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Variations in photo- and thermal sensitivities among local, improved and exotic kenaf accessions in Nigeria

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Abstract

The response of two local, eleven improved and one exotic accessions of kenaf to daylength was determined by their increase in vegetative growth after flowering in 2004. Seven out of the fourteen accessions were planted every 4 months in 2005 to determine their sensitivity to natural variations in daylength, temperature, solar radiation and relative humidity in terms of days to flower initiation, percentage gain in height after flowering and fibre yield. The plants took longer days to flower at longer daylength and higher temperature. Differences among accessions were significant for all traits in 2004. Days to flowering were more in December than in April and August, the number of days differing among accessions. Percentage gain in height after flowering differed with planting date only in the heat-tolerant accessions and was highest in December. Differences in fibre yield were not significant among accessions when planted in August, but differed significantly in April and December. On the average, fibre yield was highest in December and lowest in August. A grouping of the accessions based on their responses to daylength for both years of study was consistent. The implications of these findings in development of agronomically superior varieties and production of raw materials all round the year in Nigeria are discussed.

Key words: Kenaf, photosensitivity, thermal response, *Hibiscus cannabinus*.

Introduction

The importance of kenaf (*Hibiscus cannabinus*) as the most viable replacement for trees in paper production [10], among other products has been emphasized [7, 14]. An annual plant, native to Central Africa [13], kenaf is a low-risk cash crop whose cultivation requires minimal chemical applications. It also helps to alleviate global warming by absorbing carbon dioxide gases due to its rapid growth rate [10]. In Nigeria, environmental degradation is on the increase due to increase in oil production [5] and felling of trees in forests. It is therefore necessary to develop a renewable resource that will provide raw materials in a sustainable way.

A major constraint to utilization of kenaf in Nigeria is the non-availability of raw materials all round the year due to sensitivity of most cultivars to short daylength and temperature. Thus, there are specific times for planting and harvesting of these cultivars, causing surplus supply of raw materials at a time and shortage during the rest of the year [15].

It is the latitude, north or south of the equator of a place that determines its daily photoperiod yearly. Photosensitive varieties initiate flowering when daylength reduces to 12.5 hours, and are ideally suited for countries above the tropics specifically at latitudes 10° to 27° north or south of the equator [12, 16]. This is because they can produce and mature seed prior to a killing frost. In contrast, when planted in the tropics (latitude 0° to 10° N or S) where daylength is more uniform from June to September, these cultivars flower very early, causing a reduction in vegetative growth and low fibre yields. Dayneutral cultivars have been demonstrated as ideal for the tropics, in that, they flower late, or when they flower early, their vegetative growth is not significantly reduced [3,4]. The photo- and thermal responses of genotypes should therefore be modified through selection and breeding to better match the period of vegetative growth with the growing season in a particular environment [15]. This is critical in Nigeria where temperature and daylength vary with location. This paper describes the relative pre- and post-flowering vegetative growths, and response to different planting dates, of local, improved and exotic kenaf accessions in Nigeria, with a view to determining their photo- and thermal sensitivities for incorporation into breeding programmes.

Materials and Methods

In June 2004, seeds of 14 accessions of kenaf, comprising of one from Australia (AU-51), 2 local (LOCAL35 and 36) and 11 improved accessions were obtained from the germplasm collection of the Institute of Agricultural Research and Training (IAR&T), Ibadan. The local and improved accessions were from Nigeria. The accessions were planted in rows of 6 m in length, at a spacing of 25 cm between and 10 cm within rows. There were ten stands per row per accession. Data were taken on number of days to flowering, plant height at flowering and at harvest using a labelled sample of 5 plants per accession. The increase in vegetative growth after flowering was measured as the gain in height. This was calculated as the difference between the height at harvest and the height at flowering as a percentage of the height at flowering. At 50% flowering, mid-stem portions, 10 cm in length, were cut and weighed. The data were subjected to analysis of variance in a completely randomized design, and the means were separated at p=0.05. The FASTCLUS procedure of SAS [11] was used to cluster the accessions into 3 based on days to flowering, percentage gain in height after flowering and fibre yield (g) per length of 10 cm. Means were calculated for each cluster.

In 2004/2005, seven out of the fourteen accessions were planted in December 2004, April 2005 and August 2005, to subject them to natural variations of daylength, temperature, solar radiation and relative humidity. The seven accessions were selected based on the results of the 2004 evaluation, in which Clusters 2 and 3 were least and most sensitive to daylength respectively while Cluster 1 was average. One accession was selected from Cluster 1 while three were selected from each of Clusters 2 and 3. Planting was done in pots in Ibadan, located on latitude 7°23'16 North and longitude 3°15'47 East. There were 5 pots (replicates) per accession and 2 plants per pot, and the plants were watered daily. On each plant, data were recorded on date of flower opening, days to flower opening, plant height at flowering and at harvest, and fibre yield (g per length of 10 cm) as done in 2004. The daily solar power (MJ m^{-2}), daylength (h), and relative humidity (%) for the year 2005 were obtained from the Meteorological Unit of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, while the daily temperature (°C) was provided by IAR&T. The date of flower opening for each plant was matched to the prevailing weather variables for that day. The percentage gain in height after flowering was also calculated as done in 2004.

The number of days to flowering was regressed on the weather variables to determine their relative effects. Analysis of variance was done in a split-plot design with planting date as main plot and accession as subplots. Means were separated at p=0.05.

Results and Discussion

Differences among accessions were significant for all the traits in 2004 (Table 1). Accession 20C was the latest to flower, at ninety-six days after planting. It was followed by $V_1$400, which flowered eighty-nine days after planting. Other accessions did not differ significantly, S-72-49-9 being the earliest to flower at seventy-nine days after planting. Percentage gain in height after flowering ranged from 15.87 in accession 8B to 46.00 in 25A5M. Accessions 20C and $V_1$400 did not differ significantly from ASM25, with values of 37.86 and 38.67% respectively. Accession 8B was highest in fibre yield (11.26 g), followed by LOCAL35 (7.87 g) while the lowest was S108/14, which had 2.57 g per length of 10cm.

A more specific grouping of the accessions into 3 clusters revealed that Cluster 1 is composed of 7 accessions (Table 1), had the lowest fibre yield and least number of days to flowering while its gain in height after flowering was average between Clusters 2 and 3. Cluster 2, composed of three accessions, was the latest to mature and had the highest gain in height but low fibre yield. In Cluster 3, there are 4 accessions, and they are high yielding, early maturing and with the lowest gain in height after flowering. Members of Cluster 2 were therefore classified as dayneutral but low yielding relative to the others. Cluster 3 accessions are high yielding but daysensitive, while Cluster 1 accessions are low yielding but medium in daysensitivity.

Table 1. Means of daysensitivity parameters and fibre yield of kenaf in 2004.

Cluster	Accession	Days to flowering	Gain in height (%)	Fibre yield (g)
1	LOCAL36	79.81 [c]	21.79 [c]	2.94 [de]
	8A	86.61 [bc]	27.05 [bc]	7.12 [bc]
	AMC1081	83.41 [bc]	28.63 [bc]	4.57 [bcde]
	S108/14	85.41 [bc]	26.87 [bc]	2.57 [e]
	S-72-49-9	79.61 [c]	22.70 [c]	3.91 [cde]
	S-72-78-18-10	86.61 [bc]	21.10 [c]	6.17 [bcd]
	BG-58-7	81.21 [c]	22.74 [c]	3.43 [de]
Mean		83.23	24.43	4.38
2	20C	96.61 [a]	37.86 [ab]	3.94 [cde]
	25A5M	86.85 [bc]	46.00 [a]	4.10 [bcde]
	$V_1$400	89.41 [b]	38.67 [ab]	5.47 [bcde]
Mean		91.00	40.75	4.50
3	8B	79.81 [c]	15.87 [c]	11.26 [a]
	S-72-78-18-3	83.41 [bc]	16.08 [c]	4.71 [bcde]
	AU51	84.41 [bc]	17.79 [c]	5.10 [bcde]
	LOCAL35	85.61 [bc]	17.91 [c]	7.87 [ab]
Mean		83.30	16.93	7.26
	S.E	0.78	1.56	0.44

S.E. Standard error; Means in each column followed by the same letter are not significantly different. *P<0.05, ** P<0.01.

Fig. 1 shows the monthly trend for the weather variables in 2005. When planted in December, daylength increased until June before declining until December, while temperature increased to a maximum in February, dropped in March and reached a minimum in August before increasing again until December. The planting done in April received a steady increase in daylength, reached a peak in June and decreased until December, while temperature reduced until August before rising until December. For the August planting, there was a steady reduction in daylength and increase in temperature until December. The regression of days to flowering on the weather variables showed that daylength and temperature had significant effect (Table 2). The plants generally took longer days to flower at longer daylength and higher temperature. This agrees with previous reports that kenaf is a quantitative short day plant [9].

When planted in April 2005, all the accessions flowered in July (average daylength 12.39 h), except $V_1$400, which did in August when daylength dropped to 12.24 hours (Table 3). The same trend was obtained with August planting, wherein $V_1$400 also flowered in November (average daylength 11.65 h), 20 days later

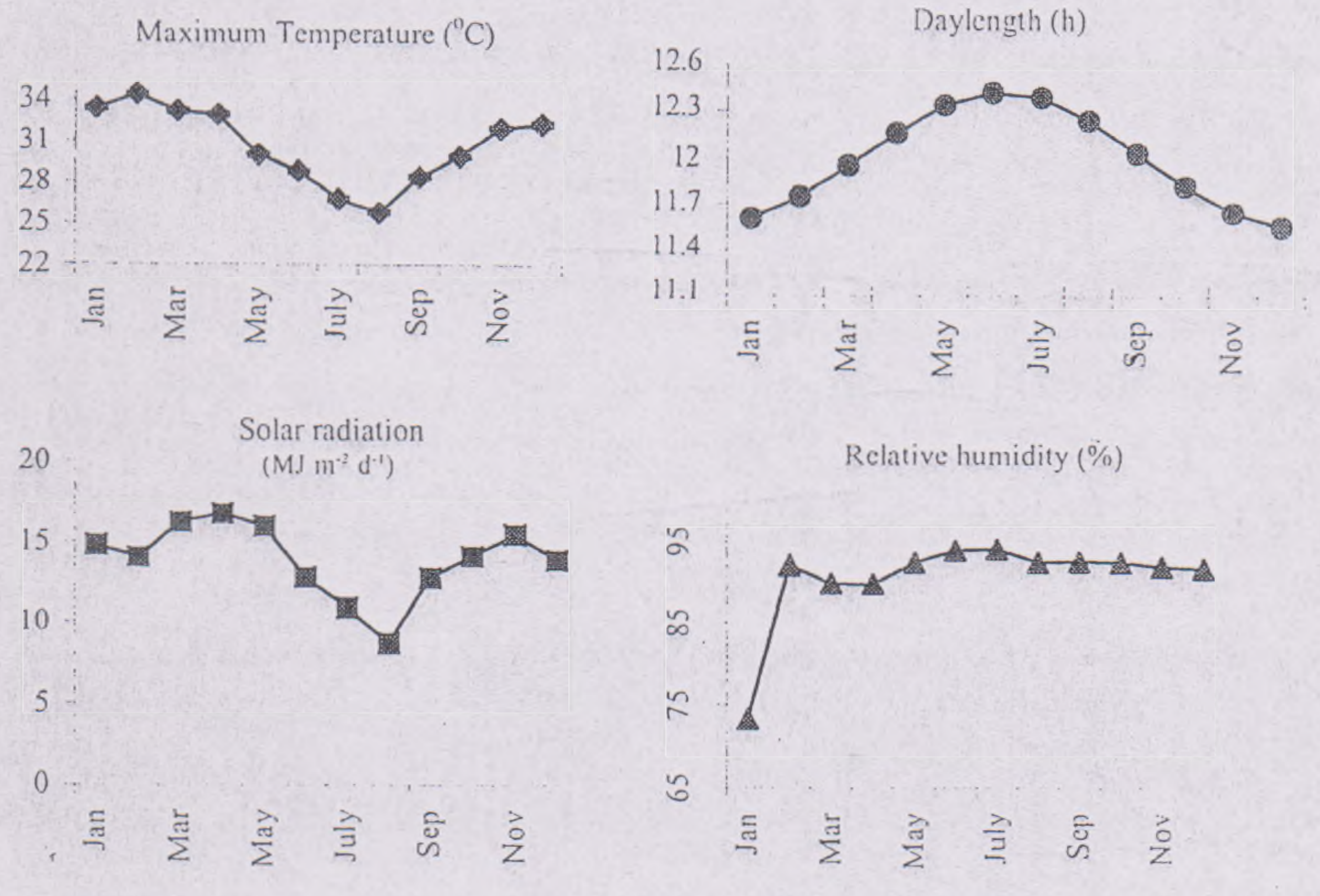

Figure 1. Mean monthly values of some climatic variables in year 2005.

than the other accessions that flowered in October (average daylength 11.82 h). The performance of the lines differed when planted in December, in that all the accessions, except LOCAL35, 20C and 8B, did not flower until June. The latter accessions initiated flowering in February, March and May respectively when daylengths were shorter and temperature higher than in June. V_1400 was also the latest to flower, and is therefore consistently late maturing relative to other accessions.

Table 2. Sums of squares of regressors and prediction equation for number of days to flowering in kenaf planted on different dates at different climatic conditions.

Source	Sums of squares
Intercept	21595.00**
Daylength	24950.00**
Temperature	4298.96**
R-square	0.7701
Prediction equation	--1885.49+147.99daylength+6.26temperature

The longer time taken for the plants to flower in December relative to April and August is due to differences in the trend of daylength and temperature among the planting dates. In April, the plants experienced shortening of daylength and reduction in temperature during their vegetative growth period, while in August there was also a shortening of daylength and an insignificant rise in temperature as they grew. In contrast, there was no decrease in daylength for the planting in December, as it increased steadily to a peak in June while temperature rose significantly. Hence, although daylength was favourably short in December, with the expectation for early flowering, high temperature prevented the heat-sensitive accessions from flowering while the relatively heat-tolerant lines LOCAL35, 20C and 8B flowered. Planting in December is therefore more of an indicator of the response of accessions to temperature than daylength, since December to March is hotter than June to November. Differences in growth between cultivars planted on the same date were reported to be due to the effect of photoperiod, while changes in temperature caused different patterns of growth between the different planting dates [8, 17]. Breeding for suitable photothermal response is thus desirable [15].

Percentage gain in height after flowering did not differ with planting date in all accessions except 8B, LOCAL35 and 20C, in which the planting done in December was significantly higher than in August and April (Table 3). These three accessions also initiated flowering at higher temperatures than the others (Table 3).

The significant variation of percentage gains in height after flowering with planting date only in the heat-tolerant accessions (Tables 3 and 5) and the highest values recorded in December also indicate differential response of accessions to temperature. Growth rate is affected by the efficiency of utilization of intercepted light energy for dry matter production and the amount of light energy intercepted, which in turn depends on leaf area development. The latter increases with increasing temperature [1] and plants reach physiological maturity and initiation of the reproductive phase early. This explains why, in December, the accessions with a higher heat threshold could intercept more light and flower earlier, allowing more time for optimum vegetative growth before harvest than the late maturing ones. Therefore, gain in height, as an indicator for dayinsensitivity is not valid for December planting when temperature is limiting, but valid for April and August. It should, however, be considered jointly with number of days to flowering, such that an accession is dayinsensitive only if it flowers early and also has a high percentage gain in height after flowering. Only 25A5M and 20C fulfill these requirements for both April and August plantings and are therefore dayinsensitive relative to other accessions except V_1400 which is the most insensitive to daylength since it consistently matured late irrespective of planting date. Relativity in response of genotypes to daylength has been reported, such that it is more of a quantitative than qualitative trait, especially at equatorial climates [3].

Fibre yield did not differ significantly among accessions when planting was done in August, but differed significantly in December (Table 4). In April, only 8B and V_1400 significantly differed. On the average, fibre yields were highest in December and lowest in August in all accessions, while differences in mean fibre yields among accessions were not significant. The equally low fibre yield among accessions in August reflects response to favorably short daylength, since kenaf is a short day plant [9]. The stress imposed by high temperature was also absent. In contrast,

Table 3. Mean values for day-neutrality parameters, prevailing temperature and photoperiod at floral initiation in 7 kenaf accessions at 3 planting dates in 2005.

Accession	Month planted	Month flowered	Daylength flowered (hrs.)	Day temp. (^oC) at flowering	Days to flowering	Gain in height (%)
ASM25	April	July	12.36b	26.73b	88.83b	23.87a
	August	Oct.	11.90c	30.40a	49.90c	25.22a
	December	June	12.43a	29.96a	166.67a	22.00a
Mean			*12.23a*	*29.03ab*	*101.80bc*	*23.69bc*
AU-51	April	July	12.34b	26.4b	92.00b	10.00a
	August	Oct.	11.85c	26.20b	56.80c	31.34a
	December	June	12.41a	29.22a	166.67a	14.43a
Mean			*12.20bc*	*27.27c*	*105.16b*	*18.59bc*
8B	April	July	12.34a	26.70b	91.77b	21.22b
	August	Oct.	11.86b	28.70b	54.40c	15.79b
	December	May	12.32a	31.23a	146.54a	59.68a
Mean			*12.18c*	*29.88b*	*97.57c*	*32.23ab*
LOCAL35	April	July	12.37a	27.26c	85.44a	9.20b
	August	Oct.	11.87b	30.60b	54.00b	15.71b
	December	Feb.	11.82b	34.68a	57.15b	110.03a
Mean			*12.02e*	*30.84a*	*65.53e*	*44.98a*
20C	April	July	12.33a	26.90b	94.60a	23.65b
	August	Oct.	11.85b	28.70b	57.20b	30.68b
	December	Mar.	11.87b	33.46a	64.17b	80.58a
Mean			*12.02e*	*29.69ab*	*71.99d*	*44.97a*
S-72-10	April	July	12.35b	26.30b	90.30b	12.71a
	August	Oct.	11.86c	28.90a	55.90c	15.44a
	December	June	12.41a	29.90a	156.72a	5.25a
Mean			*12.21ab*	*28.37bc*	*100.97bc*	*11.13c*
V_1400	April	August	12.27b	24.68b	106.48b	8.47a
	August	Nov.	11.73c	31.96a	76.02c	11.38a
	December	June	12.42a	31.06a	157.80a	14.12a
Mean			*12.14d*	*29.23ab*	*113.43a*	*11.32c*
S.E			0.02	0.24	2.74	2.40

For each accession, values followed by the same letter are not significantly different at p=0.05. Mean values in italics followed by the same upper case letter are not significantly different at p=0.05.

Table 4. Mean values for fibre yield (g) in 7 kenaf accessions at 3 planting dates in 2005.

Accession	Month planted			
	April	August	December	Mean
25ASM	7.20ab	3.80a	11.52b	7.51a
AU-51	6.84ab	5.18a	12.20ab	8.07a
8B	4.95b	3.42a	15.35a	7.90a
LOCAL35	6.39ab	5.71a	10.38b	7.50a
20C	5.60ab	4.59a	9.56b	6.58a
S-72-10	6.82ab	4.53a	8.90b	6.75a
$V_1$400	7.90a	5.48a	9.73b	7.70a
Mean (Planting date)	***6.53b***	***4.67c***	***11.09a***	

Values in each column followed by the same letter are not significantly different. Italic mean values for planting date followed by the same letter are not significantly different p=0.05.

Table 5. Ranking of 7 accessions of kenaf in dayneutrality, heat tolerance and fibre yield based on studies in 2004 and 2005.

Response decreases ↓	Dayneutrality		Fibre yield		Heat tolerance
	2004	2005	2004	2005	2005
	20C, $V_1$400, 25ASM	$V_1$400	8B	8B	LOCAL35
		25ASM, 20C	LOCAL35	AU-51	20C
	Others	Others	S-72-10	25ASM	8B
			25ASM, $V_1$400, AU-51	LOCAL35	Others
			20C	$V_1$400, 20C	
				S-72-10	

the significantly low fibre yield in the heat-tolerant accessions relative to heat-sensitive ones when planted in December is indicative of early commencement of the reproductive phase in the former since high temperature did not delay initiation of flowering. A marked temperature dependence of dry matter production in kenaf had been reported [2]. Seasonal differences in forage yield of the legume *Stylosanthes humilis* were attributed to the duration of the phase of vegetative growth [6].

Table 5 shows that the grouping of the accessions based on their responses to daylength for both years of study were consistent. In respect of fibre yield, 8B had the highest values in both years despite the different planting times. Since maximum daily temperature in Nigeria varies from 23.33°C in Jos plateau to 41.11°C in Sokoto and Maiduguri, application of molecular marker-assisted selection, combined with testing in controlled environment, will enhance the determination of the precise photo-thermal threshold of genotypes over a wider germplasm base. Accessions 8B and $V_1$400 being on the two extremes of fibre yield when planted in April suggests that their responses to daylength is contrasting, the former being daysensitive and the latter dayneutral. Since high yield is always desirable, 8B is a candidate parent material for subsequent crosses whose mate will be determined by the photothermal responses required in a particular location.

This study has determined the relative photo- and thermal responses of some kenaf accessions that can be adapted to Nigerian agroecologies. This will enhance the choice of parents that will be incorporated into breeding programmes to develop agronomically superior varieties. Fibre yields will be optimum if planting date is matched with the pattern of response of the genotype to daylength and temperature. Using genotypes with a photothermal requirement that precludes them from flowering at a particular location will lead to maximum fibre yields.

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References

[1]Charles-Edwards, D. A. 1979. Photosynthesis and crop growth. In Marcelle, R., Clijsters, H. and Van Poucke, M. (eds). Photosynthesis and Plant Development. Junk, The Hague, pp. 111-124.

[2]Charles-Edwards, D. A., Muchow, R. C. and Wood, L. M. 1983. Effect of sowing date on the growth and yield of kenaf (*Hibiscus cannabinus*) grown under irrigation in tropical Australia. III. Physiological analysis. Field Crops Res. 7:103-113.

[3]Dempsey, J. M. 1975. Fibre Crops. University of Florida Press, Gainesville, FL, pp. 203-304.

[4]Dryer, J. F. 1967. Kenaf seed cultivars. Proceedings of the First Conference on Kenaf for Pulp. Gainesville, Florida, pp. 44-46.

[5]Energy Information Administration (EIA) 2003. Country Analysis Briefs. Statistical Agency of the United States Department of Energy. On the Internet: www.eia.doe.gov/cabs/nigenv.html.

[6]Fisher, M. J., Charles-Edwards, D. A. and Campbell, N. A. 1980. A physiological approach to the analysis of crop growth data. II. Growth of *Stylosanthes humilis*. Ann. Bot. **46**:425-434.

[7]Martin, D. 1996. Kenaf: An overview. Rainforest Action Network. On the Internet: http://www.ran.org/ ran/ran_campaigns/rain_wood/ wood_con /kenaf_fact.html.

[8]Muchow, R. C. 1981. The growth and culture of kenaf (*Hibiscus cannabinus* L.) in tropical Australia. Proceedings of Kenaf Conference, May 28-29, Brisbane, Queensland, pp. 10-28.

[9]Muchow, R. C. and Wood, L. M. 1983. Effect of sowing date on the growth and yield of kenaf (*Hibiscus cannabinus*) grown under irrigation in Tropical Australia. I. Phenology and seed production. Field Crops Res. 7:81-90.

[10]Rymsza, T. A. 1999. Utilization of kenaf raw materials. Paper presented to the Forest Products Society. Boise, Idaho.

[11]SAS (Statistical Analysis Systems) 1999-2000. Proprietary Software Release 8.2 (TS2MO). SAS Institute, Cary, NC.

[12]Scott, A. 1982. Kenaf seed production: 1981-1982. Rio Farms, Inc. Biennial Report for 1980-1981. Monte Alto, Texas, pp. 60-63.

[13]Scott, A. W. Jr. and Taylor, C. S. 1988. Economics of kenaf production in the lower Rio Grande Valley of Texas. Paper presented at National Symposium on New Crops, Oct. 23-26, 1988, Indianapolis, Indiana, pp. 292-297.

[14]Stricker, J. A., Prine, G. M. and Riddle, T. C. 2001. Kenaf – A possible New Crop for Central Florida. University of Florida Cooperative Extension Service. Institute of Food and Agricultural Sciences, Gainesville, Florida. On the Internet: http://www.edis.ifas.ufl.edu/ BODY_AA220.

[15]Webber, C. L. III and Bledsoe, V. K. 1993. Kenaf: Production, Harvesting, Processing and Products. In Janick, J. and Simon, J.E. (eds). New Crops. Wiley, New York, pp. 416- 421.

[16]Webber, C. L. III., Bhardwaj, H. L. and Bledsoe, V. K. 2002. Kenaf production: Fibre, feed and seed. In Janick, J. and Whipkey, A. (eds). Trends in New Crops and New Uses. ASHS Press, Alexandria, VA, pp. 327-339.

[17]Wood, I. M., Muchow, R. C. and Ratcliff, D. 1983. Effect of sowing date on the growth and yield of kenaf (*Hibiscus cannabinus*) grown under irrigation in tropical Australia. II. Stem production. Field Crops Res. 7:91-102.