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Research Article

FORAGE YIELD AND QUALITY OF KENAF (*HIBISCUS CANNABINUS* L.) FOR CONSUMPTION AS RUMINANT FEED

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ABSTRACT

This study was carried out to evaluate 40 kenaf accessions for forage yield and quality at Universiti Putra Malaysia in 2009. Forage yield and quality traits were measured at the initial flowering stage. The kenaf accessions showed highly significant variation for most of trait studied. Plant dry matter yield ranged from 5286 kg ha^{-1} (Everglade 41) to 16801 kg ha^{-1} (IX51).

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Crude protein content of the leaf ranged from 13.6% (G46) to 22.3% (75-71) and it was higher than stem which is ranged from 2.7 % (FDW-75-8) to 7.5 % (K465/117). Leaf ADF were significantly different among the accessions, where FDW 75-82 gave the highest (24.7%) while C74 gave the lowest (16%). Broad-sense heritability was highest for days to flowering (h_B^2= 97.6%) and lowest for CP of stem (h^2= 11.2 %). In conclusion IX51, Cuba2032 (with high yield), 75-71 and Everglade 41 (with high CP content), were the most superior among the 40 kenaf accessions evaluated and were found highly potential for forage. These accessions can therefore be utilized in further breeding programs to produce new kenaf varieties with high feed value for ruminant consumption.

Keywords: kenaf; forage; crude protein (CP); acid detergent fiber (ADF); ruminant feed.

1. INTRODUCTION

Kenaf (*Hibiscus cannabinus* L.), which belongs to the Malvaceae family, is an annual herbaceous crop native to central Africa. Kenaf has a wider range of adaptation to climatic and soil conditions compared to other fiber plant species grown for commercial use. It is grown in many countries for fiber, but found potential as a source of feed for ruminant animals (Webber et al., 2002; Webber and Bledsoe, 2002). The main aim of a plant breeder for any crop improvement program is to produce genotypes which are consistently high yielding over a range of environments. Kenaf forage yield which include stem and leaf yield is referred to the total above ground plant material at the vegetative growth stage. Quality characters are also important in plant breeding and vary in different plants. A major component used for evaluating forage quality is the crude protein (CP) content. Kenaf leaves are the main source of proteins which are comprised of amino acids that are essential for animal growth and milk production. According to earlier study, crude protein in kenaf leaves ranged from 14% to 34%, stem crude protein ranged from 2% to 12%, and total crude protein ranged from 6% to 23% (Clark and Wolff, 1969). It is crucial to harvest kenaf at the early growing stage to obtain the high levels of protein because as the plant matures, the stem becomes more fibrous, the leaf to stem ratio decreases and the protein level drops (Bhardwaj and Webber, 1994). Researchers have reported differences among cultivars for leaf biomass percentages and plant protein yields (Webber *et al.*, 2002). Information on performance of kenaf varieties for forage utilization is important before any breeding program could be initiated. Development of high forage yield and quality for animal feed is the main objective of breeding program in kenaf. Hence, the present experiment was conducted to evaluate performance of 40 kenaf accessions and consequently to select the best kenaf accessions for high yield and suitable forage quality for ruminant consumption.

2. MATERIALS AND METHODS

2.1 Plant Materials and Location of Experiment

Forty kenaf accessions comprising of cultivars, landraces and breeding lines, originating from different countries were used in this study. Among the accessions in the study, V36 was selected as the control variety since it is widely used for kenaf production in Malaysia. Planting was carried out on 25 June 2009 at Field 10, Universiti Putra Malaysia (UPM), Serdang, Selangor, Malaysia (2^{o} 59' N, 101^{o} 42' E, 12 m above sea level).

2.2. Experimental Design

The experiment was conducted in a randomized complete block design (RCBD) with three replications. Each replication comprised of 40 plots.

2.3. Field Practices

Seeds were planted by hand. The size of each plot was 7.5 m^2 (5 m × 1.5 m), consisting of five rows, each 5 m long. The inter-row spacing was 30 cm, while the within-row spacing was 8 cm. The experimental plots were ploughed to a depth of 25 cm and rotovated twice. The compound fertilizer, Nitrophoska Green (N: P: K: 15:15:15) was applied at the rate of 90 kg ha^{-1} (N), 90 kg ha^{-1} (P_2O_5), and 90 kg ha^{-1} (K_2O), where half of the fertilizer was applied before planting and the rest was applied one month later. Lasso (2-chloro-2'-6'-diethyl-N-methoxymethyl) was used as pre-emergence herbicide. Seeds were sown by hand and were thinned to one plant per point at the three-leaf stage to obtain a planting density of approximately 416,666 plants per hectare. Weeds in the plots were controlled by hand-weeding during the growing season. The experimental field was irrigated using the overhead sprinkler system whenever necessary.

2.3 Data Collection

A plot was harvested by cutting the plants in the plot at ground level manually when 10% of the plant in each plot started to flower. Plants in the harvest area of each plot were harvested after those at 0.5 m from both ends were discarded to eliminate border effects. Data were collected from 10 individual plants for pre- and post-harvest measurements which included fresh plant yield, fresh leaf yield, plant dry matter yield, leaf dry matter yield, leaf to stem ratio, leaf-CP content, stem-CP content, leaf-ADF, stem-ADF and days to 10% flowering. All plants within the harvest area were weighed to determine fresh plant yield per plot. The yields were then converted on area basis to kg ha^{-1}. Leaves and stems were separately oven dried at 60˚C for 48 h to reach constant weight and the dry weights of the plant components were determined. For forage quality analysis the variables ADF and CP content were used. ADF reflects digestibility, while CP reflects nutritive quality. Leaf and stem samples were ground and screened through a 1.0 mm screen, prior to use in the analyses of forage quality. CP content was measured using the method of the Association of Official Analytical Chemists (AOAC, 1990), while ADF was determined by the method of Van Soest (1994).

2.4. Statistical Analyses

Data were analyzed using ANOVA procedure in the Statistical Analysis System (SAS) (SAS Institute Inc., 2007). Mean comparisons were made using Least Significant Difference (LSD). The broad-sense heritability (h^2_B) values for traits were estimated using the variance components method suggested by Falconer and Mackay (1996). Phenotypic correlations among traits were determined using the formula by Gomez and Gomez (1984), and calculated using the Statistical Analysis System (SAS) (SAS Institute Inc., 2007). The biplot analysis is a graphical data analysis method which is a useful tool for visualization of the relationship between genotypes and traits. It allows the visual appraisal of the large data matrices structure. The biplot analysis was conducted based on the main principal components obtained from principal component analysis (PCA) by the singular value decomposition (SVD) of the traits studied. Biplot can show inter-unit distances and indicates clustering of units as well as display variances and correlations of the variables (Greenacre, 2010). The quantitative data collected in the present research was used to reveal the association of the traits with the kenaf accessions. The data were standardized and were subjected by PCA via SVD using SAS PROC GPLOT procedure. The biplot graph was then used to visualize the association between the traits measured and the accessions (Yan & Rajcan, 2002). Rubio *et al*. (2004) reported that biplot analysis can be used for graphical display of the correlations among the traits.

3. RESULTS

3.1. Effects of Kenaf Accessions on Forage Production

Results of the ANOVA revealed that block effects were found to be significant at $p \leq 0.01$ for plant dry matter (DM) yield and leaf DM yield, while they were significant at $p \leq 0.05$ for stem DM yield, stem diameter and stem crude protein content (Table 1).

The effects of accessions were significant at $p \leq 0.01$ for plant DM yield, leaf DM yield, plant height, leaf to stem ratio, leaf-CP content, stem-CP content, leaf-ADF and days to flowering, while the effects were significant at $p \leq 0.05$ for fresh plant yield and fresh leaf yield. However, no significant variation was found among the 40 accessions for stem-ADF. The results indicate that there were high variations among the 40 kenaf accessions evaluated (Table 1).

3.2. Mean Performance of Kenaf Accessions for Forage Production

The mean performances of the kenaf accessions for the traits measured are presented in Table 2. The highest fresh plant yield was obtained from IX51, with a mean value of 69591 kg ha^{-1}, which were all found to be significantly higher than the control variety (V36) at 50899 kg ha-1. On the contrary, the lowest fresh plant yield was obtained with

Table 1. Results of ANOVA for traits measured on the 40 kenaf accessions evaluated

Source of variation	d.f.	Mean squares				
		Fresh plant yield	Fresh leaf yield	Plant DM yield	Leaf DM yield	Leaf to stem ratio
Blocks	2	175341330	30467590	21833090**	1452384**	77.5
Accessions	39	220604081**	40442208**	22177574**	1003717**	322.7**
Error	78	66829121	15982048	3991252	273622	55.8

** and * = significant at $P \leq 0.01$ and $P \leq 0.05$, respectively.

Table 1. (continued)

Source of variation	d.f.	Mean squares				
		Leaf-CP	Stem-CP	Leaf-ADF	Stem-ADF	Days to Flowering
Blocks	2	9.36	3.90*	8.26	2.03	2.43
Accessions	39	17.70**	2.97**	12.03**	19.37	430.27**
Error	78	3.69	0.89	5.41	27.50	4.00

** and * = significant at $P \leq 0.01$ and $P \leq 0.05$, respectively.

Mahmur, with a mean value of 28658 kg ha^{-1}, followed by G29, Everglade 41 and Everglade 71 (30967, 33034 and 34515 kg ha^{-1}, respectively). Accession 15 had the highest fresh leaf yield, with a mean of 24769 kg ha^{-1}. In contrast, K465/117 was found to have the lowest fresh leaf yield, with a mean of 7666 kg ha^{-1}. The highest plant DM yield was obtained from IX51, with a mean of 17546 kg ha^{-1}, followed by G46 (15558 kg ha^{-1}). These accessions were found to have significantly higher plant DM yield than the control variety, V36 (10201 kg ha^{-1}). The highest leaf DM yield was obtained from IX51, with a mean of 4227 kg ha^{-1}, which was found to be significantly higher than that of the control variety, V36 (3126 kg ha^{-1}). In contrast, K465/117 was found to have the lowest leaf DM yield (1384 kg ha^{-1}).

The highest leaf to stem ratio was obtained from Accession 75-71 (0.63), which was significantly higher than that of the control variety, V36 (0.45), while CQ3205 (0.14) was found to have the lowest leaf to stem ratio among the accessions evaluated. Accession 75-71 had the highest leaf-CP content, with a mean value of 22.3%, followed by Everglade 41, KK60 and Tainung 1, which were found to have significantly higher leaf-CP contents (21.6%, 20.9% and 20.6%, respectively) than the control variety, V36 (16.7 %). However, G46 produced the lowest leaf-CP (13.6%). In contrast, the highest stem-CP content was obtained from Accession 75-71 (7.3%), while the lowest was from FDW75-82 (2.7%). The highest leaf-ADF was obtained from FDW75-82 (24.7%), while the lowest leaf-ADF was from C74 (16.0%). However, no significant variation was observed for stem-ADF among the accessions. The earliest accession to flower was Tainung 2 (53.3 days), followed by KK60 and Tainung 1 (53.7 and 55.7 days, respectively). On the other hand, the late flowering accessions were found to be Cuba 2032, CQ3205 and K482-109, all with a mean value of 91.0 days.

Table 2. Mean performance of 40 kenaf accessions evaluated for quantitative and qualitative forage traits

Accession	Mean									
	PFY	FLY	PDMY	LDMY	LS	LCP	SCP	LADF	SADF	DTF
15	42314	24769	5475	1843	0.48	16.4	3.8	20.3	52.7	67.7
113	52565	15954	11128	2813	0.33	15.4	3.7	22.7	55.0	75.0
117	49336	16963	9867	2747	0.39	17.1	4.0	22.3	54.7	75.0
IX51	69591	21748	17546	4227	0.32	13.7	3.1	19.0	51.3	83.7
7-1X	50832	16378	10321	2607	0.34	16.8	3.8	18.7	52.7	67.0
75-52	53950	14501	13422	2662	0.25	14.4	3.5	22.3	56.7	76.0
75-71	52987	20641	8273	3154	0.63	22.3	7.3	16.3	54.0	55.7
A62-427	54624	19239	10482	2994	0.42	16.6	3.3	21.0	54.7	66.3
A63-478	44240	14123	7182	2132	0.43	19.3	4.8	17.3	51.0	56.7
BG52-38	41921	11792	10066	1931	0.25	14.4	3.6	18.0	50.3	85.3
BG58-14	42588	9882	10747	1810	0.20	14.6	4.2	19.0	50.3	88.0
BG53-31	43536	13176	10877	2754	0.37	16.3	5.1	19.7	55.0	83.7
BG53-42	41988	12314	8784	2206	0.34	17.7	4.2	20.0	51.0	83.0
BG61-20	43114	14152	9874	2725	0.39	17.1	4.9	24.0	55.0	76.0
C74	40352	13564	7812	1938	0.33	17.9	4.7	16.0	54.7	72.0
CQ3205	49709	7777	12729	1606	0.14	15.9	3.8	18.3	56.0	91.0
Cuba 2032	62231	15623	13782	2942	0.27	14.4	3.5	18.3	57.0	91.0
Cuba 797	49136	12324	13044	2541	0.25	13.9	4.3	21.7	54.0	88.0
Everglade 41	33034	11761	5286	1712	0.48	21.6	6.8	17.7	51.3	56.7
El Salvador	47714	13900	12511	2819	0.29	15.3	4.1	20.7	51.3	78.0
Everglade 71	34515	12938	5903	1983	0.51	18.7	4.1	18.3	54.0	55.3
FDW-75-33	42766	13175	7899	2151	0.38	16.7	3.5	20.3	58.0	65.7
FDW-75-82	48706	14828	11432	2627	0.30	13.9	2.7	24.7	52.0	73.7
G29	30967	11183	7541	2142	0.39	15.3	3.8	18.6	50.3	77.0
G46	65112	17038	15558	3089	0.25	13.6	3.3	19.7	54.7	86.7
G7	53550	13393	12928	2725	0.27	13.8	3.7	24.0	53.0	57.0
Ghana 07	52210	18512	11356	3289	0.41	20.0	4.3	20.7	51.0	75.0
Gregg	53935	15677	9478	2378	0.34	18.5	3.7	19.0	51.0	63.0
Guatmala4	40640	10049	10054	1931	0.24	13.9	3.9	21.7	54.7	88.0
HW1	41629	12807	10803	2444	0.29	14.6	3.9	18.3	53.3	83.0

K465/117	39677	7666	8384	1384	0.20	19.5	5.3	19.7	54.0	77.0
K465/118	50351	16272	12429	3387	0.38	14.9	3.7	19.3	51.7	77.0
K482/109	41406	7700	9994	1676	0.20	15.7	4.6	21.0	56.7	91.0
KK60	39552	14297	7463	2248	0.46	20.9	6.5	20.3	57.7	53.7
Mahmur	28658	10117	6668	2040	0.45	16.2	4.5	22.0	51.7	75.0
N.S.002	48017	13473	9694	2311	0.32	15.8	2.8	17.7	57.3	67.0
NSDB63-1	37270	12943	6177	1904	0.46	20.2	3.8	19.3	57.0	56.0
Tainung 1	44477	16927	8027	2623	0.48	20.6	5.4	20.3	51.7	55.7
Tainung 2	42862	15809	8193	2519	0.47	19.5	4.1	21.0	58.3	53.3
V36 (Control)	50899	17972	10201	3126	0.45	16.7	3.1	19.3	59.3	68.3
Mean	46324	14334	9985	2454	0.35	16.8	4.2	20.0	53.9	72.9
C.V.	17.6	27.8	20.0	21.3	21.1	11.5	22.5	11.6	9.7	2.7
L.S.D. ($P \leq 0.05$)	13502.0	6470.3	3512.9	862.9	13.1	3.2	1.5	3.8	8.5	5.7

Means followed by the same letter within a column are not significantly different at p<0.05. Max = maximum, Min = minimum, C.V. = coefficient of variance, L.S.D.= Least significant difference, FPY = fresh plant yield (kg ha^{-1}), FLY = fresh leaf yield (kg ha^{-1}), PDMY = plant dry matter yield (kg ha^{-1}), LDMY = leaf dry matter yield (kg ha^{-1}), LCP = leaf crude protein (%), SCP = stem crude protein (%), LADF = leaf acid detergent fiber (%), SADF = stem acid detergent fiber (%) and DTF = days to flowering.

3.3. Correlations among Traits

Results on correlation coefficients among the traits measured are presented in Table 3. Fresh plant yield was found to be positively correlated (at $p \leq 0.01$) with fresh leaf yield (r = 0.57), plant DM yield (r = 0.83) and leaf DM yield (r = 0.77).

Table 3. Correlation coefficients among traits measured on the 40 kenaf accessions evaluated

	FPY	FLY	PDMY	LDMY	LS	LCP	SCP	LADF	SADF
FLY	0.57^{**}								
PDMY	0.83^{**}	0.17							
LDMY	0.77^{**}	0.70^{**}	0.66^{**}						
LS	-0.23	0.54^{**}	-0.58^{**}	0.19					
LCP	-0.34^{*}	0.12	-0.67^{**}	-0.19	0.69^{**}				
SCP	-0.38^{*}	-0.11	-0.47^{**}	-0.23	0.44^{**}	0.72^{**}			
LADF	0.07	-0.01	0.22	0.14	-0.17	-0.34^{*}	-0.26		
SADF	0.09	-0.03	0.00	-0.04	0.01	0.05	-0.09	0.09	
DTF	0.23	-0.31	0.59^{**}	0.04	-0.75^{**}	-0.71^{**}	-0.35^{*}	0.09	-0.11

N = 120, ** and * = significant at $p \leq 0.01$ and $p \leq 0.05$, respectively, FPY = fresh plant yield, FLY = fresh leaf yield, PDMY = plant dry matter yield, LDMY = leaf dry matter yield, LS = leaf to stem ratio, LCP = leaf-crude protein content, SCP = stem-crude protein content, LADF = leaf-acid detergent fiber, SADF = stem-acid detergent fiber and DTF = days to flowering.

However, fresh plant yield was found to be negatively correlated (at $p \leq 0.05$) with leaf-CP content (r = -0.34) and stem-CP content (r = -0.38). Fresh leaf yield was found to be positively correlated (at $p \leq 0.01$) with fresh plant yield (r = 0.57), leaf DM yield (r = 0.70) and leaf to stem ratio (r=0.54). Plant DM yield was found to be positively correlated (at $p \leq 0.01$) with fresh plant yield (r = 0.83), leaf DM yield (r = 0.66) and days to flowering (r = 0.59), while it was negatively correlated (at $p \leq 0.01$) with leaf to stem ratio (r = -0.58), leaf-CP content (r = -0.67) and stem-CP content (r = -0.47). Leaf DM yield was found to be positively correlated (at $p \leq 0.01$) with fresh plant yield (r = 0.77), fresh leaf yield (r = 0.70) and plant DM yield (r = 0.66).

Leaf to stem ratio was found to be positively correlated (at $p \leq 0.01$) with fresh leaf yield (r = 0.54), leaf-CP content (r = 0.69) and stem-CP content (r = 0.44), while it was found to have negative correlations (at $p \leq 0.01$) with plant DM yield and days to flowering (r = -0.58 and -0.75, respectively). Leaf-CP content was found to be positively correlated (at $p \leq 0.01$) with leaf to stem ratio (r = 0.69) and stem-CP content (r = 0.72), but was negatively correlated with plant DM yield (r = -0.67), days to flowering (r = -0.71) (all at $p \leq 0.01$), and fresh plant yield (r = -0.34) and leaf-ADF (r = -0.34) (all at $p \leq 0.05$). Leaf-ADF was found to be negatively correlated (at $p \leq 0.05$) with leaf-CP content (r = -0.34). Days to flowering was found to be positively correlated with plant DM yield (r = 0.59) (at $p \leq 0.01$). However, this trait was found to be negatively correlated with leaf to stem ratio (r = -0.75), leaf-CP content (r = -0.71) (both at $p \leq 0.01$) and stem-CP content (r = -0.35) (at $p \leq 0.05$).

3.4. Broad-Sense Heritability (h^2_B) for Traits

Broad-sense heritability estimates for the characters measured are presented in Table 4. Broad-sense heritability estimates were found to be high for days to flowering (97.3%), leaf to stem ratio (61.5%), plant DM yield (60.3%) and leaf-CP content (55.8%). They were found to be moderate for leaf DM yield (47.1%), stem-CP content (43.8%) and fresh plant yield (43.4%), but low for fresh leaf yield (33.8%), leaf-ADF (29.0%), and stem-ADF (-10.9).

Table 4. Phenotypic variance (σ^2_P), genotypic variance (σ^2_G), environmental variance (σ^2_E) and broad sense heritability (h^2_B) for the traits measured on the 40 kenaf accessions

Trait	σ^2_P	σ^2_G	σ^2_E	h^2_B (%)
Fresh plant yield	118087441	51258320	66829121	43.4
Fresh leaf yield	24135435	153387	15982048	33.8
Plant DM yield	10053359	6062107	3991252	60.3
Leaf DM yield	516987	243365	273622	47.1
Leaf to stem ratio	144.8	89.0	55.8	61.5
Leaf-CP content	8.4	4.7	3.7	55.8
Stem-CP content	1.6	0.7	0. 9	43.8
Leaf-ADF	7.6	2.2	5.4	29.0
Stem-ADF	24.8	-2.7	27.5	-10.9
Days to flowering	146.1	142.1	4.0	97.3

3.5. Visualization of Relationships between Accessions and Traits

The accession by trait biplot explained 64.3 % of the total variation of the standardized data (PC1 = 43.6% and PC2 = 20.7%) (Figure 1). In a biplot, a vector is drawn from the biplot origin to each marker of the traits to facilitate visualization of the relationships between and among the traits. The correlation coefficient between any two traits can be approximated by the cosine of the angle between the vectors. Positive associations were found between fresh plant yield, fresh leaf yield, plant DM yield, leaf DM yield and stem-ADF, between leaf-ADF, leaf to stem ratio and days to flowering, and between leaf-CP content and stem-CP content, as indicated by the small acute angles between their vectors. However there were negative associations between fresh leaf yield and leaf DM yield with leaf-ADF, CP content and days to flowering. In addition, a negative association was also found between plant yield and CP content, as indicated by the large obtuse angles between their vectors (angles more than 90 degrees). Based on agronomic performance of accessions evaluated (Figure 1), the kenaf accessions could be classified into four groups.

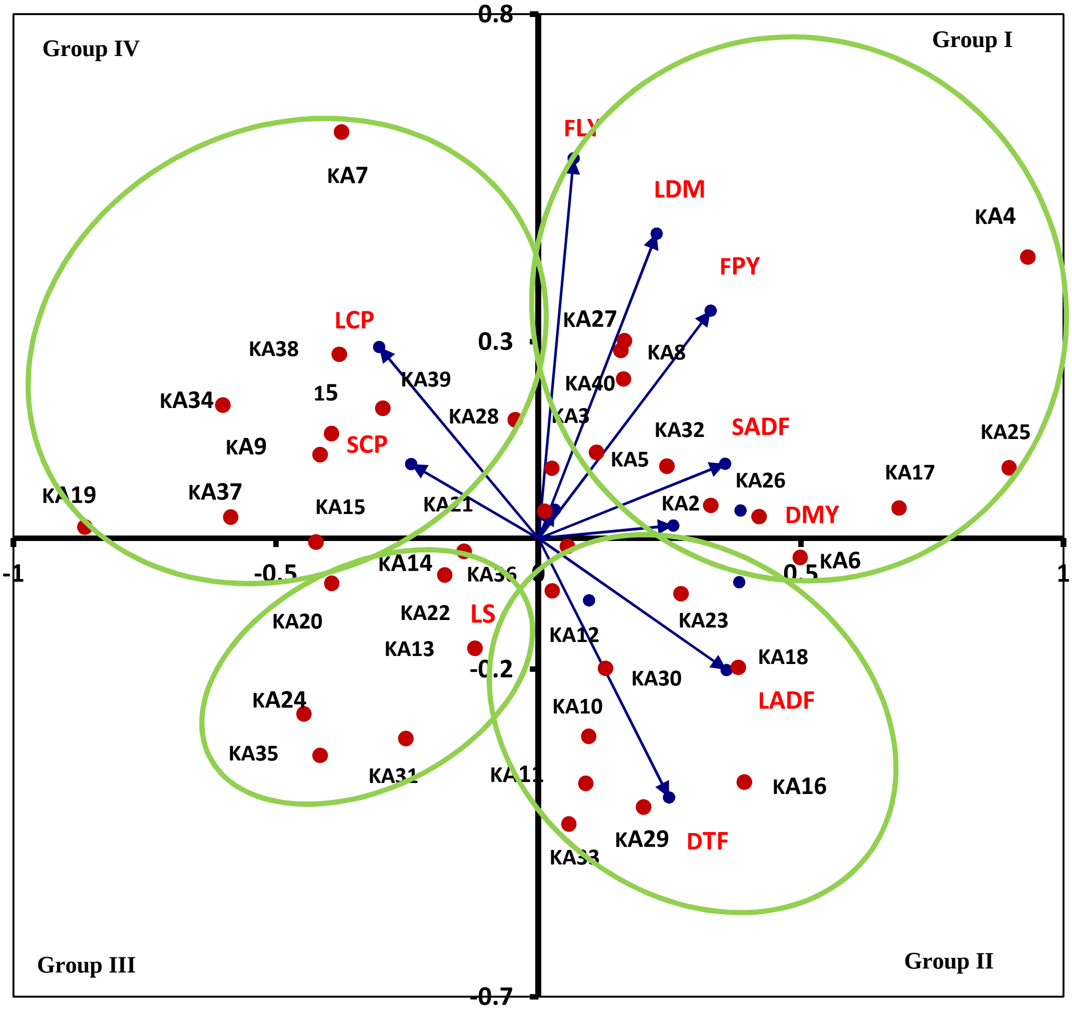

Fig.1. Singular value decomposition biplot showing relationships among traits measured and kenaf accessions grown under optimum conditions (Field 10, UPM)

FPY = fresh plant yield, FLY = fresh leaf yield, DMY = dry matter yield, LDM = leaf dry matter, LS = leaf to stem ratio, LCP = leaf-crude protein content, SCP = stem-crude protein content, LADF = leaf-acid detergent fiber, SADF = stem-acid detergent fiber and DTF = days to flowering.

KA1= 15, KA2 = 113, KA3 = 117, KA4 = IX51, KA5 = 7-1X, KA6 = 75-52, KA7 = 75-71, KA8 = A62-427, KA9 = A63-478, KA10 = BG52-38, KA11 = BG58-14, KA12 = BG53-31, KA13 = BG53-42, KA14 = BG61-20, KA15 = C74, KA16 = CQ3205, KA17 = Cuba 2032, KA18 = Cuba 797, KA19 = Everglade 41 , KA20 = El Salvador, KA21 = Everglade 71, KA22 = FDW75-33, KA23 = FDW75-82, KA24 = G29, KA25 = G46, KA26 = G7, KA27 = Ghana 07, KA28 = Gregg, KA29 = Guatemala 4, KA30 = HW1, KA31 = K465/117, KA32 = K465/118, KA33 = K482/109, KA34 = KK60, KA35 = Mahmur, KA36 = N.S.002, KA37 = NSDB63-1, KA38 = Tainung 1, KA39 = Tainung 2 and KA40 = V36 (control variety).

Group I contains kenaf accessions with high plant yield and moderate to low CP content (except Ghana 07 with moderate plant yield and high CP content), Group II contains accessions with moderate yield and low CP content, Group III bearing accessions with moderate to low plant yield and moderate to low CP content, and Group IV containing accessions with low plant yield and high CP content (except Greeg, C74 and Accession 15, with moderate CP content). Among the accessions, Cuba 2032, G46, IX51, Ghana 07, A62-427, Accession 117, 7-1X, Accession 113, G7, K465-118, V36 and 75-52, were found to have high plant yields and moderate to low CP (except Ghana 07 with moderate plant yield and high CP content) (Group I). Accessions CQ3205, Cuba 797, FDW75-82, HW1, BG53-31, BG52-38, BG53-14, N.S.002, Guatmala 4 and K482-109 were found to have moderate yield and low CP content (Group II). Accessions FDW75-33, El Salvador, BG53-42, G29, Mahmur, BG61-20 and K465-117 were found to have moderate to low plant yield and moderate to low CP content (Group III). Accessions 75-71, Everglade 41, Tainung 1, Tainung 2, Accession 15, Gregg, A63-478, C74, Everglade 71, KK60 and NDSB63-1 were found to have low plant yield and high CP content (except Greeg, C74 and Accession 15, with moderate CP content) (Group IV).

4. DISCUSSION

Results of the ANOVA revealed high phenotypic variations among the different kenaf accessions evaluated, indicating that the accessions varied significantly for most of the traits studied. These findings are in agreement with the results of previous investigations which indicated significant variations among kenaf genotypes for traits studied (Cheng et al, 2002; Webber and Bledsoe, 2002; Balogun et al, 2008). These variations could be exploited for specific purposes in breeding programs.

Accessions IX51, G46, Cuba 2032 and Cuba 797 were found to have high plant DM yield among the kenaf accessions. IX51, G46, Cuba 2032 and Cuba 797 also had higher plant DM yields than the control variety, V36 and were found to perform better in tropical climates. High leaf DM yield was observed on IX51, G46 and Cuba 2032. Plant yield and leaf yield are important components for forage production, because leaves are the primary source of protein in animal feed (Webber and Bledsoe, 2002). Hossain et al. (2011) reported considerable differences in leaf DM yield in five kenaf varieties evaluated.

Among the accessions days to flowering was found to be negatively correlated with leaf to stem ratio. This indicated that, plants that flowered earlier had higher leaf to stem ratio than those that flowered later, as shown by Accessions 75-71 and Everglade 41. In contrast, late flowering accessions such as Cuba 2032, G46 and Cuba 797 were found to have low leaf to stem ratio. Leaf to stem ratio is an important trait in forage production, and hence Accessions 75-71 and Everglade 41 with high leaf to stem ratio can be used for ruminant consumption.

Crude protein of forage is one of the most important criteria in forage quality. In breeding kenaf for forage, it is important that the crop produces high CP and an optimum plant yield at early flowering stage. High CP is considered a favorable trait for forage production because it contains amino acids that are useful for animal growth and milk production. Among the accessions evaluated, Accession 75-71 and Everglade 41 exhibited highest CP in the leaf. Therefore, Accessions 75-71 and Everglade 41 with their high protein could be used and exploited further in breeding programs. Everglade 41 was also recommended as a good source of protein by Eduardo et al. (2008). In the present investigation, leaf-CP content was higher than stem-CP content. The results were in agreement with results of previous studies which reported higher CP content in the leaves compared to the stems (Chantiratikul et al, 2009; Hossain et al, 2011). The low stem-CP content was mainly due to rapid accumulation of the fibrous components in stems.

Stem-ADF was found to be higher than leaf-ADF. This was in agreement with the results reported by Phillips et al. (1999), who found higher stem-ADF than leaf-ADF in kenaf varieties. ADF value refers to the cell wall portions of the forage that are made up of cellulose and lignin. Therefore, Accessions 75-71 and C74 with lower ADF would be more suitable for forage production. Days to flowering were significantly different among the kenaf accessions. Cuba 2032, CQ3205 and K48/109 were found to be late flowering (91 days after planting), while Accession 75-71, KK60, Everglade 41 and Tainung 1 were found to be earlier flowering (56 days after planting). In addition, the early flowering accessions had high CP content and leaf to stem ratio, which are important characteristics for forage production. This finding was also in agreement with previous reports (Chantiratikul et al, 2009; Hossain et al, 2011). Previous research showed that days to flowering varied significantly among kenaf varieties (Cheng et al, 2002; Balogun et al, 2008). Dempsey (1975) classified kenaf cultivars based on maturity stage into three groups: i.e. ultra-early, early to medium and late flowering cultivars. According to

Dempsey (1975) Cuba 2032 was grouped as late flowering, which was similar to the findings in the present study.

Findings on correlations among traits are useful in depicting an effective breeding program for any crop. Based on the results of the present investigations, positive correlations were found between yield, fresh leaf yield and leaf DM yield. Thus, improvement in one character will result in a simultaneous improvement of the other characters. In a study by Balogun et al. (2008) plant DM yield was found to have positive correlations with yield related traits in kenaf accessions. Mostofa et al. (2002) reported positive correlations among all the characters studied, except for the number of nodes and days to flowering. Positive correlations were also reported between fresh plant yield and yield related traits in kenaf accessions (Foroughi, 2012). Fresh plant and DM yields showed negative correlations with leaf to stem ratio and CP content. In a study on the relationships between forage yield and quality of sorghum, a negative correlation was obtained between CP and forage yield, while a positive correlation was found between CP and leaf to stem ratio (Moyer et al, 2003). Plant maturity had the most pronounced effect on forage yield and quality. Generally, days to flowering are specifically associated with plant varieties (Rowell and Stout, 2007). In this study, a positive correlation between days to flowering and plant DM yield indicates that late maturing accessions including G46 and Cuba 2032 had higher plant DM yield than early maturing ones including Everglade 41 and Accession 75-71. Balogun *et al*. (2008) observed negative correlation between days to flowering, plant height, and three yield parameters (bast, core and fiber yield). Gul et al. (2008) also reported negative correlations between days to flowering, number of seed pod^{-1}, seed yield plant^{-1}, 100-seed weight and harvest index. The positive correlation between leaf-ADF and days to flowering indicates that ADF content increases with plant maturity. Negative correlation between forage yield and maturity was reported by Rodney et al. (1992). They also reported late maturing soybean cultivars had higher forage yield but lower quality when harvested at the same stage of maturity.

Heritability estimates ranged from -10.9 to 97.3% for stem ADF and days to flowering, respectively. Plant DM yield, leaf to stem ratio, CP content and days to flowering were found to have high broad-sense heritability. This indicated that the genetic effects were higher than environmental effects. The highest heritability estimates for days to flowering, indicated that this trait was controlled by fewer number of genes compared to the yield traits. Agronomic traits with high heritability are useful for selection, and selection for these traits might be effective for improvement of kenaf accessions. High heritability for days to flowering (h^2_B = 0.98) and fresh plant yield (h^2_B = 0.44) in kenaf cultivars was reported by Mostofa *et al*. (2002). Similar results were also reported by Liu (2005), who showed high broad-sense heritability estimates for days to flowering on kenaf cultivars. The heritability estimate for stem-ADF in the present study was practically zero (-10.9). Negative heritability and variance estimates can be assumed to be zero (Robinson et al, 1955), but they should be reported (Dudley and Moll, 1969). The heritability estimates of zero for crop weight (-0.08) in *Vitis* spp. (Firoozabady and Olmo, 1987) and for stem rating (-0.03) in two cucumber populations (Paul et al, 2001) have been reported.

Biplot analysis visualized 64.3% of the total genetic variation among the accessions. This indicates the complexity of the relationships between the accessions evaluated and the traits measured. The accessions evaluated were classified into four distinct groups based on their agronomic performance using accession by trait analysis. Some accessions, including IX51 and Cuba 2032, showed high potential for high plant yield as being classified in Group I, while accessions with high CP content, including Accession 75-71 and Everglade 41, were classified in Group IV. It is therefore suggested that potential crosses could be made between accessions of Group 1 and Group 4 to produce varieties with relatively high CP and plant yield for better forage production. Yan and Rajcan (2002) reported that biplot analysis was able to visualize 52% of the total genetic variation which existed among soybean cultivars. Ogunbodede (1997) identified six clusters from a two-dimensional ordination of the first two principal axes in kenaf accessions. In a study on genetic evaluation of kenaf Golam (2011) used PCA to separate the kenaf accessions into three groups. Yan and Rajcan (2002) used biplot analysis for identification of genotypes with high yield and high oil content in soybeans.

5. CONCLUSION

As conclusion, significant differences were observed for most of the traits measured including yield and yield related traits, CP content, ADF and days to flowering. High plant DM yield and high CP content, the two important traits for kenaf forage production, were observed among the accessions. The accessions with high plant DM yield, which include IX51, G46, Cuba 2032 and Cuba 797 (Group I) (except Cuba 797, which was classified into Group 2) and Accession 75-71 Everglade 41, KK60 and Tainung 1 with high CP content (Group IV), with higher forage yield and quality than the control variety (V36) are suitable varieties and can be utilized in further breeding programs to produce new varieties with high feed value for ruminants. This study revealed that plant DM yield was positively correlated with leaf and stem yield, plant height, stem diameter and days to flowering, and therefore these traits are important contributing factors to plant DM yield and should be used as selection criteria for yield improvement in kenaf.

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