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Evaluation of genetic variability of kenaf (*Hibiscus cannabinus* L.) from different geographic origins using morpho-agronomic traits and multivariate analysis

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Abstract

Morpho-agronomical characterization was done for 16 kenaf accessions from 4 different geographic origins to assess the variation and genetic relationships according to their origin. To evaluate their genetic relationships, correlation matrix with 13 quantitative traits were used for Principal Component Analysis (PCA) analysis, which produced three groups. Similar grouping pattern was obtained by clustering the accessions using the dissimilarity matrix of Ward's method. Clustering of the accessions with origin showed the association of genetic variability among the accessions with their source of origin. To evaluate the genetic variability among the accessions, fishers distance was calculated with significant p-value. The highest distance was observed among the accessions originated from Australia and China. Discriminant analysis with two major factors revealed that days of 50 % flowering and maturity may be the important traits to differentiate the accessions according to the origins. The late to middle flowering accessions from different origins can be used to grow high fibre yield producing kenaf in the tropical environment.

Keywords: Kenaf, Morpho-agronomic traits, Fibre weight, Days of flowering.

Abbreviations: PCA – Principal Component Analysis, DA – Discriminant analysis**,** Jag – Fermentation process to get fiber from jute type crop.

Introduction

Kenaf (*Hibiscus canabinus* L.) is an ancient crop with a long history of growing for several thousand years for food and fibre. It is thought to have originated in sub-Saharan Africa with evidence of its domestication around 4000 BC in the Sudan region (Dempsey, 1975) but now grows in almost all over the globe. The most common use of kenaf soft fibre from the stem is packaging. Kenaf fibre is used in clothing-grade cloth, engineered wood, insulation, soil-less potting mixes, animal bedding and material that absorbs oil and liquids. It is also useful as a drilling fluid loss preventative for oil drilling muds, for a seeded hydromulch for erosion control, as cut bast fibre for blending with resins for plastic composites (Liu, 2000). Kenaf can be made into various types of environmental mats, such as moldable mats for manufactured parts and containers and seeded grass mats for instant lawns. Recently, more applications of kenaf have been developed, for example, pulping and papermaking, oil absorption and bioremediation, board and filtration media making and animal feed (AKS, 2000; JKA, 2000). Two species of kenaf account for one-third of the world production, including (*Hibiscus cannabinus* L.) along with a closely related species called roselle (*Hibiscus sabdariffa* L.). Kenaf yields approximately three to five times much fibre than southern yellow pine (LeMahieu et al., 2003). This plant is rapidly replacing jute, because is cheaper to produce and has less labour intensive requirements. Kenaf has received the greatest attention because of its greater adaptability and easy of handling than allied fibre crops and commercially cultivated in more than 20 countries, particularly in India, China, Thailand and Vietnam as an important crop (FAO, 1998). China, India and Thailand account for 90 percent of the global area sown to kenaf and more than 95 percent of global production (FAO, 2003). Other important production areas include Russia, Mozambique, Iran, Taiwan, El Salvador, Gautemala, Dahomey, Ivory Coast and Nigeria Latin America and some other countries of Asia (FAO, 2003; Dempsey, 1975). Kenaf may be grown on a wide range of soils under varied climatic conditions and does not necessarily compete with food crops. In major kenaf growing areas, kenaf grows in a latitude range of 16°S to 41°N with a mean relative humidity range of 68-82% and the mean growing temperature during the season ranges from 22.6°C to 30.3°C. During the growing season the mean rainfall per month ranges from 100-329 mm and 500-625 mm over a period of 5 to 6 months is essential for the successful production of kenaf fibre (Crane, 1947). For gentic improvement of kenaf, identification of genotypic potentiality for a specific location is very important. Additionally, the cleistogamous nature of reproduction causes difficulties to generate new genetic variability through conventional breeding in kenaf family. Study of genetic resources to identify the genetic relationships among the accessions and to find suitable resources with better environmental adaptive accessions are the critical factors for selection. Ogunbodede and Ajibade, (2001) evaluated different agronomic traits of kenaf and they observed genetic variations in several kenaf genotypes in African hot and humid environments. Genotypic characteristics and relation-

Table 1. Origin and code of 16 different kenaf Accessions

Sl No	Accessions (Genotypes)	BJRI Code	Country of Origin
1	E16	3741	Kenya
2	E17	3744	Kenya
3	E20	3747	Kenya
4	E23	3806	Kenya
5	E66	4896	China
6	E67	4974	China
7	E70	5016	China
8	E71	5017	China
9	E60	4640	Australia
10	E62	4654	Australia
11	E58	4637	Australia
12	E59	4638	Australia
13	E52	4447	USA
14	E56	4628	USA
15	E03	1584	USA
16	E10	1690	USA

ships between kenaf accessions are limited and identification of kenaf varieties is problematic, which significantly hinders their effective utilization and conservation (Zhou et al., 2002). The present paper is aimed to characterize the kenaf accessions using morpho-agronomic traits from different source of origin and to aid the selection programs to produce adaptive varieties in the tropical region with better fibre yield.

Results and discussion

Mean, range and coefficient of variation of 13 quantitative traits and frequency of 2 qualitative traits (totally 15 morpho-agronomic traits) were shown in Table 2. Duncan's Multiple Range Test (DMRT) was done to identify the significant differences among quantitative traits of the accessions. The result of the DMRT test was summarized in (Table 3). The results showed that there were no significant difference among the accessions in plant height (PH), base diameter (BD), core diameter (CD), number of nodes (NN), green weight with leaves and fruit (GW), leaf length (LL), leaf width (LW), petal length (PL) and middle diameter (MD). This may be due to the fact that kenaf has been reported to have a wider range of adaptation to environmental factors than other fibre plants cultivated for commercial use (Dempsey, 1975). Significant differences were observed among the accessions in 50 % flowering date (FD), days of maturity (DM), stick weight (SW) and fibre weight (FW). The result of differences in accessions in flowering date had the similarity with the results of Balogun et al. (2008), where days of flowering varies significantly among kenaf varieties. There were no significant differences among the accessions in middle diameter (MD), which was initially proposed for the identification of different kenaf varieties (Cheng et al., 2002).

Correlation analysis

The correlation analysis (Table 4) showed that FW had high positive correlation with GW, SW and non-significant negative correlation with DF and DM. GW and SW had high positive correlation with PH, BD, CD and NN but non-significant negative correlation with DF and DM. The negative correlation of DF and DM with FW, PH, BD, CD, NN are the indicator of low fibre yield per plant, which may initiate by early maturity and causes shorter plants with shorter internodes and petiole lengths, since initiation of flowering reduce the vegetative growth (Webber et al., 2002). Moreover, this may be because of the length of the growing season, which influences the stick yield (Webber, 1993) and other yield components such as plant height (Ching et al., 1993; Webber, 1996). DF and DM were highly positively correlated but had significant negative correlation with LL, LW, and PL. The negative correlation was observed between DM and LL, LW and PH (Balogun et al., 2008).

Principal component analysis

The principal component analysis using correlation matrix and Pearson correlation coefficient indicated that the first three components accounts for 86.73 % of the total variation (Table 6). PC1, PC2 and P 3 explained 53.79 % and 25.47 % and 7.46 % of the variation, respectively. The first component is characterized by plant height, base diameter, core diameter, number of nodes, green weight with leaves and fruit, leaf length, leaf width, petal length, middle diameter, stick weight and fibre weight. The second component was characterized by days to 50 % flowering date and days of maturity. The first two components that accounted for 79.24 % of the total variation with 16 kenaf accessions against a scatter plot showed three-group pattern (Fig. 1). Therefore, based on PCA analysis of the morpho-

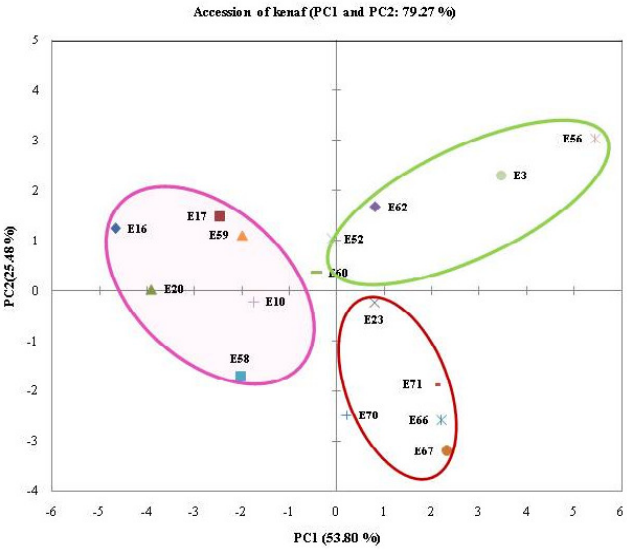

Fig 1. Scatter plot from first two component of PCA analysis showing the variation of 16 kenaf accessions. Accessions' codes refer to the Table 1.

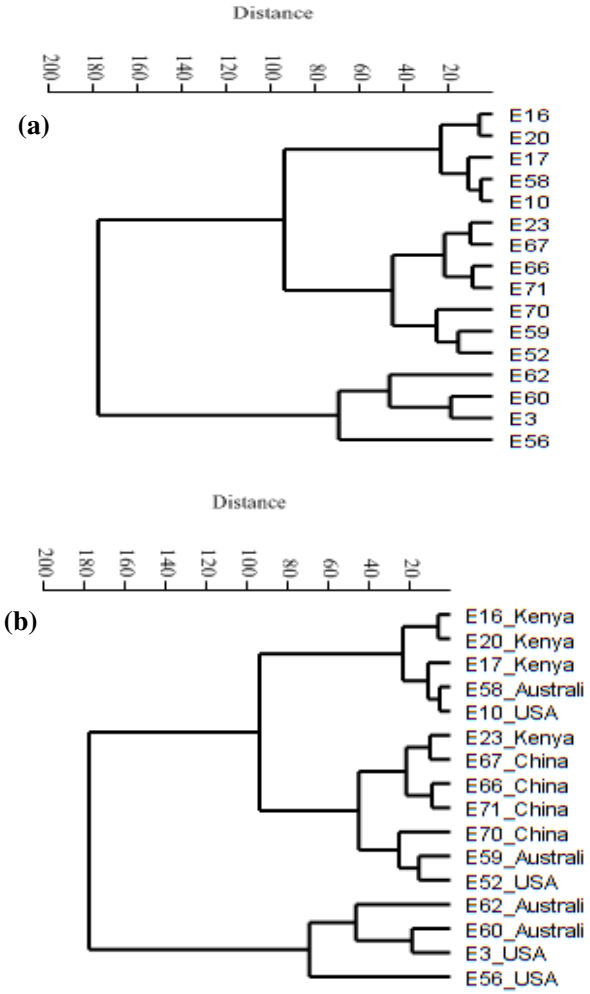

Fig 2. Dendogram showing the genetic relationships by ward's method. (a) genetic relationships among kenaf accessions, (b) genetic relationship including the orgin of accessions.

agronomic traits, the kenaf accessions were approximately divided into three groups.

Cluster analysis

Agglomerative ierarchical cluster analysis on 13 morpho-agronomic traits using Euclidian distance and Ward's (1963) method made more specific three-grouping of clusters. Cluster 1, 2 and 3 were formed by 5, 7, 4 accessions from a total of 16 accessions, respectively (Table 5). This similarity of cluster result with PCA analysis strengthens the proposed 3 grouping of kenaf accessions. Cluster 1 was characterized by low PH, FW and SW and encompassed accessions E10, E16, E17, E20 and E58. Cluster 2 included the accession of E66, E67, E70, E71, E59, E52, E23 and was characterized by middle PH, FW and SW but high LL, LW and PL. Cluster 3 contained the more promising accessions E60, E62, E56, E3 with high FW and SW. Cheng et al. (2002) and Balogun et al. (2008) reported the effect of flowering in the formation of three cluster. In our experiment the late flowering and matured accession belong to the cluster 1. The early flowered and matured accessions were in cluster 2. The accessions those were flowered and matured at intermediate time was in the cluster 3. To measure the similarity of the accessions with more homogenous group dendogram was created by a total of 15 morpho-agronomical traits using Ward's (1963) agglomeration method. It produced three major clusters (Fig 2) showing distance among the accessions. Dendogram including the origin of accession revealed that geographical location may have the effect in the genetic variation of kenaf (Fig 2). Most of the kenaf accessions originated from china and Kenya were in two different clusters. The rest of accessions from Australia and USA were in the same cluster.

Discriminant analysis

Discriminant analysis (DA) of 15 morpho-agronomic traits showed that DF and DM were the major traits associated with DA factors and could differentiate the accessions based on geographic origin (Table 6). DA analysis using the flowering and maturity revealed that days of flowering and maturity could be a significant trait to differentiate the accessions according to their origin (Table 6). Cheng et al. (2002) proposed the kenaf varieties into three groups based on the selected morpho-agronomic characters, the early-medium types (first group), medium-late (second group), and late maturity (third group). Siepe et al. (1997) divided kenaf germplasm into two main groups: the early-maturing and late-maturing types. In the present investigation, early flowered and matured accessions originated from China was differentiated from late flowered and matured accessions from Kenya (p value <0.05) with highest fishers distance of 18.84. The significant distance between Australian and late flowering Kenyan accessions and between USA and Kenyan were 2.82 and 3.11, respectively. Middle flowered and matured accessions originated from Australia and USA had the non-significant fisher distance of 0.63. As DF and DM are highly correlated to one another, we proposed that closely related accessions may only form a group in flowering and low fisher distances due to their low variability. The accessions from Australia and USA could be described as medium late flowering and the accession of Kenya as late flowering group (Cheng et al., 2002). The accessions from China may be described as early flowering rather than late (Cheng et al 2002), because there was a comparatively higher distance between the early flowering accessions of China and late flowering accessions of Kenya.

Table 2. Mean, minimum and maximum values, ranges and coefficients of variation for 13 quantitative traits, frequency and percentage of 2 qualitative traits of 16 accessions of kenaf (*Hibiscus cannabinus* L.).

Quantitative traits

	PH	BD	CD	MD	NN	DF	DM	GW	LL	LW	PL	SW	FW
Mean ± SD	165.84 ± 19.91	10.23 ± 1.37	8.99 ± 1.2	6.91 ± 0.85	32.53 ± 4.83	50.75 ± 4.57	52.06 ± 4.68	121 ± 40.1	9.03 ± 1.28	7.75 ± 1.28	7.42 ± 1.24	15.1 ± 4.94	3.93 ± 1.41
Range	74.6	4.58	4.58	3.08	16.23	16	16	138.32	4.78	4.7	4.68	20.83	5.01
Minimum	142.67	8.36	7.3	5.32	27.17	41.5	43.5	66.4	6.45	5.35	4.93	7.67	1.8
Maximum	217.27	12.94	11.87	8.4	43.39	57.5	59.5	204.72	11.23	10.05	9.6	28.5	6.81
CV (%)	12.00	13.41	13.35	12.26	14.85	9.01	8.99	33.1	14.16	16.53	16.69	32.70	35.6

Qualitative traits

Green stem color (GS)	Light red stem color (LRS)	Lobed leaf (LL)	Un-lobed leaf (UL)
12f	4f	10f	6f
75%	25%	63%	38%

PH =Plant height (cm), BD =Base diameter (mm), CD =Core diameter (mm), MD =Middle diameter (mm), NN =Number of nodes, FD =50% Flowering date (Days), DM =Days of maturity, LL= leaf length (cm), LW =leaf width (cm), PL =Petal length (mm), GW=Green weight with leaves and fruit (gm), SW= Stick weight (gm), FW = Fibre weight (gm). SG = Green stem color, RS = Light red stem color, LL = Lobed leaf, UL = Un-lobed leaf, f = Frequency

Table 3. Duncan multiple range test (DMRT) of the 16 accessions with different parameters for 13 quantitative traits.

Accession	PH	BD	CD	MD	NN	DF	DM	LL	LW	PL	GW	SW	FW
E16	142.67a	8.59a	7.39a	6.38a	27.50a	54ab	55ab	6.45a	5.35a	4.93a	73.00a	7.67ab	2.17bc
E17	149.33a	9.85a	8.91a	7.05a	27.34a	54a	60a	7.55a	6.88a	6.08a	82.12a	10.83ab	3.80abc
E20	145.67a	8.36a	7.71a	6.08a	28.33a	53a	57ab	8.55a	6.70a	6.00a	66.40a	8.33b	1.80c
E23	174.17a	10.57a	9.04a	7.70a	33.50a	50abc	55ab	9.68a	8.35a	8.05a	118.00a	15.50ab	3.53abc
E66	172.67a	11.04a	9.38a	7.41a	35.34a	42c	44c	10.63a	8.85a	8.85a	129.30a	17.17ab	3.00abc
E67	177.00a	9.76a	8.69a	7.01a	32.17a	43bc	44c	11.23a	9.35a	9.60a	118.10a	17.97ab	6.00ab
E70	160.00a	10.53a	9.19a	6.57a	29.75a	47abc	47bc	10.28a	9.60a	8.25a	99.60a	12.67ab	2.80abc
E71	169.29a	11.17a	9.57a	7.48a	31.71a	48abc	48bc	10.40a	10.05a	9.13a	138.20a	16.25ab	3.92abc
E60	188.50a	9.83a	8.53a	5.32a	36.94a	47abc	53abc	7.48a	7.28a	7.03a	140.50a	14.12ab	3.92a
E62	152.50a	10.06a	8.62a	7.53a	37.67a	51abc	52abc	8.00a	7.55a	6.05a	189.34a	15.83ab	6.81a
E58	153.50a	8.47a	7.30a	5.81a	27.84a	51abc	49bc	9.23a	8.38a	7.25a	84.97a	14.44ab	3.28abc
E59	149.59a	10.05a	8.26a	6.68a	27.17a	58a	57ab	8.55a	6.11a	7.50a	111.30a	13.00ab	3.50abc
E52	162.25a	11.30a	9.66a	7.04a	30.50a	53ab	56ab	8.83a	7.12a	7.38a	127.75a	14.50ab	3.73abc
E56	217.27a	12.94a	11.87a	8.05a	43.39a	54a	53abc	9.58a	7.30a	7.60a	204.72a	28.50a	5.95abc
E3	187.50a	12.57a	11.04a	8.40a	39.17a	57a	53abc	9.30a	7.90a	7.60a	163.00a	21.33ab	5.35abc
E10	151.50a	8.61a	8.72a	6.06a	32.17a	53bab	53abc	8.75a	7.30a	7.40a	87.60a	13.67ab	3.35abc

Means with the same letter within the same column are not significantly different at 5% probability level. PH =Plant height (cm), BD =Base diameter (mm), CD =Core diameter (mm), MD =Middle diameter (mm), NN =Number of nodes, FD =50% Flowering date (Days), DM =Days of maturity, LL= leaf length (cm), LW =leaf width (cm), PL =Petal length (mm), GW=Green weight with leaves and fruit (gm), SW= Stick weight (gm), FW = Fibre weight (gm).

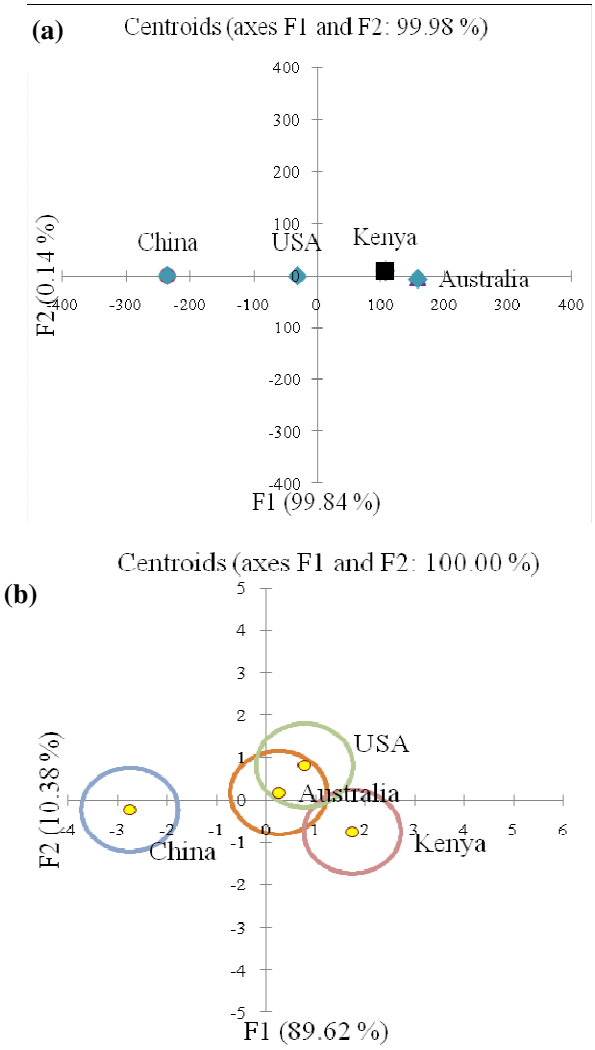

Fig 3. Chart showing the centroids of 4 different geographic kenaf accessions by DA analsyis depending on (a) 15 morpho-agronomic triats. (b) flowering and maturity traits (centroids and the confidence circles around the means).

Moreover, there were also comparatively higher distance between the accessions of china and the middle late flowering groups of USA and Australia. Therefore, proposed grouping of kenaf accessions may be as early, medium-late and late flowering. Maturity period has been reported to be an indication of sensitivity of kenaf varieties to photoperiod and later maturing varieties were photo insensitive relative to early maturing genotypes when planted in the tropics (Webber et al., 2002). Therefore, medium-late flowering individuals are relatively photo insensitive accessions with high fibre in tropical regions. To find the variability of accessions according to their different geographical origin, which include the significant level was calculated for 15 morpho-agronomic traits using fisher's distances (Table 7). The fisher distance among the accession of 4 different geographic origins was significant with p-value< 0.05, except for Australian and Kenyan accessions. The accessions from Australia and USA had significant fishers distance of 496.44. Significant highest distance (2145.76) was observed between accession originated from Australia and China. The lowest distance (39.84) was found between accessions of USA and Kenya. These may be the indication of the low and high variability of those accessions due their differences in morphology and geographic origin.

Materials and methods

Experimental site and soil

The research was conducted at the experimental field of Genetics and Molecular Biology, Institute of Biological science, University of Malaya, Kuala Lumpur, Malaysia, during the period from November, 2010 to February, 2011. The experimental field was located at 3.20° N 101.40°E with elevation of 22 m from sea level. The climatic condition was hot and humid with frequent rain (average 224 mm).

Experimental material

A total of 75 germplasms were obtained from Bangladesh Jute Research Institute (BJRI) Gene Bank, through IJSG (International Jute Study Group), Dhaka, Bangladesh. After a preliminary screening of these 75 germplasms, 16 outstanding genotypes were used in this investigation, originating from 4 different geographic regions such as Australia, China, Kenya and United States of America (USA). Brief descriptions of these 16 genotypes have been provided in Table 1.

Experimental design

The experiment was laid out in a randomized complete block design (RCBD) with three replications. Each experimental plot was 2.5 m long and 2.0 m wide, with 6 rows, 40 cm apart, giving a gross plot area of 5.0 m^2. Distance between plots and plants were 1 m and 15 cm, respectively.

Conduction of the experiment

Land preparation and sowing

The land was initially ploughed on October 15, 2010. Final land preparation was done on October 30, 2010. The land was thoroughly prepared by four ploughing and cross-ploughing followed by laddering in order to level the soil. Weeds stubble and crop residues were removed to make the land clean. Drainage channel was made around the plot to remove the excess rainwater from the experimental plots. Two seeds were planted on each hill. In line sowing, 40 cm row to raw distance was maintained.

Application of fertilizers

Plots were fertilized with the N_2, P_2O_5, and K_2O at the rate of 122, 122, and 144 Kg ha^{-1}, respectively. One-third of N_2 and other fertilizes were distributed during the final land preparation. The two-third of remainder urea was top dressed in two equal splits on 20 and 35 days after sowing.

Intercultural operations

Each plot was weeded three times on 15, 30 and 45 days after sowing. Thinning was also done simultaneously. The final thinning of kenaf plant was carefully done to maintain a plant to plant distance of at least 10 cm, which contributed to adjust the population density in different plots. The crop was slightly infested by insects and diseases. Therefore, insect-pests and disease control measures were adopted. Fungicide

Table 4. Pearson correlation matrix for 13 morpo-agronomic traits of 16 kenaf accessions.

Traits	PH	BD	CD	NN	DF	GW	LL	LW	PL	MD	DM	SW	FW
PH	1												
BD	0.77**	1											
CD	0.80**	0.94**	1										
NN	0.84**	0.70**	0.76**	1									
DF	-0.19	0.03	0.09	-0.11	1								
GW	0.74**	0.78**	0.74**	0.89**	-0.03	1							
LL	0.41	0.41	0.39	0.22	-0.58*	0.22	1						
LW	0.31	0.30	0.26	0.19	-0.70 **	0.21	0.85**	1					
PL	0.47	0.43	0.39	0.23	-0.60*	0.26	0.93**	0.83**	1				
MD	0.46	0.80**	0.76**	0.54*	0.09	0.64**	0.40	0.26	0.31	1			
DM	-0.26	-0.12	-0.07	-0.21	0.82**	-0.18	-0.75**	-0.79**	-0.72**	-0.09	1		
SW	0.88**	0.80**	0.85**	0.84**	-0.07	0.83**	0.51*	0.35	0.50*	0.65**	-0.32	1	
FW	0.54*	0.52*	0.53*	0.69*	-0.03	0.82**	0.22	0.22	0.24	0.56*	-0.19	0.72**	1

*Significant at 5%, **Significant at 1% probability levels. PH =Plant height (cm), BD =Base diameter (mm), CD =Core diameter (mm), MD =Middle diameter (mm), NN =Number of nodes, FD =50% Flowering date (Days), DM =Days of maturity, LL= leaf length (cm), LW =leaf width (cm), PL =Petal length (mm), GW=Green weight with leaves and fruit (gm), SW= Stick weight (gm), FW = Fibre weight (gm).

Table 5. Means and numbers of the kenaf (*Hibiscus cannabinus* L.) accessions forming three clusters.

Cluster	NA	PH	BD	CD	MD	NN	DF	DM	LL	LW	PL	GW	SW	FW
1	5	148.53	8.77	8.00	6.27	28.63	53	55	8.11	6.92	6.33	78.82	10.99	2.88
2	7	166.42	10.63	9.11	7.13	31.45	48	50	9.94	8.49	8.39	120.32	15.29	3.78
3	4	186.44	11.35	10.01	7.32	39.29	52	53	8.59	7.51	7.07	174.39	19.94	5.51

NA= Number of accession, PH =Plant height (cm), BD =Base diameter (mm), CD =Core diameter (mm), MD =Middle diameter (mm), NN =Number of nodes, FD =50% Flowering date (Days), DM =Days of maturity, LL= leaf length (cm), LW =leaf width (cm), PL =Petal length (mm), GW=Green weight with leaves and fruit (gm), SW= Stick weight (gm), FW = Fibre weight (gm).

Table 6. The eigenvalues of the correlation matrix for 13 quantitative traits of 16 kenaf accessions and correlations of 15 morpho-agronomic traits with discriminant factors according to their different geographic origin.

Traits	Principal component			DA factor correlation with trait		
	PC 1	**PC 2**	**PC 3**	**F1**	**F2**	**F3**
Eigenvalue	6.99	3.31	0.97	30853	42.95	6.64
Variability (%)	53.79	25.48	7.46	99.84	0.14	0.02
Plant height (cm)	0.324	0.092	-0.155	-0.297	-0.231	0.380
Base diameter (mm)	0.326	0.165	0.299	-0.398	-0.171	0.457
Core diameter (mm)	0.324	0.190	0.269	-0.422	-0.098	0.653
Middle diameter (mm)	0.274	0.156	0.406	-0.333	0.129	0.340
Nude number	0.309	0.188	-0.365	-0.151	-0.319	0.444
Days of 50% flowering (days)	-0.112	0.444	0.346	0.605	0.129	0.535
Days of maturity(days)	-0.181	0.427	0.235	0.740	0.348	0.377
Leaf length (cm)	0.250	-0.356	0.288	-0.793	-0.174	-0.042
Leaf width (cm)	0.217	-0.399	0.099	-0.739	-0.205	-0.300
Petal length (mm)	0.252	-0.351	0.217	-0.769	-0.292	-0.098
Green weight (gm)	0.317	0.208	-0.272	-0.129	-0.488	0.319
Stick weight (gm)	0.352	0.110	-0.056	-0.327	-0.380	0.482
Fibre weight (gm)	0.266	0.153	-0.352	-0.082	-0.450	0.233
Steam, light red				-0.178	0.254	0.182
Steam, green				0.178	-0.254	-0.182
Leaf, Lobed				-0.269	0.322	0.174
Leaf, unloved				0.269	-0.322	-0.174

Table 7. Fisher distances of 16 kenaf accessions of 4 locations by using 15 different morpho-agronomic and flowering and maturity traits.

	Australia	China	Kenya	USA
Australia	0	8.46*	2.82	0.63
China	2145.76*	0	18.84*	12.45*
Kenya	39.84	1624.22*	0	3.11
USA	496.44*	579.01*	265.20*	0

* Significant at 5% probability levels. Normal letters for 15 traits and bold letters for 50 % flowering and maturity traits.

pencozeb 80WP 40gm per 10 liter water and Diaginone 1.75 ml per 2 liter water were used. No Irrigation was required for the crops after sowing.

Data collection

Prior to harvest ten randomly selected plants from each unit plot were collected to take note of the morph-agronomic data. After each harvest the height was measured from the ground level to the top of the plants recorded from 10 random plants. The fibre and stick yields were recorded from the whole individual line. The fibre was dried by direct sunshine for 4-5 days to complete drying. The dryness of fibre was observed by 'hand touch' to ensure the dryness. The fibre bundles were assorted plot wise, tag labels and weighed. Kenaf sticks were also dried continuously for seven days to get dry sticks weight. The Basal diameter was measured by a slide caliper at 15 cm above the base of the plants. The other data that were taken were middle diameter (mm), core diameter (mm), leaf length (cm), leaf width (cm), green weight with fruits and leaves (gm), days of 50 % flowering and maturity (days).

Extraction of kenaf fibre and stripping

The kenaf plant was cut at the ground level with the help of a sickle. The fibre and stick yields were recorded from the whole individual line. By retting process kenaf fibres were extracted from the kenaf plants and were put into the pond. After making the jag, it was steeped in the pond water with the help of water hyacinth and other aquatic weed. The depths of water were sufficient to allow the kenaf bundle to float. The pond was 1.8 m deep. Fibre was stripped manually from stick after completion of proper retting. At fibre stripping the upper layer of bark was removed from lower portion of the kenaf plant by hand pushing to minimize the cuttings. The fibre was washed in clean water to ensure quality fibre.

Statistical analysis

Analysis of variance and significant F-test were carried out following the procedure of New Duncan's Multiple Range Test (DMRT)(Gomez and Gomez, 1983). The statistical

programs used for the analysis were SAS 2.0 and XLSTAT Version 2011. Dendogram was made by PAST 2.10.

Conclusion

Study of genetic variation of different kenaf accessions from various genetic resources was done using the morpho-agronomic traits to estimate the genetic relationships and variation. The most variable traits of the 16 kenaf accessions from 4 different locations were fibre weight (FW), days of flowering (DF), days of maturity (DM), green weight (GW) and stick weight (SW). There were high positive correlation between DF and DM but they had negative correlation with most of the other traits including FW. Most of the high FW producing accessions formed a cluster and were originated from Australia and USA. The accessions from Australia and USA had significant fisher's distance in total of 15 morpho-agronomic traits. Date of flowering and maturity may be an aid to identify certain kenaf accessions along with other morpho-agronomic traits to grow in tropical region like Malaysia, where medium late flowering and matured accessions performed better than the early or late flowering genotypes. We suggest application of relatively variable and medium late flowering accessions originated from Australia and USA, classified in cluster 3 of this study, to grow in tropical region like Malaysia. This suggestion based on their variability, time of flower initiation and high fibre yield.

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