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Evaluation of kenaf (*Hibiscus Cannabinus* L.) genotypes for agronomic performance and fibre industrial quality

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Abstract Significant variation of Kenaf (*Hibiscus Cannabinus* L.) was found to be genotypes, environments and genotype × environment existed in flowering, plant height, stem diameters and fibre yields. Accessions SAU75-414, GS14-52 and AEHC-3 had bast fibre yields higher than the mean value while SAU75-414 and GS14-52 had the highest core fibre yields. Accessions GS14-52, SAU75-414, AU75-452, IFEKEN DI-400, AEHC-3 and IFEKEN 400 had high quality ratios greater than 60%. Thus high fibre yielding SAU75-414, GS14-52 and AEHC-3 are promised both in agronomic performance and fibre quality. Plant height had positive significantly correlated with both types of fibre yields and e-modulus (0.721^{**}). Tensile strength also had positive significant correlations with bast (0.534^{*}) and core (0.606^{*}) fibres, thus the tensile strength can be determined during the plant growth using plant height. E-modulus positively correlated with plant height, base diameter, fibres yields and tensile strength. Based on this, the tensile strength and e-modulus corroborate as versatile selection tools. Accessions SAU75-414, GS14-52 and AEHC-3 combined high fibre yield with high bast fibre and yarn quality. In view of the properties, they are recommended for further experimentation for improvement on fibre yield and quality for use of the farmers and industrialists.

Keywords: Kenaf, Quality ratio, Tensile strength, Yarn

Introduction

Kenaf (*Hibiscus cannabinus* L.) is a multi-purpose fibre crop that can provide income to farmers and contributes to a nation's earnings. The crop is currently attracting the interest of both the farmers and industrialists in Nigeria because of its food, environmental, industrial, and economic benefits (Balogun *et al.,* 2009). It is cultivated for fibres for use in the industries as well as artisans in their cottage factories (Webber *et al*., 2002). All the harvestable components of a kenaf plant have industrial importance. The crop still has many undiscovered potentials uses especially for its mechanical characteristics. Many research are ongoing to further discover more of the potentials of kenaf

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for use in the industries (Webber and Bledsoe, 2002; Alexopoulou and Monti, 2013). Kenaf is found to have more potentials when spun into yarn to produce several products ranging from clothing or apparel to various agricultural applications and structural facilities such as in housing and transportation.

Two types of fibres, namely bast and core fibres, exist for different uses. The bast fibre is obtained from the bark while the core fibre is from the inner (pith) core of the plants. Kenaf has a high growth rate, growing to a height of 4 to 6 m. The dry matter yield averages of about 6 to 10 t ha^{-1} and improved varieties reaching up to 30 t ha^{-1} have been reported in Malaysia (Masnira *et al*., 2015). On the contrary, a yield of only 19.6 to 25.5 t ha^{-1} representing 4.6 to 5.5 t $ha-^{1}$ is realizable in sub-Saharan Africa (FAO, 2019). In Nigeria, the farmers have explored the potentials of two registered commercial varieties, yet the yield is still low despite government intervention on the availability of incentives to farmers to further encourage them on the continuous production of higher yield. Similarly, artisans and industrialists have exhaustively used the available varieties for fibre-based products with the desire to harness the utilization of kenaf when spun to yarn.

Mechanical properties of fibres have been reported to determine the characteristics of the spun yarn with such fibres (Chalachew, 2014). Farmers and industrialists have therefore developed a strong desire for varieties with improved yield and enhanced fibre good quality for yarn production. However, despite the global high relevance of kenaf when processed into fibre, information on its mechanical properties for industrial exploitation is meagre. There is also a dearth of information on the mechanical quality pattern of the fibres of the frontline accessions kenaf in Nigeria that processors, artisans and industrialists can use to optimize usage of the crop. Relationships among agronomic and fibre mechanical quality traits will assist the farmers in their choice of varieties to plant and help the breeders in improvement of the crop for fibre quality. The objectives were to determine the agronomic performances and industrial quality of fibres of 14 genotypes of kenaf as well as establish the relationship between their performances and mechanical qualities.

Materials and methods

Agronomic evaluation of the crop

A total of 12 accessions with two commercial varieties (IFEKEN 400, IFEKEN DI-400) of kenaf were selected for evaluation under rain at Institute of Agricultural Research and Training, Ibadan station in 2017 and 2018. Seeds of each genotype were planted in a four-row plot, 5 m each, at a spacing of 20 cm within row and 50 cm between rows in each of the two plantings. The trial was laid out in randomized complete block design with three replications. Four seeds were sowed per hill and thinned to 2 per stand to adjust the population density to 100,000 plants ha^{-1} at 3 weeks after planting (WAP). The plants were dosed with 60 kg ha^{-1} NPK fertilizer at 4 WAP. The plots were kept weed free throughout the trial. Cultural practices were applied according to the recommendation of IAR&T (2015).

Days to 50% flowering was taken for each genotype per plot. Agro-morphological data were also collected from 10 randomly selected plants per plot at 50%, flowering on plant height, as well as basal, middle and top stem diameters. The basal, middle and top stem diameters were at 5 cm above ground level, middle of the plant and 5 cm from the tip of the plant, respectively. The stem diameters were taken using vernier calipers. All the plants in each plot were harvested after data collection at 50% flowering stage and fibres were extracted from the plants by retting process after cutting at the ground level. Freshly cut kenaf plants were tagged per plot and soaked in water for 14 days to obtain the fibres. The soaked plants were removed from the water and bast fibres were stripped from main stick (core) by hand. The bast fibre was washed in clean water and weighed after drying by direct sunshine for five days using a sensitive scale.

Fibre quality analysis

Samples of bast fibre of the 14 genotypes were taken to the laboratory for quality analysis on mechanical characteristics. The samples of different categories were prepared for tension test (tensile stress, e-modulus, extension and maximum load) using Universal Mechanical Testing Machine (Instron-Series 3369) available at the Centre for Energy Research Development, Obafemi Awolowo University, Ile-Ife. Samples were also spun into yarn and subjected to test for the determination of the quality ratio of the spun yarn. The set up was done in a completely randomized design with three replications. Data were also obtained on the tensile strength of yarn and yarn count of the samples.

Data analysis

Agro-morphological data collected on the field were pooled across the two years and subjected to analysis of variance (ANOVA) with the mechanical data taken in the workshop using SAS (2009). The Least Significant Difference was used to separate the means in both cases. Correlation coefficients were used to detect the relationships among the agronomic and mechanical characters. Bar charts were also employed to explain the variations among the genotypes with respect to their mechanical properties.

Results

Variation in phenological and agro-morphological characteristics of the genotypes

Significant variation due to genotypes, environments and genotype × environment (G × E) existed in days to 50% flowering, plant height, basal, middle and top stem diameters as well as bast and core fibres yields of the 14 genotypes evaluated in 2017 and 2018 (Table 1). The coefficients of variation (CV) ranged from low (8.38 %) to moderately high (19.48 %) indicating the closeness of the values among the cultivars and a high level of similarity in the performance of kenaf varieties. Accessions SAU75-414 (97.2 days) and SLE154-2 (91.0 days) had the highest number of days to flowering while SLE14-13 and GS14-52 were among those with the least days to 50% flowering which were 65.2 and 63.8 days, respectively (Table 1).

Plant height values of less than 310 cm were found in the accessions AU 24524 (307 cm), 2QQ 13 (306 cm), SLE14-1 (305 cm) and ACG33-293 (302 cm). The basal, middle and top stem diameters of SAU75-414, IFEKEN DI-400, IFEKEN 400 and GS14-52 were consistently higher than those of other genotypes. It was found that SAU75-414, IFEKEN DI-400, IFEKEN 400, GS14-52 and AEHC-3 had bast fibre yields statistically higher than the mean while SAU75-414 and GS14-52 had the highest core fibre yields.

Strength characteristics of the kenaf fibres

The values and rank of the mechanical properties of the bast fibre were shown in Table 2. Five genotypes which included the identified three promising accessions and two existing varieties were ranked best based on the strength characteristics. The promising accessions were SAU75-414, GS14-52 and AEHC-3 while IFEKEN DI-400 and IFEKEN 400 were the two existing high fibre yielding varieties in Nigeria. They had values comparatively higher than others in all the parameters. However, only one of the promising accessions (SAU75-414) has a higher capability to resist toughness than IFEKEN 400 with young modulus value of 22.5 MPa. Accession SAU75-414 had the highest load carrying capability of 7.21 N followed by GS14-52 with 6.53 N while AU2452-43, SLE14-13, 2QQ 13 and AU24524 were with the least load carrying capacity was positive and highly significantly correlated with plant height (0.721^{**}), base diameter (0.643^{**}), bast fibre yield (0.677^{**}), core fibre yield (0.673**) and tensile strength (0.713^{**}).

Table 1. Performance of the selected 14 genotypes of kenaf evaluated on-station in 2017 and 2018 growing seasons

Genotype	Day to 50% flowering (days)	Plant height (cm)	Base stem diameter (cm)	Middle stem diameter (cm)	Top stem diameter (cm)	Fibre yield ($t\ ha^{-1}$)	
						Bast	Core
2GQQ 13	73.15	306.23	3.28	2.30	1.63	2.79	4.20
AEHC-3	75.00	314.00	3.55	2.00	1.71	3.03	4.26
AU 24524	76.35	307.00	2.82	1.91	1.43	2.68	3.73
SLE14-2	91.00	319.68	3.04	2.50	1.65	2.78	3.93
AU75-192	73.00	311.87	3.43	2.36	1.64	2.54	3.42
AU75-452	88.65	316.87	3.03	2.05	1.41	2.82	4.01
IFEKEN DI-400	78.85	312.53	3.69	2.45	1.73	3.12	4.88
IFEKEN 400	77.85	316.20	3.60	2.45	1.74	3.01	4.30
ACG33-293	72.65	302.13	2.75	2.02	1.44	2.39	3.12
AU2452-43	84.30	312.83	3.40	2.36	1.51	2.91	4.22
SAU75-414	97.15	329.75	3.79	3.08	1.91	3.31	5.11
SLE14-1	74.00	305.25	3.01	2.22	1.50	2.53	3.39
SLE14-13	65.20	317.50	3.02	2.21	1.47	2.53	3.40
GS14-52	63.80	318.72	3.63	2.31	1.82	3.06	4.40
Mean	77.93	313.61	3.29	2.30	1.61	2.82	4.03
Genotype	21.43^{***}	389.01^{*}	0.11^{**}	0.11^{**}	0.10^{**}	0.81^{***}	4.82^{***}
Year	1922.04^{*}	55790.59^{***}	10.21^{***}	10.11^{***}	9.09^{**}	14.63^{***}	70.06^{***}
Genotype × year	15.40^{*}	619.49^{*}	0.07	0.07^{*}	0.07^{**}	0.63^{***}	3.08^{***}
LSD	1.84	9.25	0.14	0.12	0.08	0.09	1.01
CV (%)	8.38	14.37	15.07	10.89	10.79	19.48	18.62

*, **, *** significant at $P < 0.05$ or $P < 0.01$ or $P < 0.01$, respectively

Table 2. Correlations of the core and bast fibres yields with the industrial properties of the kenaf genotypes

	Plant height	Base stem diameter	Bast fibre yield	Core fibre yield	Tensile strength	E-modulus	Extension value
Base stem diameter	0.577^{*}						
Bast fibre yield	0.684^{**}	0.842^{***}					
Core fibre yield	0.627^{*}	0.819^{***}	0.978^{***}				
Tensile strength	0.290	0.464	0.534^{*}	0.606^{*}			
E-modulus	0.721^{**}	0.643^{**}	0.677^{**}	0.673^{**}	0.713^{***}		
Extension value	-0.543^{*}	-0.350	-0.199	-0.110	0.252	-0.302	
Maximum loading	0.180	0.444	0.431	0.495	0.906^{***}	0.686^{***}	0.204

Spun yarns characteristics

Result showed that significant variations existed in all the quality parameters of the spun yarn (Figure 1). The highest tensile strength of about 20 lbs/spy was found in IFEKEN DI-400 with the tensile strengths of GS14-52 and SAU75-414 significantly similar to IFEKEN DI-400, the quality ratios of the spun yarn ranged from 32.89% to 83.81% with S14-52 and SAU75-414 having the highest values (Fig.2). Accessions with the low yarn count such as AU75-452, AU 24524 and IFEKEN 400 had quality ratio lower than GS14-52 and SAU75-414 which had higher yarn counts.

Relationships among the agronomic and mechanical properties of the kenaf

Plant height of the crop had positive significant correlations with both the bast and core fibres yield, and e-modulus (0.721**) but negative significant correlation with extension value (-0.543*) (Table 2). Similarly, the base diameter, bast fibre and core fibre had highly significant correlations with one another. It was also found that tensile strength had positive significant correlations with bast (0.534*) and core (0.606*) fibres, thus the tensile strength of the fibre can be determined during the plant growth on the field using plant height. E-modulus.

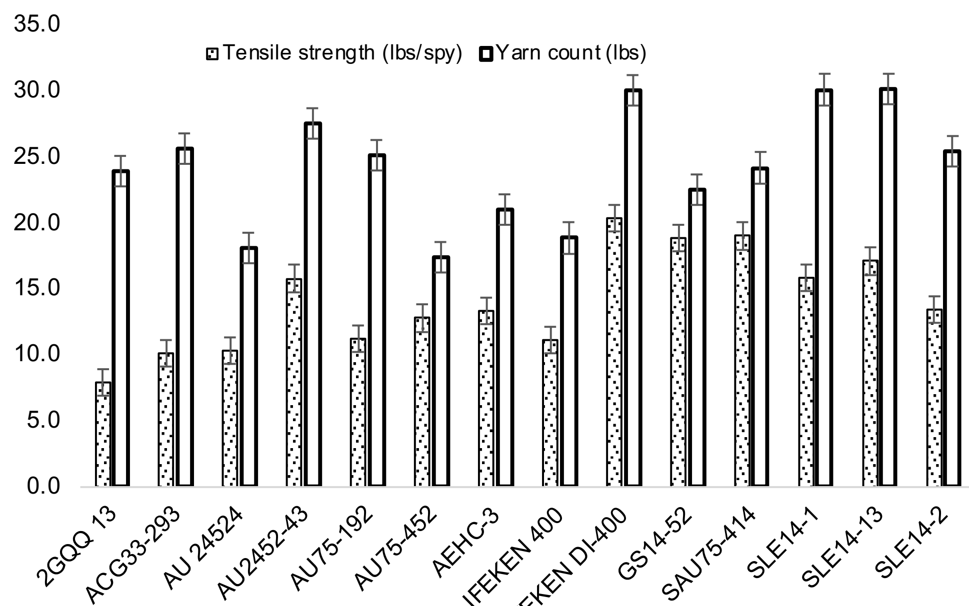

Figure 1: Comparison of tensile strength and yarn count of
14 genotypes of kenaf eenaf evaluated in 2021

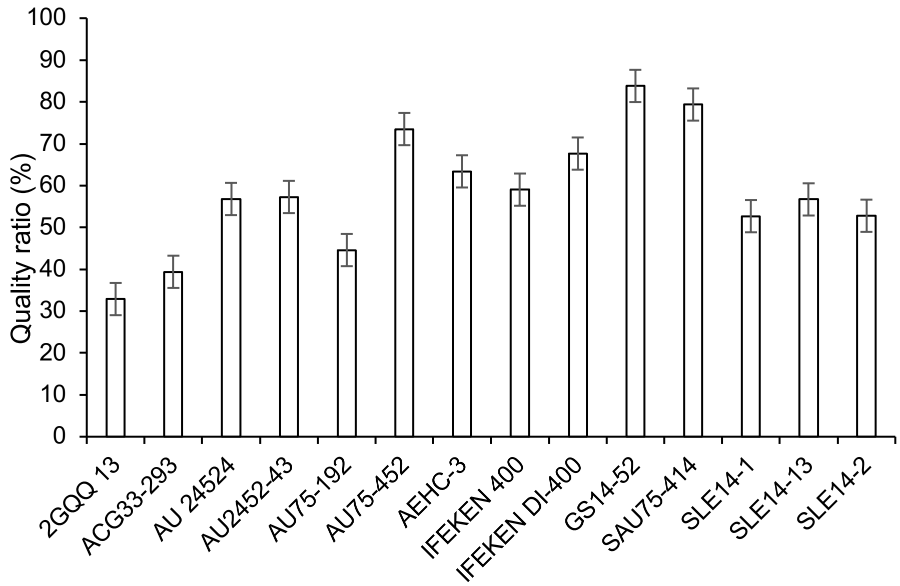

Figure 2: Comparison of quality ratio fo 14 genotypes of kenaf tested in 2021

Discussion

The significant variation due to genotype suggests that each of the cultivars possesses individual genetic potential that differs from another. Moreover, the significance due to the effects of environment and G × E prove there is differential response of the cultivars to change in the environment. The change in response of crop varieties to change in environments have been reported in several reports (Fernando, 2013; Elroda *et al.,* 2013; Bourguignon *et al.*, 2017). Ogunniyan (2016) also observed in a study involving agro-morphological characteristics of kenaf that the growth of the plant is ambiguous in nature. Morphology of kenaf varieties is closely related, thus variation in varietal performance of the crop is minimal. The CV was moderately high in the bast, and core fibre yields because they are estimated yield parameters.

The two accessions with the highest days to flowering also had the highest plant height which was either greater or equal to 320 cm. These set of accessions could be graded as late maturing in accordance with reports of Ogunniyan (2016). There are indications that SAU75-414 had values that were higher than the means for all the parameters and performed better than any of the two commercial varieties namely IFEKEN 400 and IFEKEN DI-400 in all the traits. The values for the SAU75-414 were however significantly higher than the values for the highest performing commercial variety (IFEKEN DI-

400). The results further showed that accession GS14-52 is also promising to consider the seven traits on which the genotypes were evaluated. AEHC-3 had plant height, basal and top diameters, and core fibre yield that were significantly similar to that of the better commercial varieties (IFEKEN DI-400). The results also showed that the bast fibre yield of AEHC-3 was not different from those of the two most promising accessions as well as the one of the commercial varieties (IFEKEN 400). The results have consistently showed SAU75-414, GS14-52 and AEHC-3 superior to other genotypes including the two commercial varieties.

The result of the strength charactrisitcs of the kenaf fibres indicates that SAU75-414 can resist deformation better than the existing commercial kenaf varieties which makes kenaf more useful for several industrial applications. It was found that the load carrying capacity of 2QQ 13 and SAU75-414 were higher than the highest value reported among currently existing commercial varieties in Nigeria (Atta *et al.*, 2021). The accessions, especially SAU75-414, have proved superiority over existing commercial varieties in terms of mechanical properties.

The highest tensile strength of IFEKEN DI-400 is likely to be due to the high value of yarn count as supported by the reports of Aisyal *et al.* (2018) on the relationship of yarn count and strength. However, some accessions with low yarn count were seen to have better strength values which indicates improvement on kenaf varieties. The parameters were found to be least in 2QQ 13, ACG33-293 and AU 24524, each of which had about 10 lbs/spy. Yarns with high strength are preferred by factory operators, artisans and processors because such yarns are malleable and can be further processed into various desirable end products (Samad *et al.*, 2002). This factor indicates GS14-52 and SAU75-414 with IFEKEN DI-400 are suitable for the industries. On the contrary, the results show that the yarn count was least in AU75-452, AU 24524 and IFEKEN 400 while they had low tensile strength. The AEHC-3, GS14-52 and SAU75-414 which had high tensile strength performed better than the remaining genotypes with high yarn counts. These results are to a certain extent in consonance with the findings of Shah *et al.* (2013) which indicated that yarn count is always directly proportional to tensile strength especially when GS14-52 and SAU75-414 are considered.

On the quality ratio of the different accessions of kenaf, it was reported that yarn count is inversely proportional to the quality of spun yarn (Aisyal *et al.* (2018), therefore, quality ratio of GS14-52 and SAU75-414 in this study shows that certain varieties of kenaf can have high yarn count as well as high quality ratio. Nevertheless, this finding might be due to the methods of processing of the fibres, hence processing methods need to be considered in the future studies. Considering the yarn suitability for use in the industry in relation to quality ratio, accessions GS14-52, SAU75-414, AU75-452, IFEKEN DI-400, AEHC-3 and IFEKEN 400 appear promising due to their quality ratios which were greater than 60%.

The result on the relationships among the agronomic and mechanical properties of the kenaf emphasizes the strong reliance of the fibres' yield on both the plant height and stem diameter. The taller the plant and wider its girth, the higher the fibre yield. The dry matter in the plant is expected to be determined by the biomass which constitutes the plant that accrue to the yield. Similar observations have been made in some studies where the dependence of bast and core fibre yields on both the plant height and stem diameter has been reported (Ogunniyan *et al.,* 2016; Olanipekun *et al*., 2021). Based on the result of this study, the tensile strength and E-modulus prove themselves as versatile tools of selection since they had very high association with other both agronomic and quality parameters.

In conclusion, the SAU75-414, GS14-52 and AEHC-3 combined high fibre yield with high fibre and yarn quality greater than the existing and commercial varieties of kenaf. In view of the properties, the accessions are recommended for further experimentation for improvement on both yield and quality of the fibres for use of farmers and industrialists.

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