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MORPHOLOGICAL CHARECTERIZATION OF KENAF (*Hibiscus cannabinus* L.) IN MALAYSIAN TROPICAL ENVIRONMENT USING MULTIVARIATE ANALYSIS

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ABSTRACT

Kenaf (*Hibiscus cannabinus* L.) is a green resource of natural fibre. But our understanding of genotypic characteristics and relationships between kenaf genotypes grown up in certain environmental condition is limited, which is important for effective kenaf breeding program for mass commercial production and fundamental need for utilization of this resource. Thirty two kenaf genotypes originated from different parts of the world were cultivated in open field of Malaysian tropical environment. A total of 15 morphological data were collected and multivariate analysis was used to identify the genetic variation among the genotypes. There were significant differences among the genotypes in fibre weight, days to 50% flowering and days to maturity. Principal component analysis showed that days to flowering, days to maturity, plant diameter and leaf shape were the traits responsible for major variation among the genotypes. In cluster analysis different kenaf genotypes produce three distinct groups which can be used for selection of parents of in the breeding program. From total three clusters, high yielding late mature genotypes of the cluster 3 can be used to cross with middle flowering genotypes of cluster 2 to produce relatively photo insensitive variety with better fibre and stick yield in Malaysian tropical environment.

Key words: Kenaf, Characterization, Genotype, Cluster analysis, Principal Component Analysis.

INTRODUCTION

The Persian originate name "kenaf" is used to signify both the tall economic and horticultural important plant (*Hibiscus cannabinus* L.) with large showy flowers, characteristic of the Mallow family, and the bast fibre obtained from the stem of that plant (Crane and Acuna, 1945; Dempsey, 1975; Li, 1980). The annual plant kenaf is related to okra (*Hibiscus esculentus*), hollyhock (*Althaea rosea*) and cotton (*Gossypium hirsutum* L.) (Scott and Taylor, 1988). It is a short-day, herbaceous plant and grows in tropical and temperate climates and thrives with abundant solar radiation and high rainfall. In present world due to global environmental issues and inadequate raw fibre resources scientists have developed more important potential economic and environmental benefits of the utilization of kenaf in the areas of soil remediation, reduced soil erosion due to wind and water, toxic waste cleanup, removal of oil spills on water, replacement or reduced use of fibre glass in industrial products, the increased use of recycled plastics reduced chemical and energy use for paper production and greater recycled paper quality, (Webber *et al*. 2002). Now China, India, and Thailand accounts for 95% of world production of kenaf and in 2005-2006 total kenaf production was 0.33 million tons of which India, China and Thailand produced 42%, 25% and 11%, respectively, and the rest 22 % was produced by other countries of the world (FAO, 2006). Kenaf has received the greatest attention because of its greater adaptability and easy of handling than allied fibre crops. Kenaf yields approximately three to five times as much fibre as southern pine (Lemahieu *et al*. 2003; Rymsza, 1999). In Malaysia, kenaf was first introduced in the early 1970s and was recognized as a potential alternative fibrous material for the production of panel products such as fibre board and particle board in the late 1990s (Abdul Khalil *et al*. 2010). Factors that affect kenaf fibre yield include adaptability to the cultivated area, rainfall, temperature, soil type, fertility etc (Dempsey, 1975). To cultivate kenaf on a commercial scale in Malaysian tropical environment it is necessary to evaluate the available kenaf genotypes in terms of morphological and agronomic characters. Moreover, identification of genetic relationship and to study genetic diversity is one of the most important factors for selection of genotypes for effective breeding program. Therefore, the present research was aimed on morphological characterization of kenaf genotypes for identification genetic variation and to aid in selection to establish useful kenaf breeding program in Malaysia.

MATERIALS AND METHODS

The research was conducted during the period from November, 2010 to February, 2011 at the experimental field of Genetics and Molecular Biology, Institute of Biological Science, University of Malaya, Kuala Lumpur, Malaysia. The experimental site was situated in the tropical climate zone with frequent rain (ranged from 165 to 250 mm) and located at 3.20° N, 101.40°E with elevation of 22 m from sea level. Thirty-two genotypes of kenaf belonging to different sources of origin were collected from Bangladesh Jute Research Institute (BJRI) Gene Bank, through IJSG (International Jute Study Group), Dhaka, Bangladesh. The origins of genotypes are given in Table 1.

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 of 40 cm apart and plant to plant distance of 10 cm, giving a gross plot area of 5.0 m^2. Plot to plot distance was 1 m. The land was prepared for sowing by four ploughing and cross-ploughing ploughing and levelled by laddering. To drain the excess rain water field, a drainage channel was dug around the plots. The 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 whole of other fertilizes were broadcasted during the time of final land preparation and two-third of urea was top dressed in two equal splits at 20 and 35 days after sowing. Two seeds were planted per hill (planting hole) and plots were weeded three times at 15, 30 and 45 days after sowing. After sowing no irrigation was required for the crops. To adjust the population density in different plots thinning of kenaf plant was done to maintain a plant to plant distance approximately 10 cm. According to the level of infestation and infection insect-pests and disease control measures were adopted.

Morphological data were collected from ten randomly selected plants from each unit plot. The height was measured from the ground level to the top of the plants. The Basal diameter was measured by a slide calliper at 15 cm above the base of the plants. The fibre and stick yields were recorded from the whole individual line. Kenaf fibres were extracted from the kenaf plants by retting process after cutting at the ground level. A pond of 1.5 m depth was used to allow kenaf bundle to float. After completion of proper retting, fibre was stripped from stick manually and washed in clean water to ensure fibre quality. The fibre was dried by direct sunshine for 4-5 days and to ensure proper dryness fibre was observed by 'hand touch'. The fibre bundles were assorted plot wise, tagged with labels and weighed. To get sticks weight stick yields were recorded from the whole individual line and were dried continuously for seven days.

Analysis of variance and assortment of significant means (New Duncan's Multiple Range Test) was carried out following the procedures (DMRT) as narrated by Gomez and Gomez (1983). Correlation studies were conducted by determining Pearson's correlation coefficient (Best and Roberts, 1975; Hollander and Wolfe, 1973) which corresponds to the classical linear correlation coefficient whose value ranges from -1 to 1 and measures the degree of linear correlation between two traits. For Principal Component Analysis (PCA) analysis Pearson's correlation which has the advantage of giving positive semi-defined matrices was used. Clustering was done by Agglomerative Hierarchical Clustering following Ward's (1963) method which aggregates two groups so that within-group inertia increases as little as possible to keep the clusters homogeneous. The statistical programs used for the analysis were SAS 9.2 and XLSTAT Version 2011.

RESULTS AND DISCUSSION

To identify the significant differences among traits of 32 kenaf genotypes 15 morphological data was collected and analysis of variance was performed (Table 2, Table 3). The result of New Duncan's Multiple Range Test (DMRT) (Table 4) showed that there were significant differences among the genotypes in all traits including plant height (PH), base diameter (BD), core diameter (CD), middle diameter (MD), top diameter (TD), number of nodes (NN), leaf length (LL), leaf width (LW),leaf angel (LA), petal length (PL), days to 50% flowering (DF),(Days to maturity (DM), green weight with leaves and fruit (GW), stick weight (SW) and Fibre weight (FW) ($P < 0.001$). The different genotypes were collected from different parts of globes, therefore many factors such as variation in planting date, plant maturity period, length of growing season, photosensitivity may affect the kenaf yield and made the wide variability of different traits among the genotypes (Webber and Bledsoe, 2002). The middle diameter was relatively stable phenotypic trait for all the kenaf genotypes and Cheng *et al*. (2002) proposed it for the identification of different kenaf varieties. The significant differences for DF and DM among kenaf genotypes had the similarity with the observation of Golam *et al.* (2011) and Balogun *et al*. (2008), where they observed significant variations in days of flowering among kenaf varieties while planted in Malaysian tropical and African arid environment respectively.

The correlation analysis showed different level of relationship among the traits and PH, BD, CD, MD, GW, SW were significantly and positively correlated (Table 5). FW had highly significant positive correlation with PH, BD, CD, MD, NN, DF, DM GW, SW and non significant positive correlation TD, LW, LL, LA. Similar pattern of relationship was observed with GW and SW

with the other traits, except SW had non-significant positive correlation with DF and negative correlation with LA. GW and SW had high positive correlation with PH, BD, CD and NN but non-significant negative correlation with DF and DM. DF and DM had highly significant positive correlation with BD, CD, MD and FW. They had non-significant positive correlation with PH and negative correlation with LL, LW. Balogun *et al*. (2008) also reported similar results. PL had non-significant positive correlation with DF and negative correlation with DM. The positive correlation of FW with DF, DM, BD, CD, NN and negative correlation of PL with DM suggest the fibre yield per plant may be reduced by early maturity because early flowering and maturity causes short plants with shorter internodes and petiole lengths. Webber *et al*. (2002) had reported that initiation of flowering reduced the vegetative growth of the plant. SW had significant positive correlation with DM. Webber (1993) also reported that the length of the growing season has influence in stick yield.

Table 1. Origin and code of 32 different kenaf genotypes (Entries).

Sr. no	Entry	BJRI Code	Origin	Sl no	Entry	BJRI Code	Origin
1	E1	1565	Bangladesh	17	E34	4338	Tanzania
2	E69	5014	China	18	E35	4732	Tanzania
3	E2	1583	USA	19	E18	3745	Kenya
4	E38	4372	Sudan	20	E39	4391,	Guatemala
5	E6	1624	Iran	21	E40	4404	USSR
6	E8	1653	Iran	22	E45	4433	France
7	E9	1662	Uganda	23	E46	4435	France
8	E11	1691	USA	24	E47	4436	France
9	E65	4895	China	25	E49	4442	Costa Rica
10	E14	2731	Bangladesh	26	E57	4634	Thailand
11	E22	3778	Kenya	27	E30	4264	Tanzania
12	E26	4136	Kenya	28	E64	4769	Kenya
13	E28	4198	Kenya	29	E68	4980	Pakistan
14	E29	4202	Tanzania	30	E73	5069	Nepal
15	E75	5084	Nepal	31	E27	4197	Kenya
16	E32	4284	Tanzania	32	E13	1985	Unknown

Table 2. Mean values, minimum, maximum, ranges, standard deviation and coefficients of variation, F value from 15 quantitative traits of 32 genotypes of kenaf (*Hibiscus cannabinus* L.).

Traits	PH	BD	CD	MD	TD	NN	LL	LW	LA	PL	DF	DM	GW	SW	FW
Mean	157.39	9.89	8.64	6.75	3.53	31.35	9.14	7.81	63.90	7.52	50.64	50.65	109.10	13.37	3.22
Std Dev	36.69	2.27	2.15	1.25	0.89	7.92	1.34	1.48	5.29	1.19	5.26	5.43	52.43	5.17	1.65
Minimum	77.33	5.04	4.02	4.05	2.03	15.90	6.75	2.13	54.00	5.00	40.00	39.00	27.00	5.01	1.33
Maximum	213.22	14.59	13.24	9.45	5.78	52.77	12.40	10.50	75.00	10.90	70.00	66.00	229.00	26.00	9.55
Range	135.89	9.55	9.22	5.40	3.75	36.87	5.65	8.37	21.00	5.90	30.00	27.00	202.00	20.99	8.22
CV	16.09	16.27	15.76	11.01	17.23	16.81	8.76	14.07	6.06	11.76	5.29	4.67	29.4	23	24
F value	4.17	3.85	5.30	6.30	4.31	4.63	6.17	3.33	3.49	3.32	9.2	14	5.8	5.78	10

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

Table 3. Means squares of sources of variation of 15 quantitative traits of 32 germplasm of kenaf (*Hibiscus cannabinus* L.).

Source	DF	PH	BD	CD	MD	TD	NN	DF	DM	LL	LW	LA	PL	GW	SW	FW
Genotypes	31	2822.58**	8.71**	8.52**	2.45**	1.47**	131.52**	62.83**	78.85**	3.68**	4.03**	54.28**	2.55**	6336.89**	59.53**	6.66**
Error	64	630.71	3.43	2.74	1.15	0.47	29.45	10.62	5.60	0.88	1.29	15.30	0.86	1010.32	10.86	0.80
Corrected Total	95															

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

Table 4. Means of the quantitative traits of 32 genotypes of kenaf (*Hibiscus cannabinus* L.).

Genotype	PH	BD	CD	MD	TD	NN	LL	LW
E69	212.13^{a}	9.055	8.33^{b-d}	5.865^{d-g}	4.1^{a-f}	30^{c-f}	10.125^{a-e}	9.8^{ab}
E65	207.72^{a-b}	10.52^{b-e}	9.677^{b-c}	6.545^{a-g}	4.4183^{a-e}	34.65^{b-e}	11.135^{a}	9.11^{a-c}
E49	200.5^{a-c}	11.78^{ab}	9.91^{b-c}	6.03^{d-g}	2.42^{h-i}	39.335^{b-c}	7.585^{g}	6.14^{g}
E38	190.17^{a-d}	11.13^{a-d}	10.005^{a-c}	6.855^{a-f}	3.62^{b-i}	38^{b-d}	8.75^{b-g}	7.015^{c-g}
E29	189.97^{a-d}	10.875^{a-d}	10.025^{a-c}	7.395^{a-e}	3.05^{d-i}	37.5^{b-d}	10.575^{a-c}	9.20^{a-c}
E57	185.5^{a-d}	11.205^{a-d}	10.535^{a-b}	7.385^{a-f}	2.735^{f-i}	34.835^{b-e}	9.775^{a-e}	10^{a}
E32	184.75^{a-d}	10.952^{a-d}	9.382^{b-d}	7.2083^{a-f}	3.2883^{c-i}	33.167^{b-f}	11.1333^{a}	9.116^{a-c}
E28	180.5^{a-f}	10.345^{b-e}	10.025^{a-c}	6.895^{a-f}	3.06^{d-i}	34.835^{b-e}	9.575^{a-f}	7.375^{c-g}
E68	175.34^{a-f}	9.2^{b-f}	10.025^{a-c}	6.94^{a-f}	4.9467^{a-b}	32.165^{b-f}	11.075^{a}	9.025^{a-d}
E64	174.83^{a-f}	11.14^{a-d}	9.55^{b-d}	7.725^{a-d}	4.635^{a-c}	33.335^{b-f}	10.25^{a-d}	8.1^{a-f}
E2	174.67^{a-f}	11.72^{a-c}	9.87^{b-c}	7.73^{a-d}	5.0567^{a}	52.332^{a}	8.3^{f-g}	7.24^{c-g}
E35	174.33^{a-f}	9.9^{b-e}	8.737^{b-d}	6.91^{a-f}	3.415^{c-i}	34.665^{b-e}	8.925^{b-g}	7.7^{b-g}
E9	168.33^{a-g}	14.39^{a}	13.04^{a}	8.57^{a}	4.23^{a-e}	41.165^{b}	9.225^{b-g}	7.325^{c-g}
E13	164^{a-g}	9.995^{b-e}	6.23^{d-e}	6.815^{a-g}	3.115^{d-i}	29^{c-g}	9.45^{a-f}	8.525^{a-e}
E18	159.84^{b-h}	9.885^{b-e}	8.31^{b-d}	6.245^{c-g}	3.04^{e-i}	29^{c-g}	8.725^{c-g}	7.575^{b-g}
E30	158.25^{b-h}	10.425^{b-e}	9.075^{b-d}	6.865^{a-f}	3.725^{a-h}	31.5^{b-f}	10.6^{a-b}	7.6^{b-g}
E46	157.69^{c-h}	8.235^{b-f}	7.405^{b-e}	6.775^{a-g}	3.22^{d-i}	30.165^{c-f}	8.725^{c-g}	7.8^{a-g}
E27	157.08^{c-h}	11.03	9.27^{b-d}	6.645^{a-g}	3.145^{d-i}	31.335^{b-f}	9.665^{a-e}	8.615^{a-d}
E39	154^{c-h}	11.055^{a-d}	9.195^{b-d}	7.22^{a-f}	3.73^{a-h}	32.67^{b-f}	8.525^{d-g}	6.8^{d-g}
E26	152.17^{c-h}	10.69^{b-d}	9.54^{b-d}	7.37^{a-f}	3.365^{c-i}	29.71^{c-g}	9^{b-g}	7.875^{a-f}
E45	141.25^{d-i}	9.68^{b-e}	9.02^{b-d}	6.975^{a-f}	3.9^{a-g}	29.585^{c-g}	7.4583^{g}	6.925
E6	141.13^{d-i}	8.01^{c-f}	7.5^{b-e}	5.255^{e-g}	2.56^{g-i}	27.5^{d-g}	7.7417^{f-g}	6.325^{e-g}
E47	140.26^{d-i}	9.2^{b-f}	8.35^{b-d}	8.45^{a-b}	3.7^{b-h}	26.165^{e-h}	9.45^{a-f}	8.45^{a-e}
E75	138.34^{e-i}	10.525	9.125^{b-d}	6.71^{a-g}	4.435^{a-e}	25^{e-h}	9.5^{a-f}	8.96^{a-d}
E1	138.21^{e-i}	11.48^{a-d}	10.185^{a-b}	8.36^{a-c}	4.01^{a-f}	33.165^{b-f}	7.45^{g}	5.55^{g}
E34	137.34^{e-i}	8.035^{b-f}	6.762^{c-e}	6.2^{d-g}	3.73^{a-h}	27.135^{d-g}	9.05^{b-g}	8.35^{a-f}
E40	134.17^{f-i}	8.45^{b-f}	6.795^{c-e}	5.225^{f-g}	3.0517^{d-i}	24.625^{e-h}	9.45^{a-f}	8.975^{a-d}
E11	134.16^{f-i}	8.205^{b-f}	7.695^{b-e}	6.385^{b-g}	2.73^{f-i}	27.5^{d-g}	8.325^{f-g}	7.125^{c-g}
E14	119.75^{g-j}	6.875^{e-f}	4.537^{e}	5.7533^{d-g}	2.285^{i}	23.5^{f-h}	7.5^{g}	6.275^{e-g}
E8	114.04^{h-j}	9.105^{b-f}	7.54^{b-e}	6.04^{d-g}	3.355^{c-i}	34^{b-f}	8.375^{f-g}	8.025^{a-f}
E73	97.84^{i-j}	7.747^{d-f}	7.357^{b-e}	6.05^{d-g}	3.8217^{a-g}	19.165^{g-h}	9.475^{a-f}	7.575^{b-g}
E22	78.17^{j}	5.625^{f}	5.047^{e}	4.7083^{g}	3.2^{d-i}	16.5^{h}	7.45^{g}	5.56^{g}

Significant at 1% probability level. Means with the same letter within the same column are not significantly different PH =Plant height (cm), BD =Base diameter (mm), CD =Core diameter (mm), MD =Middle diameter (mm), TD= Top diameter (mm), NN =Number of nodes, DF =50% Flowering date (Days), DM =Days of maturity, LL= leaf length (cm), LW =leaf width (cm).

Continuation Table 4

Genotype	LA	PL	DF	DM	GW	SW	FW
E69	60^{e-h}	8.075^{a-d}	41.333^{i}	41^{n}	92.5^{e-j}	17^{a-b}	3.795^{b-f}
E65	65^{a-g}	9.56^{a}	48^{d-h}	43^{m-n}	129.66^{b-e}	14.355^{b-e}	3.56^{b-g}
E49	66^{a-f}	5.9167^{g-i}	46.5^{e-i}	49.5^{h-k}	177.5^{ab}	18.845^{a-b}	4.16^{b-d}
E38	72.5^{a}	6.94^{d-i}	48.5^{d-h}	55.167^{b-f}	203^{a}	22.343^{a}	4.1^{b-e}
E29	60^{e-h}	8.47^{a-d}	55.5^{a-c}	53^{d-h}	128.8^{b-e}	19.165^{a-b}	4.665^{b}
E57	61^{d-h}	8.125^{a-d}	47^{e-i}	47.167^{i-m}	130.8^{a-e}	14.5^{b-e}	4.135
E32	64.167^{b-g}	8.59^{a-d}	52^{b-f}	50.167^{h-j}	99.66^{d-j}	15.54^{b-c}	4.061^{b-e}
E28	62.5^{c-h}	7.855^{a-g}	53^{b-e}	50.667^{g-j}	115.5^{c-g}	10.2^{c-h}	3.125^{b-i}
E68	61^{d-h}	9.225^{ab}	47.5^{d-i}	44.5^{l-n}	111.59^{c-h}	18.665^{a-b}	4.26^{bc}
E64	57.5^{g-h}	8.15^{a-d}	48.5^{d-h}	49.167^{h-k}	145.13^{a-d}	19.33^{a-b}	3.835^{b-f}
E2	61^{d-h}	8.875^{a-c}	52.5^{b-f}	57^{b-d}	166.5^{a-c}	14.67^{b-e}	3.835^{b-f}
E35	57.5^{g-h}	6.9^{d-i}	50.5^{c-h}	52^{f-g}	116.2^{c-g}	15.67^{b-c}	2.935^{b-i}
E9	70^{a-c}	7.8917^{a-f}	46.417^{f-i}	64.667^{a}	203.06^{a}	19.165^{a-b}	9.4833^{a}
E13	65^{a-g}	7.75^{a-h}	47.5^{d-i}	48.5^{h-l}	110.3^{c-h}	13.765^{b-f}	2.585^{d-i}
E18	56^{h}	7.275^{c-i}	53^{b-e}	52.5^{e-h}	94.1^{d-j}	16^{b-c}	2.35^{e-i}
E30	62.5^{c-h}	7.875^{a-f}	54^{b-d}	50^{h-k}	51.63^{i-j}	15.29^{b-d}	4.2083^{b-d}
E46	67.5^{a-e}	6.9^{d-i}	51.5^{c-h}	50.333^{h-j}	77.6^{e-i}	13^{b-f}	3.335^{b-i}
E27	66^{a-f}	8.125^{a-d}	55.833^{a-c}	55^{c-g}	110.34^{c-h}	15.335^{b-d}	2.47^{d-i}
E39	58.5^{f-h}	7.2^{c-i}	61.5^{a}	58.667^{b-c}	132.8^{a-e}	12.82^{b-g}	3.335^{b-h}
E26	62.5^{c-h}	7.475^{b-i}	61^{a}	60.167^{b}	109^{c-h}	14.34^{b-f}	3.805^{b-f}

E45	65^{a-g}	7.225^{c-i}	55.5^{a-c}	51.667^{f-i}	108.9^{c-h}	13.562^{b-f}	2.86^{c-i}
E6	71^{a-b}	6.025^{f-i}	50^{c-h}	48.5^{h-l}	50.1	7.065^{g-h}	1.865^{g-i}
E47	72.5^{a}	7.3^{c-i}	48^{d-h}	46.167^{j-m}	105.59^{c-i}	7.5^{f-h}	2.45^{d-i}
E75	63.5^{b-h}	8.21^{a-d}	45.5^{g-i}	43.5^{m-n}	199.5^{a}	7.515^{f-h}	2^{g-i}
E1	67.5^{a-e}	5.825^{i}	58^{a-b}	56.5^{b-e}	45.42^{j}	15.25^{b-d}	3.185^{b-i}
E34	60^{e-h}	7.98^{a-d}	50.5^{c-h}	49.5^{h-k}	77^{e-i}	10.33^{c-h}	1.83^{g-i}
E40	63.5^{b-h}	7.125^{c-i}	48.5^{d-h}	49.5^{h-k}	52.2^{i-j}	8.29^{e-h}	1.915^{g-i}
E11	63.5^{b-h}	7.015^{c-i}	52^{b-f}	52.167^{e-h}	76.98^{e-j}	6.665^{g-h}	1.6183^{h-i}
E14	67.5^{a-e}	6.05^{f-i}	49^{d-h}	48.667^{h-l}	54.47^{g-j}	9^{d-h}	2.1^{f-i}
E8	68.5^{a-d}	7.175^{c-i}	51^{c-h}	46.667^{i-m}	118.97^{c-f}	10.085^{c-h}	2.09
E73	63.5^{b-h}	7.1^{c-i}	46^{f-i}	50.167^{h-j}	58.68^{f-j}	6.83^{g-h}	1.4633^{i}
E22	62.5^{c-h}	6.575^{e-i}	45^{h-i}	45.5^{k-m}	37.74^{j}	5.883^{h}	1.5^{i}

Significant at 1% probability level. Means with the same letter within the same column are not significantly different.
LA= Leaf angel (cm) PL =Petal length (mm), GW=Green weight with leaves and fruit (gm), SW= Stick weight (gm), FW = Fibre weight (gm).

Table 5. Pearson correlation matrix for 15 morpo-agronomic traits of 32 different kenaf genotypes.

Traits	PH	BD	CD	MD	TD	NN	DF	DM	LL	LW	LA	PL	GW	SW	FW
PH	1														
BD	0.69**	1													
CD	0.64**	0.89**	1												
MD	0.43*	0.76**	0.75**	1											
TD	0.02	0.77	0.47*	0.41*	1										
NN	0.79**	0.78**	0.58**	0.57**	0.20	1									
DF	0.03	0.57**	0.53**	0.51**	0.10	0.36*	1								
DM	0.14	0.52**	0.50**	0.37*	0.11	0.39*	0.73**	1							
LL	0.53**	0.27	0.35	0.27	0.32	0.12	-0.08	-0.11	1						
LW	0.47**	0.18	0.23	0.18	0.18	0.08	-0.23	-0.23	0.83**	1					
LA	-0.17	0.03	0.00	0.06	-0.20	-0.02	0.17	0.39**	-0.25	-0.25	1				
PL	0.50**	0.57*	0.41*	0.34	0.51**	0.36*	0.02	-0.07	0.82**	0.75**	-0.34*	1			
GW	0.56**	0.78**	0.65**	0.53**	0.32	0.67**	0.35**	0.55**	0.18	0.22	0.09	0.37**	1		
SW	0.79**	0.68**	0.69**	0.53**	0.20	0.70**	0.26	0.41**	0.35**	0.27	-0.15	0.34	0.58**	1	
FW	0.55**	0.73**	0.77**	0.58**	0.35	0.66**	0.71**	0.65**	0.31	0.15	0.07	0.33	0.59**	0.75**	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), TD= Top diameter (mm), NN =Number of nodes, DF =50% Flowering date (Days), DM =Days of maturity, LL= leaf length (cm), LW =leaf width (cm), LA=leaf angle (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 15 quantitative traits of 32 kenaf genotypes.

Characters	Principal component[1]		
	First (6.94; 46.27 %)	Second (3.04; 20.24 %)	Third (1.23; 8.17 %)
Plant height	0.300	-0.124	-0.235
Base diameter	0.345	0.134	-0.026
Core diameter	0.341	0.111	-0.025
Middle diameter	0.294	0.151	0.231
Top diameter	0.210	-0.116	0.284
Node number	0.314	0.130	-0.152
Days to 50% flowering	0.240	-0.369	0.174
Days to maturity	0.201	-0.434	0.163
Leaf length	-0.015	0.241	-0.391
Leaf width	0.268	-0.322	0.183
Leaf angle	0.065	0.364	0.575
Petal length	0.130	0.506	0.230
Green weight	0.276	0.027	-0.322
Stick weight	0.297	0.056	-0.165
Fibre weight	0.299	0.148	-0.169

([1] values in the parentheses correspond to the eigenvalues and proportion of the total variation accounted for each component).

Table 7. Means and numbers of the 32 kenaf (*Hibiscus cannabinus* L.) genotypes forming three clusters.

Cluster	NA	PH	BD	CD	MD	TD	NN	DF	DM	LL	LW	LA	PL	GW	SW	FW
1	11	132.44	8.45	7.33	6.16	3.27	26.34	47	49	8.59	7.15	64.09	6.89	61.44	10.32	2.30
2	16	169.24	10.24	9.00	7.02	3.62	32.35	50	52	9.65	8.46	62.92	7.95	116.92	14.48	3.37
3	5	174.39	11.91	10.39	7.18	3.95	39.16	53	56	8.60	7.34	66.60	7.56	189.91	16.50	4.71

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

Principal component analysis (PCA) by using Pearson correlation coefficient revealed total 15 PCA components for total variation of 32 kenaf genotypes by using 15 morphological traits. First three components had the eigenvalues greater than 1 and explain 74.69 % of the total variation (Fig. 1; Table 6). The first component of PCA analysis explained 46.28 % of total variation and includes plant height, base diameter, core diameter, middle diameter, stick weight and fibre weight. Therefore, variation of the first PCA component could be explained by plant height and plant diameter (BD, CD, MD), number of nodes and major yield traits of kenaf plants which includes the fibre weight. The second component explained 20.24 % of total variation and includes 50% flowering days, days of maturity, petal length, leaf width, leaf length and leaf angle. Therefore, the second component could be denoted by plant developmental stages (DF, DM), petal length and leaf area (LW, LL, LA). The third component describes only 8.17 % of the variation including top diameter. Three-group pattern was observed against a scatter plot by the first two major components which accounted for 66.52 % of the total variation (Fig. 2). Therefore, based on PCA analysis with 15 morpho-agronomic traits from 32 kenaf genotype from different source of origin can approximately divided into three groups.

More specific grouping of the kenaf was obtained by Agglomerative Hierarchical Cluster (AHC) analysis and to measure the distance within the cluster and the genotype, dendogram was created following Ward (1963). It produced three major clusters showing distance within the genotype by forming clusters with more homogenous group (Fig. 3, Table 7). From total 32 kenaf genotypes, Cluster 1, 2 and 3 contained 11, 16, and 5 genotypes, respectively. The low fibre and stick yield producing early maturing genotypes were in cluster 1 and contained genotype E1, E6, E11, E14, E22, E34, E18, E40, E46, E30 and E73. Cluster 2 contained genotype E69, E8, E65, E26, E28, E29, E32, E35, E39, E45, E47, E57, E64, E68, E27, E13 and was characterized by middle fibre weight, plant height and diameter. The high fibre and stick weight producing late flowering genotypes E2, E38, E9, E75 and E49 were in cluster 3. Cheng *et al.* (2002) and Balogun *et al*. (2008) reported the effect of flowering in the formation of different clusters in kenaf. Similar result was also obtained in our experiment. Late flowering and matured genotype belongs to the cluster 3. The early flowered and matured genotypes were in cluster 1 and those flowering and maturing at intermediate time was in the cluster 2. The maturity period has been reported to be an indication of sensitivity of kenaf varieties to photoperiod, later maturing varieties being photo-insensitive relative to early maturing when planted in the tropics (Webber *et al*. 2002).

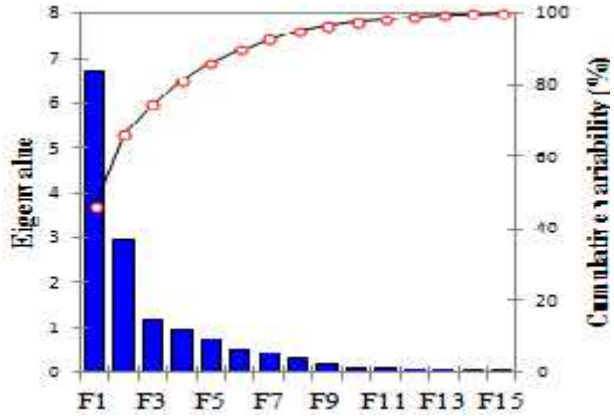

Fig. 1. Scree plot constructed with total 15 principal components for total variation in 15 morphological traits of 32 kenaf genotypes.

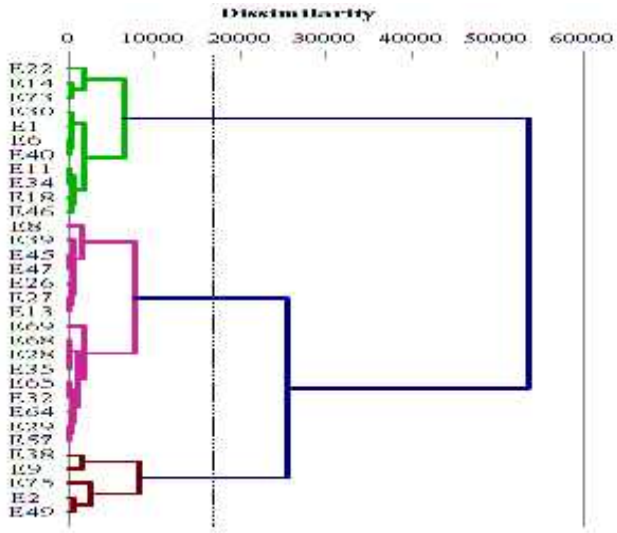

Fig. 3. Dendogram showing the genetic relationships of 32 kenaf genotypes by Ward's method.

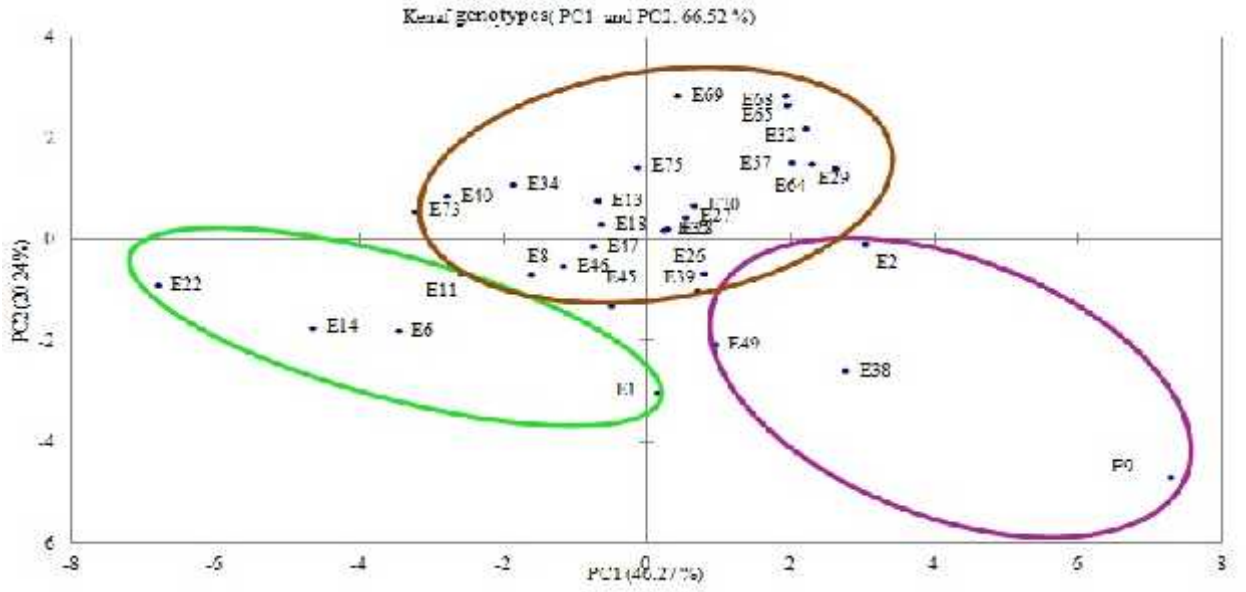

Fig. 2. Scatter plot from first two components of PCA analysis showing the variation of 32 kenaf genotypes.

In our investigations, the candidate kenaf genotypes for better fibre yield were grouped under cluster 3 but late matured and photo-insensitive, while intermediate flowerings genotypes were grouped under cluster 2 and they are relatively photo-sensitive. So it is suggested that for potential cross can be made between the genotypes of cluster 3 and cluster 2 to get relatively photo insensitive variety with better fibre yield.

Conclusion: Fibre weight (FW) is the key parameter of kenaf yield and in the present investigation significant differences in fibre weight were observed among the genotypes. Significant positive correlations were also observed between fibre weight (FW) and other traits such plant height (PH), base diameter (BD), core diameter (CD), middle diameter (MD), number of nodes (NN), days to 50% flowering (DF), days to maturity (DM), green weight with leaves and fruit (GW) and stick weight (SW). Total 74.68 % of the variation was explained by the first three principal components. Plant diameters (BD, CD, TD), developmental stages (DF, DM) and leaf area (LW, LL, LA) were mostly prejudiced by the major components. The three major cluster contained different photosensitive genotypes along with high yielding potential ones. The study of genetic diversity of different kenaf genotype explores the relationships between the genotypes which are in need for production, conservation and utilization of this green resource. It will be very useful for varietal improvement of kenaf in Malaysian tropical environment by selecting genotype with different genetic backgrounds. This information will facilitate efficient breeding programs for better yielding adaptive verities to promote better environment with raw fibre resource.

REFERENCES

Abdul, K., H. P. S., I. Yusra, A. F., A.H. Bhat, and M. Jawaid (2010). Cell wall ultra structure, anatomy, lignin distribution, and chemical composition of Malaysian cultivated kenaf fiber. Ind. Crop Prod. 31(1): 113-121.

Balogun, M. O., J. A. Raji and S. R. Akande (2008). Morphological characterization of 51 kenaf (*Hibiscus cannabinus* L.) accessions in Nigeria. Revista UDO Agrícola 8 (1): 23-28.

Best D. J. and D. E. Roberts (1975). Algorithm AS 89: The Upper Tail Probabilities of Spearman's *rho*. J. Appl. Stat. 24: 377–379.

Cheng, Z. B., L. Lu, B. S. Baldwin, K. Sameshima and J. K. Chen (2002). Comparative studies of genetic diversity in kenaf (*Hibiscus cannabinus* L.) varieties based on agronomic and RAPD data. Hereditas. 136 (3): 231-239.

Crane, J. C., and J. B. Acuna (1945). Effect of plant spacing and time of planting on seed yield of kenaf (*Hibiscus cannabinus* L.). Agron. J. 37: 969-977.

Dempsey, J. M. (1975). Fiber crops. The University Presses of Florida, Gainesville.

F. A. O. (2006). Jute, Kenaf, Sisal, Aabaca, Coir and Allied Fibers Statistics. http://www.fao.org/ es/esc/en/ 20953/21005/highlight_51023en.html.

Golam F., M. A. Alamgir, M. M. Rahman, B. Subha and M. R. Motior (2011). Evaluation of genetic variability of kenaf (*Hibiscus cannabinus* L.) from different geographic origins using morpho-agronomic traits and multivariate analysis. Aust. J. Crop Sci. 5(13): 1882-1890.

Gomez, K. A. and A. A. Gomez (1983). Statistical Procedures for Agriculture Research. 2nd edition, paperback, pp: 680.

Hollander M. and D. A. Wolfe (1973). Nonparametric Statistical Methods. New York: John Wiley & Sons. pp: 185–194.

Lemahieu, P. J., E. S. Oplinger and D. H. Putnam (2003). Kenaf. In: Alternative Field crops Manual. http://www.corn.agronomy.wisc.edu/FISC/Alternatives /Kenaf.htm.

Li, Z. D. (1980). Kenaf. In: Theory and technology of fiber crops (in Chinese) (Ed.). Scientific and Technological Press, Shanghai, pp: 541–595.

Rymsza, T. A. (1999). Utilization of Kenaf raw materials. Paper presented to the Forest Products Society. Boise, Idaho. June 30, 1999.

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

Ward, J. H. (1963). Hierarchical grouping to optimize an objective function. J. Am. Stat. Assoc. 58: 238-244.

Webber, C. L. (1993). Yield components of five kenaf cultivars. Agron. J. 85(3): 533–535.

Webber C. L. III. and V. K. Bledsoe (2002). Kenaf yield components and plant components. In: Janick, J., A. Whipkey (Eds.) Trends in New Crops and New Use. ASHS Press, Alexandria, VA, pp: 348–357.

Webber, C. L., H. L, Bhardwaj, and V. K. Bledsoe (2002). Kenaf Production: Fibre, Feed and Seed. In: Janick, J., A. Whipkey (Eds.), Trends in new crops and new uses. ASHS Press, Alexandria, VA, pp: 327-339.