	0.77	0.71	-	-	A	A
Tainung 2	Bark	2.45	2.59	2.57	2.65	A	AB	-	-
	Core	0.71	0.69	0.72	0.73	-	-	A	AB
SF459	Bark	2.44	2.74	2.73	2.64	A	A	-	-
	Core	0.71	0.69	0.75	0.69	-	-	A	B
7N	Bark	2.41	2.61	2.83	2.77	A	AB	-	-
	Core	0.71	0.69	0.71	0.70	-	-	A	AB
Bark[c]	Middle	C	B	A	AB	-	-	-	-
	Bottom	B	B	A	A	-	-	-	-
Core	Middle	B	B	A	B	-	-	-	-
	Bottom	A	A	A	A	-	-	-	-

[a]Mean comparisons were performed using the least significant difference (LSD) criteria at the significance level $\alpha = 0.05$.
[b]Mean comparison is by column. Cultivars of the same letter are not significantly different.
[c]Mean comparison is by row. Cultivars of the same letter are not significantly different.

VIII. Mean fiber lengths of kenaf cultivars in 1994[a]

Cultivar	Section	Urbana, IL	Dixon Spring, IL	Overton, TX	Weslaco, TX	Bark,[b] Mid.	Bark, Bot.	Core, Mid.	Core, Bot.
Everglades 71	Bark	2.74	2.62	2.42	2.60	A	A	-	-
	Core	0.80	0.76	0.75	0.77	-	-	A	A
Tainung 2	Bark	2.63	2.70	2.42	2.64	A	A	-	-
	Core	0.71	0.73	0.71	0.73	-	-	A	B
SF459	Bark	2.67	2.72	2.42	2.61	A	A	-	-
	Core	0.70	0.77	0.73	0.73	-	-	A	B
7N	Bark	2.56	2.56	2.53	2.65	A	A	-	-
	Core	0.74	0.87	0.77	0.79	-	-	A	A
Bark[c]	Middle	A	A	C	B	-	-	-	-
	Bottom	B	AB	B	A	-	-	-	-
Core	Middle	A	A	A	A	-	-	-	-
	Bottom	A	A	A	A	-	-	-	-

[a]Mean comparisons were performed using the least significant difference (LSD) criteria at the significance level $\alpha = 0.05$.
[b]Mean comparison is by column. Cultivars of the same letter are not significantly different.
[c]Mean comparison is by row. Cultivars of the same letter are not significantly different.

IX. Mean bark fiber lengths of kenaf cultivars in 1995[a]

- No significant difference in core fiber widths was noted between specimens obtained from the middle and bottom stem sections.
- The length-to-width ratios of kenaf plants grown in Texas were much higher than those grown in Illinois. The middle sections of bast fibers exhibited higher ratios than those from the bottom sections, while there was no significant difference between core fibers from the two sections.
- The growing conditions in 1994 and 1995 contributed to varia-

tions in fiber lengths and had significant effects on fiber widths and length-to-width ratios.

There is no difference among the evaluated cultivars for the fiber dimensions obtained from the middle sections of stems. However, this does not necessarily mean that one cultivar could be grown as an alternative to another in terms of optimal utilization. Consideration should be given to the type of cultivar that is planted in a particular environment to obtain the best yields and fiber properties. Other factors, such as the chemical constituents of the cultivars and their growth characteristics, should be further taken into consideration for selection. TJ

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