Morphological characterization of 51 kenaf (*Hibiscus cannabinus* L.) accessions in Nigeria

Caracterización morfológica de accesiones de kenaf (*Hibiscus cannabinus* L.) en Nigeria

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ABSTRACT

Fifty-one accessions of *Hibiscus cannabinus* L. were evaluated for 14 morphological parameters in Ibadan, southwestern Nigeria. The correlation matrix of the quantitative parameters was used to perform principal components (PC) analysis to understand the relative contributions of each trait to the variation observed, while Fastclus procedure was used to cluster the accessions into five groups. The most widely varied traits were earliness, number of apical branches and leaf lobes per plant with 483.3, 97.9 and 60.6% coefficients of variation, respectively. Correlation between fibre yield parameters and earliness was negative and significant. The first three PCs explained 66.23% of the variation, with only number of apical branches not highly weighted by any of the PC. The five clusters were distinguished by earliness, plant height, fibre yield, stem spine density, stem girth and apical branching. The variation was seen as a manifestation of environmental response in addition to the genotypic constitution. These results will aid in parent selection during breeding programmes.

Key words: *Hibiscus cannabinus*, cluster analysis, principal component analysis, earliness, fibre yield

RESUMEN

Se evaluaron 51 accesiones de *Hibiscus cannabinus* L. para 14 caracteres morfológicos en Ibadan, Suroeste de Nigeria. La matriz de correlación de los caracteres cuantitativos se usó para realizar el análisis de componentes principales para entender las contribuciones relativas de cada carácter a la variación observada, mientras el Procedimiento Fastclus se usó para agrupar las accesiones en cinco conglomerados. Los caracteres más ampliamente variables fueron precocidad, número de ramas apicales y lóbulos foliares por planta con coeficientes de variación de 483,3; 97,9 y 60,6%, respectivamente. La correlación entre los caracteres de rendimiento de fibra y precocidad fue negativa y significativa. Los primeros tres componentes principales explicaron 66,23% de la variación, sólo el número de ramas apicales no tuvo una alta evaluación por los componentes principales. Los cinco grupos fueron distinguibles por la precocidad, altura de planta, rendimiento de fibra, densidad de la espina del tallo, circunferencia del tallo y ramificación apical. La variación fue vista como una manifestación de la respuesta ambiental en adición a la contribución genotípica. Estos resultados ayudaran en la selección de padres durante los programas de mejoramiento.

Palabras clave: *Hibiscus cannabinus*, kenaf, análisis de agrupamiento y de componentes principales

INTRODUCTION

The importance of kenaf (*Hibiscus cannabinus*) as the most viable replacement for trees in paper production (Rymsza, 1999), among other products has been emphasized (Martin, 1996; Stricker *et al*., 2001). An annual plant, native to Central Africa (Scott and Taylor, 1988), 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 (Rymsza, 1999). Under ideal conditions kenaf will grow to a height of five to six meters in six to eight months and produce up to 30 t/ha of dry stem material (Wood, 2003). Kenaf yields approximately three to five times as much fibre as southern yellow pine (LeMahieu *et al*., 2003).

In Nigeria, environmental degradation is increasing due to increase in oil production (EIA, 2003) and felling of trees in forests. The need to develop a renewable resource that will provide raw materials in a sustainable manner has therefore led to the recent acceptance of kenaf as an industrial crop.

In addition, the ban on use of synthetic packaging materials in importation and exportation of agricultural produce has necessitated the use of natural fibres like kenaf. Despite its importance, Africa produces only 2.91% of the global production of kenaf (FAO, 2003).

Although kenaf is not new to Nigeria, the plan to cultivate it on a commercial scale for fibre production, and its high intra-cultivar variation has made it necessary to evaluate the available germplasm in terms of morphological and agronomic characters. Identification of kenaf varieties and understanding of genotypic characteristics and relationships is limited in Nigeria, and thus significantly hinders their effective utilization. This study was conducted to understand the morphological characterization of kenaf accessions in Nigeria and use this information to aid in varietal selection.

MATERIALS AND METHODS

Fifty-one accessions of kenaf used in this study were obtained from the germplasm collection of the Institute of Agricultural Research and Training (IART.) Ibadan, Nigeria. In June 2003, the accessions were planted in rows 6 m in length, at a spacing of 25 cm between and 10 cm within rows. One accession was planted per row. Eighty days after planting, a descriptor list was prepared based on the wide diversity noticed in the field. Twelve quantitative traits and two qualitative traits were used to analyse the diversity. The quantitative traits are incidence of flower initiation at 80 days after planting (FL%), plant height (PL), maximum number of leaf lobes per plant (NLL), number of nodes per plant (NND), length of third internode (INTL), number of apical branches per plant (APB), density of spines on the stem (SSD) on a scale of 1(low) to 3 (high), petiole length (PL), stem girth (SG), core, bast and total fibre yield per plant (CORE, BAST, FIBRE, respectively) on a dry weight basis. The two qualitative traits were stem and petal colours. Measurements were made on a sample of six plants per accession for each parameter. The core, bast and total fibre yields were determined at 100% flowering by cutting the whole stem and weighing. The outer portion (bast) was then peeled off and weighed, while the remaining inner core was also weighed.

The correlation matrix of the 12 quantitative characters was used to conduct principal components analysis (PCA) using SAS (1998). The eigenvalues as a proportion of the total variance gave the relative contribution (%) of each principal component to the observed variation. Variables that had extreme high or low coefficients for each component were noted. The fastclus procedure of SAS was used to cluster the lines into five groups.

RESULTS AND DISCUSSION

A high level of variability was observed among the 51 accessions in the field (Table 1). The wide range observed for many of the parameters shows the complexity in describing the different accessions of kenaf. The most widely varied quantitative characters were APB, FL% and NLL with 483.2, 97.9 and 60.6% coefficients of variation, respectively. APB ranged from 0 to 6 while NLL ranged from 1 to 7. INTL and SSD had 38.2 and 38.3% coefficients of variation, respectively. Low

Table 1. Mean values, ranges and coefficients of variation for 12 quantitative characters of 51 accessions of kenaf (*Hibiscus cannabinus* L.) in Nigeria in 2003.

Variable	Mean	Range	CV (%)	Standard Deviation
Flowering at 80 days (%)	51.1	0.0-100.0	97.9	50.1
Plant height (cm)	163.4	60.1-299.6	16.5	27.0
Number of leaf lobes	4.4	1.0-7.0	60.6	2.7
Number of nodes	36.1	19.0-56.0	20.2	7.3
Internode length (cm)	4.6	1.8-12.5	38.2	1.8
Number of apical branches	0.1	0.0-6.0	483.2	0.7
Stem spine density	2.2	1.0-3.0	38.3	0.8
Petiole length (cm)	15.3	7.2-26.6	19.2	2.9
Stem girth (cm)	1.1	0.6-2.0	18.3	0.2
Bast yield (g)	95.0	37.3-227.7	34.01	32.3
Core yield (g)	140.9	58.6-335.1	35.62	50.2
Total fibre yield (g)	241.2	103.4-530.7	33.70	81.3

variations were recorded for PH, SG and PL and they were 16.5, 18.3 and 19.2 cm, respectively. BAST, CORE and FIBRE yield ranged from 37.3 to 227.7g, 58.6 to 335.1g and 103.4 to 530.7g per plant, respectively. Wide variability for morphological and agronomical characters in collections of *Hibiscus cannabinus* has been reported (Siepe *et al*., 1997). Our findings also agree with previous reports that days to flowering vary significantly among kenaf varieties (Cheng *et al.*, 2002).

Table 2 shows that PH was positively and significantly correlated with INTL, SSD, PL, SG, BAST, CORE and TOTAL fibre yields. Correlations of percent incidence of flowering at 80 days after planting (FL%) with each of PH, INTL, PL, SG and the three yield parameters (BAST, CORE and FIBRE) were negative and significant. Total fibre yield and each of plant height, number of nodes per plant (NND), INTL, SSD, PL, SG core and bast yields were positively and significantly correlated.

Significant, negative correlations between percent incidence of flowering at 80 days after planting and each of plant height, internode and petiole lengths and stem girth suggest that both set(s) of variables contributes equally to the grouping of the accessions. It also indicates that early maturity results in short plants with shorter internode and petiole lengths and small stem girth, the latter being indicators of low fibre yield per plant (Webber *et al.*, 2002) since vegetative growth is reduced when flowering is initiated. In addition, the maturity period has been reported to be an indication of sensitivity of kenaf varieties to photoperiod, later maturing varieties being photoinsensitive relative to early maturing ones when planted in the tropics (Webber *et al.*, 2002). Photoinsensitive varieities are therefore preferred for the tropics, due to their relatively late flower initiation and high fibre yields (Dempsey, 1975; Dryer, 1967) as found with members of cluster 3 in this study. Significant, positive correlations between PH and each of INTL, SSD, PL and SG suggest that when PH is used as a descriptor, these four latter traits become redundant in grouping the accessions.

A total of 66.23% of the total variance was explained by the first three principal components (PCs) (Table 3). PC1, PC2 and PC3 explained 39.66% and 15.06% and 11.51% of the variation respectively. PC1 gave higher loadings to FIBRE, BAST and CORE yields, SG and PH while PC2 was dominated by NNDS, PL, INTL, SSD and PH. NLL, FL% and INTL were weighted high by PC3. APB was weighted low by the 3 principal components and was therefore redundant in the variation observed.

A more specific grouping into five, using fastclus procedure of SAS revealed that clusters 1, 2, 3, 4 and 5 contained 2, 16, 2, 12 and 19 accessions respectively (Table 4). The two members of cluster 1 had flowered by 80 days after planting. This was followed by clusters 4, 2 and 5 in which 56.9%, 52.1% and 44.2% of the accessions flowered by 80 days after planting respectively while only 25% of cluster 3 had flowered at the same time. In contrast, PH and SG were in decreasing order of clusters 5, 2, 3, 4 and 1. Accessions belonging to clusters 4 and 5 had the highest number of apical branches while members of cluster 1 were completely unbranched.

Table 2. Pearson correlation matrix for quantitative variables of 51 accessions of kenaf (*Hibiscus cannabinus* L.) in Nigeria in 2003.

	FL% †	PH	NLL	NND	INTL	APB	SSD	PL	SG	BAST	CORE
PH	-0.59***	1.00									
NLL	0.16	-0.24	1.00								
NND	-0.04	0.04	0.13	1.00							
INTL	-0.36**	0.30*	-0.14	0.49***	1.00						
APB	-0.16	0.10	0.20	0.02	-0.02	1.00					
SSD	-0.15	0.29*	-0.01	0.56***	0.51***	-0.06	1.00				
PL	-0.29*	0.55***	0.10	0.00	-0.16	0.20	0.12	1.00			
SG	-0.28*	0.63***	-0.05	0.39**	0.21	0.13	0.29*	0.54***	1.00		
BAST	-0.36*	0.54**	-0.14	0.33*	0.20	-0.02	0.39**	0.53***	0.62***	1.00	
CORE	-0.28*	0.37**	-0.04	0.49***	0.34*	-0.03	0.46***	0.31*	0.45**	0.85***	1.00
FIBRE	-0.28*	0.43**	-0.08	0.45***	0.29*	-0.03	0.46***	0.40**	0.52***	0.94***	0.97***

† For acronyms see Material and Methods
*, **, ***: Coefficients are significant at p=0.05, 0.01, 0.001 respectively.

Bast, core and total fibre yields were highest in Cluster 3 and lowest in cluster 1 while clusters 2, 5 and 4 were medium in these traits. Stem colour varied from green through brown to purple in all the clusters. Petals of clusters 1 and 3 were yellow while those of accessions belonging to cluster 2 ranged from light yellow through yellow to dark yellow. Cluster 4 had some accessions with yellow petals and others with light yellow or purple petals. In cluster 5, the petals were either yellow or dark yellow (Table 5).

Table 3. Principal component scores for 12 variables of 51 accessions of kenaf (*Hibiscus cannabinus* L.) in Nigeria in 2003.

Descriptor	PC1	PC2	PC3
Flowering at 80 days	-0.23	0.23	0.40
Plant height	0.32	-0.33	-0.30
Number of leaf lobes	-0.06	-0.04	0.63
Number of nodes	0.24	-0.46	0.19
Internode length	0.22	0.39	-0.37
Number of apical branches	0.03	-0.23	0.20
Stem spine density	0.27	0.36	-0.03
Petiole length	0.25	-0.47	0.24
Stem girth	0.34	-0.18	0.09
Core yield	0.41	-0.09	0.11
Bast yield	0.39	0.14	0.15
Total fibre yield	0.41	0.07	0.16
Eigenvalues	4.76	1.81	1.38
% total variance	39.66	15.06	11.51

Thus, the distinguishing features of cluster 1 are early maturity; short plants, small stem girth and low fibre yield with no apical branches and few spines on the stems. Members of cluster 2 are characterized by medium maturity, tall plants, big, spiny stems and medium fibre yield. Members of clusters 3 have the highest fibre yield, are late to mature, with big, spiny stems and apically branched. In clusters 4 and 5, the accessions are average in all the descriptor parameters.

The differential performance of the accessions in this study may be a function of environmental adaptation in addition to the genetic component (Ogunbodede and Ajibade, 2001). Also, kenaf has been reported to have a wider range of adaptation to environmental factors than other fibre plants cultivated for commercial use (Dempsey, 1975). Thus, performance of the accessions especially in relation to the quantitative traits may be location-specific. Breeding for desirable traits will therefore be specific to environment. Members of cluster 3 are candidates in breeding for increased fibre yield due to their relative tallness, high yield and photoinsensitivity. However, since apical branching is

Table 4. Accesions of kenaf (*Hibiscus cannabinus* L.) forming five clusters in Nigeria in 2003.

Clusters				
1	2	3	4	5
Sf-459 Ifeken100-Mut30	S-69-J-113 V210019	A-60-282	Cuba	Au-42
	S-72-45-9	5108/14	V2400	Ballagade7
	G-45		25-Asm	Y-6987
	A-60-284		V1100	V1200
	Au-194		Au-72	A-63-511
	A2159		Bs-1	A-60-280
	S-72-49-9		Au-24	Ac-313
	Au-75		Local34	575-1-17
	Local35		Hc-583	Au-15
	Unknown-1		Au-191	1892-10
	8a		Tainung2	Au-71
	Au-51		Cuba-20mut	Local36
	S-72-78-18-10			V1400
	Local33			S-72-78-18-3
	Fanek			Amc-1081
				Bg-58-7
				Cuba2032
				Lac103
				8b

undesirable in kenaf for ease of harvesting, cluster 3 members can be crossed to cluster 1 accession to incorporate non-branching trait. Although identification of individual varieties will be enhanced by molecular characterization (Cheng *et al.*, 2004), true varieties will be delineated by the traits for which they are known, whether molecular or morphological.

CONCLUSION

The most widely varied traits were FL%, APB and NLL with 483.3, 97.9 and 60.6% coefficients of variation, respectively. Correlation between fibre yield parameters and earliness to maturity was negative and significant. The first three PCs explained 66.23% of the variation, with only number of apical branches not weighted high by any of the principal components. The 5 clusters were distinguished by earliness to maturity, plant height, fibre yield, stem spine density, stem girth and apical branching. The variation was seen as a manifestation of environmental response in addition to the genotypic constitution. These results will aid in parent selection during breeding programmes.

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Table 5. Means of five clusters of accessions of kenaf (*Hibiscus cannabinus* L.) in Nigeria in 2003.

	Clusters				
Trait	1	2	3	4	5
Flowering at 80 days (%)	100.00	52.08	25.00	56.94	44.21
Plant height (cm)	110.27	167.82	164.79	150.84	173.18
Number of leaf lobes	6.08	4.31	5.25	4.56	4.25
Number of nodes	36.50	38.19	42.42	32.38	35.85
Internode length (cm)	3.87	4.53	6.97	4.12	4.76
Number of apical branches	0.00	0.04	0.17	0.21	0.18
Stem spine density	1.75	2.29	2.58	1.90	2.18
Petiole length (cm)	11.60	15.81	14.80	14.20	15.90
Stem girth (cm)	0.81	1.20	1.07	1.03	1.19
Bast yield (g)	47.43	113.34	134.37	72.89	95.40
Core yield (g)	87.39	165.71	231.66	112.67	135.35
Total fibre yield (g)	138.90	285.54	373.35	189.94	235.74
Stem colour	Variable	Variable	Variable	Variable	Variable
Petal colour	Yellow	Yellow, Light yellow, Dark yellow	Yellow	Yellow, Light yellow, Purple	Yellow, Dark yellow
Number of accessions (51)	2	16	2	12	19

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