

Seasonal Performance and Traits Relationship of Kenaf (*Hibiscus Cannabinus* L.) Cultivars Grown in Forest-Savannah Transition Agro-Ecology

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Abstract

A two-season experiment was conducted to evaluate effects of seasons on agronomic performance of some cultivars of kenaf in a forest-savannah agro-ecology. This study also elucidated the relationship among traits of the crop. In each season, cultivars were arranged in a randomized complete block design with three replications. The crop was harvested for fibre and seeds. Morphological, flowering and yield data were collected and subjected to analysis of variance separately and across seasons. Pearson's correlation analysis was also performed across seasons to detect the associations among the crop's traits. Variation due to cultivars existed in all the agronomic parameters except the basal stem diameter. The effect of seasons and cultivars × seasons were significant in plant height and basal, middle and top stem diameters only. The kenaf cultivars are more sensitive to water supply during their vegetative stage than flowering or seed production stage. Various levels of significant differences existed in vegetative traits which were higher under rain than irrigation. Variation in the flowering pattern within season showed that the cultivars belong to various maturity groups. Cultivars AU-2452-4³, AU-2452⁴, AU-6028-2⁶, AU-2452⁶, AU-2452⁵ and V1 400 flowered late. Seed yield per plot (5m²) varied among the cultivars with a mean of 1.6 kg. Cultivar 2QQ 17¹ had highest seed weight. The AU-2452⁴, AU-754⁴, AU-60-282⁶ and 2QQ 17¹ may be considered for building construction because of their high core fibre yields along with other industrial attributes.

Keywords: Bast fibre core fibre; Cultivars; Cultivars seasons; Malvaceae; Season effects

Introduction

Kenaf (*Hibiscus cannabinus* L.), the third largest fibre crop of economic importance after cotton and jute, belongs to the family Malvaceae. The crop is a fast growing short-day C₃ herbaceous plant that originated from tropical Africa, and it is cultivated for both food and fibre in West Africa. It attains a height of between 5 to 6m in 120 and 130 days in tropical and temperate regions with abundant solar radiation and high rainfall (Alexopoulou *et al.*, 2000; Webber and Bledsoe 2002; Shukor *et al.*, 2009). Kuchinda and Ogunwole (2000) and Saka *et al.* (2007) reported that the crop gave high yields and economic returns when intercropped with arable crops.

Kenaf has the potential to serve dual purposes of cash and food crops. It is currently attracting both farmers and industrialists' interest because of its food, environmental and economic benefits (Nkaa *et al.*, 2007; Balogun *et al.*, 2009). It is a reliable source of roughage and protein for livestock, and it has potentials to provide income to farmers and contributes to national earnings. Its environmental benefit in vast agro-ecosystems of the world involves biomass production as substitute to non-renewable resources (Dutt *et al.*, 2009). The crop is cultivated for utilization in the areas of soil remediation, reduction of soil erosion due to wind and water, toxic waste clean-up, replacement or reduction in use of

fibre glass in industrial products (Webber *et al.*, 2002).

Kenaf fibre yield per hectare varies considerably and ranges from 12 to 30 t ha⁻¹ (Villar *et al.*, 2009). Variation in the crop's yield is associated with type of cultivars, soil type, location, climate and the management practices. These parameters as well as season which is dictated by the prevailing weather condition at the time of cultivation of the crop could be vital to consider selection of best cultivars for specific location of cultivation and for end users' desired traits (Mahapatra *et al.*, 2009; Alexander *et al.*, 2007).

Kenaf has greater adaptability to various growing environments and its handling is easier than any other fibre crop (Lemahieu *et al.* 2003). The crop fits well into farming systems of the tropics, it has multipurpose uses for food, income generation and environment amelioration. Based on this, it is currently attracting farmers and industrialists. Despite these great attributes, cultivation of the kenaf is still minimal in sub-Saharan Africa (Keshk *et al.*, 2006) and limited research work has been done on it. Chief among the factors responsible for the low cultivation of the crop is inadequate information on available cultivars suitable for specific season. Information on the performances of different cultivars is useful in selection and development of improved varieties. Evaluation of available cultivars of the crop shall provide information on variation in the agro-morphology as well as growing, flowering and fruiting patterns of kenaf. The effects of season in crop production cannot be over-emphasized because environmental factors prevailing at the time of cultivation of the crop manipulate the overall performance of the crop. Hence, the effects of cultivars, seasons as well as

cultivars × environments are important in selecting promising cultivars for specific locations. Very little research work has been done on kenaf in this regards and relationships among the traits of different germplasm are still poorly understood. This is responsible for the very limited information on the crop. With this study, cultivars suitable for cultivation in specific seasons can be identified and the correlation among the yield and other traits can be well understood. Therefore, this research was conducted to determine the variation in the effects of seasons on yield and yield components as well as traits relationship of kenaf cultivars grown in forest-savannah transition agro-ecology.

Materials and methods

Experimental site, materials, design and field layout. A total of 32 kenaf cultivars (cvs.) were evaluated in the field during the dry (January to May) and rainy (May to September) seasons of 2014 in Ibadan (Longitude 3° 84'E, Latitude 7° 38'N) which represents rainforest-savannah transition agro-ecology of Nigeria. The 32 kenaf cultivars comprised of 29 exotic lines obtained from different parts of the world, especially United States of America and Mexico, one indigenous line and two varieties developed by Institute of Agricultural Research and Training, Nigeria. Seeds of each cultivar were planted in a two-row plot, 5 m long each, at a spacing of 25 cm within row and 1 m between rows in each of the two seasons. The cultivars were arranged in a randomized complete block design with three replications. Dry season evaluation was done under irrigation and the rainy season trial was rain-fed. Sources of water to the plants provided the season effects in

this study.

Crop cultivation and processing. Four seeds were sowed per hill and thinned to two per stand to adjust the population density to 80,000 plants ha⁻¹ at three weeks after planting. A commercial fertilizer, N:P:K 15:15:15, was applied at the rate of 60 kg ha⁻¹ at four weeks after planting. The plots were kept weeds and pests free throughout the study.

Each plot was divided into two halves; plants on one half were harvested for fibre at 50% flowering stage whereas those on the second half were harvested for seed. Both the fibre and the seeds were harvested and processed appropriately. At harvest, kenaf plants were cut from ground level and fibres were extracted from the plants by retting. Freshly cut kenaf bundles were tagged per plot and soaked in a running stream and allowed to float for 14 days after which the fibre was stripped from core manually and washed in clean water to ensure fibre quality. The fibre was dried by direct sunshine. Fibre dryness was taken by hand feeling. Dry plants with pods on the second half of the field were cut just before the seeds shattered and threshed for seed recovery.

Data collection and analysis. Morphological data were collected from ten randomly selected plants from each plot. The height (PH) was measured from the ground level to the top of the plants. The basal stem diameter (BSD), mid-length stem diameter (MSD) and top stem diameter (TSD) respectively were measured by a venier calliper at 15 cm above the base, mid-length and 15 cm below the apex of the plants. Days to first flowering (DTFF) and days to 50 % flowering (D50%F) were obtained by counting number of days from planting to emergence of first flower and 50 % flowering. Number of nodes

were counted per plant. The internode length (INLG), leaf width (LWD), leaf length (LGT) and petiole length (PTLT) were measured using meter rule. Basal core diameter (BCD) was obtained with vernier callipers at 15 cm up the base of the plant, seed weight (SWT), bast dry weight (BDWT) and core dry weight (CDWT) were collected by weighing. All the vegetative growth data were taken 80 days after planting.

Data collected were subjected to analysis of variance using SAS (2004). The data were analysed separately and across seasons as appropriate. Cultivar × season was used to explain results when the interaction was significant and Fisher's protected least significant difference (LSD) was used to separate main effect means when the interaction was not significant. Pearson's correlation analysis was also performed on the data across seasons to determine the associations among the traits of the crop.

Results

Variation in agronomic traits of the kenaf in a forest-savannah transition agro-ecology. Significant variation due to genotypes, existed ($p < 0.01$) in all the agronomic parameters considered in the evaluation of the cultivars except the basal stem diameter. The effects of seasons and cultivars × seasons were significant in plant height and basal, middle and top stem diameters only (Table 1). Means, ranges and coefficients of variation among the kenaf cultivars were shown in Table 2. The coefficients of variation (CVs) ranged from low to moderately high (9.93 to 24.08 %). The CVs of cultivars of vegetative parameters were lower than those of yield parameters. Coefficient of variation of each of core, bast

Table 1. Mean square of some agronomic traits of kenaf cultivars evaluated in forest-savannah transition agro-ecology

Trait	Mean square			
	Cultivar	Season	Cultivar × season	Error
Day to first flowering	562.43 ^{***}	488.48 ^{ns}	312.12 ^{ns}	1.01
Day to 50 % flowering	439.92 ^{***}	439.92 ^{ns}	211.23 ^{ns}	3.51
Plant height	2586.91 ^{***}	11571.28 ^{***}	2247.67 ^{***}	391.25
Base stem diameter	0.79 ^{ns}	0.35 ^{***}	0.57 ^{***}	0.09
Middle stem diameter	0.33 ^{***}	3.53 ^{***}	0.22 ^{***}	0.04
Top stem diameter	0.06 ^{***}	1.53 ^{***}	0.07 ^{***}	0.02
Core diameter	0.52 ^{***}	0.53 ^{ns}	0.12 ^{ns}	0.05
Bast weight	18.15 ^{***}	17.80 ^{ns}	17.01 ^{ns}	2.17
Core weight	152.24 ^{***}	165.71 ^{ns}	144.44 ^{ns}	34.23
Seed weight	6532.45 ^{***}	6032.45 ^{ns}	5901.10 ^{ns}	180.60

^{ns}, *, **, *** Non-significant or significant at $P < 0.05$ or $P < 0.01$ or $P < 0.001$, respectively

Table 2. Mean, standard error, range and coefficient of variation of agro-morphological traits of kenaf evaluated across seasons in forest-savannah transition agro-ecology

Trait	Mean±se	Range		Coefficient of variation (%)
		Maximum	Minimum	
Plant height (cm)	242.65±3.21	317.30	59.50	13.17
Basal stem diameter (cm)	2.41±0.04	3.41	1.09	17.38
Middle stem diameter (cm)	1.45±0.02	1.95	0.75	14.69
Top stem diameter (cm)	0.82±0.01	1.13	0.51	16.08
Day to first flowering	59.35±1.40	116.00	36.33	22.80
Day to 50 % flowering	75.49±1.21	122.33	61.66	16.01
Seed weight (kg/5m ²)	1.53±4.77	2.37	0.70	55.78
Length of internode (cm)	15.33±0.37	25.50	11.76	24.08
Number of node per plant	54.83±0.95	78.87	33.53	17.28
Base core diameter (cm)	2.37±0.05	3.90	1.24	18.92
Bast dry weight per plant (g)	9.42±0.27	15.47	4.05	28.80
Core dry weight per plant (g)	23.24±0.84	45.20	9.00	36.19
Width of leaf lobe (cm)	2.89±0.18	7.50	0.76	10.49
Leaf length (cm)	14.27±0.14	19.70	10.80	9.93
Petiole length (cm)	17.95±0.29	27.00	11.85	16.03

and seed weights was greater than 28 %. The ranges were wide in all the characters except leaf length.

Effect of seasons on growth and yield of kenaf in a forest-savannah transition agro-ecology. Effect of seasons on the performance of the kenaf cultivars were presented in Table 3. There were various level of significant differences in plant height as well as base, middle and top stem diameters. The vegetative growth of the plants was higher under rain than irrigated except in cultivars G45-2 and Ex-Shika which performed better under irrigation. The values for plant height and stem diameters were higher under rain but the effect of seasons was not significant in the MSD in the Cuba 19². Plant height and BSD were higher in AU-7541⁴ and AU-2452³ under rain whereas Pankeshin JG had higher MSD and TSD under rain than under irrigation. Variation in the pattern of seasons on other growth and yield traits of the cultivars was as in presented in the Table 3. Effect of seasons on flowering and yield components of the kenaf cultivars was mostly not significant.

Flowering behaviour and seed yield of kenaf evaluated in forest-savannah transition agro-ecology. Variation in days to flowering and duration from DTFF to D50%F as well as seed yield per plot of the kenaf cultivars was presented in Table 4. Mean DTFF and D50%F, and duration from DTFF to D50%F were about 61, 77 and 15 days respectively. The pairs of maximum and minimum values for these parameters were about 88 and 47 for DTFF; 99 and 64 for D50%F; and 26 and 2 for duration from DTFF to D50%F. Cultivars AU-2452-4³ had both the highest DTFF and D50%F whereas 2QQ-17¹ had the least DTFF. Table 4 also showed that AU-2452-4³, AU-2452⁴, AU-6028-2⁶, AU-2452⁶, AU-2452⁵ and V1-400 were cultivars that had

highest D50%F and that cultivars AC-313-24⁴, V-100-10¹, Tianung 1 and Tianung 2 had least D50%F. Ifeken DI-400 had least days interval from DTFF to D50%F whereas AU-6028-2⁶ had the highest. The seed yield per plot varied among the cultivars with a mean of 1.6 kg, and ranged from 0.61 to 2.37 kg. Cultivars AU-2452-4³ and 2QQ 17¹ respectively had lowest and highest seed weight.

Fibre yield of kenaf evaluated in forest-savannah transition agro-ecology.

Variation existed in the core diameter, bast and core fibre weights among the cultivars evaluated (Table 5). Cultivars 2QQ 1³, AU-2452³, 2QQ 17³ and Tianung 1 had less than 2 cm core diameter whereas AU-2452⁴ and 2QQ 17¹ had the highest (35.88g and 38.86g respectively). Only Cuba 19¹, 2QQ 17¹, Cuba 19², AU-2452⁴ and AC-313-24⁴ had bast fibre weight significantly higher than the mean whereas AU-2452⁴, AU-7541⁴, AU-60-282⁶ and 2QQ 17¹ were significantly higher than the mean of core fibre weight.

Characters relationship of kenaf evaluated in derived savannah agro-ecology.

The inter-relationship among agronomic characters of the kenaf cultivars was presented in Table 6. Relationships existed among the flowering traits and seed and fibres yield of the crop. The DTFF was highly and positively related to DT50F (0.89) but negatively related to SWT and CRD. The DT50F was also negatively related to PH and SWT. Both the DTFF and D50%F was found to be positively related to LLWD. The PH had a negative significant association with MSD and CRD, but had positive significant association with NND. The BSD and PTLT related to other parameters more than any other trait, but the BSD had more positive significant

Table 3. Variation in vegetative growth of the 32 cultivars of kenaf evaluated under irrigation and rain-fed in forest-savannah transition agro-ecology

Cultivar	Season	Plant height (cm)	Base stem diameter (cm)	Middle stem diameter (cm)	Top stem diameter (cm)
G 45-2	Irrigated	225.17 ^{***}	2.23 ^{***}	1.28 [*]	0.92 ^{ns}
	Rain-fed	332.33	3.23	1.67	1.05
2QQ 1 ³	Irrigated	231.73 ^{***}	2.24 ^{ns}	1.36 ^{ns}	0.74 ^{ns}
	Rain-fed	271.33	2.56	1.54	0.92
AU-7541 ⁴	Irrigated	190.40 ^{***}	2.61 ^{**}	1.54 ^{ns}	0.91 ^{ns}
	Rain-fed	320.00	3.18	1.35	0.87
Ifeken 100	Irrigated	247.13 ^{ns}	2.14 [*]	1.62 [*]	0.86 ^{ns}
	Rain-fed	263.33	2.62	1.38	0.80
AU-2452-4 ³	Irrigated	261.83 ^{***}	2.18 ^{**}	1.62 [*]	0.81 [*]
	Rain-fed	315.00	2.91	1.10	0.61
Ex Shika 24 ²	Irrigated	255.70 ^{ns}	2.76 ^{ns}	1.42 ^{ns}	0.76 ^{ns}
	Rain-fed	270.00	2.94	1.64	0.87
A-60-282-5 ¹	Irrigated	322.77 ^{ns}	2.52 ^{ns}	1.61 [*]	0.79 ^{ns}
	Rain-fed	323.33	2.19	1.35	0.76
Cuba 19 ²	Irrigated	252.77 ^{***}	2.60 ^{**}	1.46 ^{ns}	0.40 ^{***}
	Rain-fed	304.00	3.25	1.38	0.84
AU-2452 ⁴	Irrigated	224.03 ^{***}	2.33 ^{ns}	1.39 ^{ns}	0.79 ^{ns}
	Rain-fed	313.33	2.55	1.61	0.90
AU-60-282 ⁶	Irrigated	256.50 ^{ns}	1.77 ^{ns}	1.11 ^{ns}	0.62 ^{ns}
	Rain-fed	260.77	1.78	1.17	0.63
AU-724 ⁸	Irrigated	235.97 ^{***}	2.75 [*]	1.55 ^{ns}	0.99 ^{***}
	Rain-fed	330.67	2.20	1.36	0.80
2QQ 17 ³	Irrigated	245.37 ^{***}	2.93 ^{ns}	1.81 ^{ns}	0.51 ^{***}
	Rain-fed	344.00	2.82	1.79	0.82
Cuba Ovate 5 ¹	Irrigated	241.30 ^{***}	2.36 ^{ns}	1.01 [*]	0.66 [*]
	Rain-fed	336.67	2.19	1.57	0.85
AU-2452 ⁶	Irrigated	253.07 ^{ns}	2.31 ^{**}	1.33 ^{**}	0.79 [*]
	Rain-fed	278.67	1.74	0.77	0.62
AC-313-24 ⁴	Irrigated	255.25 [*]	2.43 ^{***}	1.54 ^{**}	0.84 ^{**}
	Rain-fed	289.00	1.56	0.77	0.57
Cuba 19 ¹	Irrigated	212.77 ^{***}	2.48 ^{***}	1.27 ^{**}	0.79 ^{***}
	Rain-fed	340.33	2.38	0.71	0.45
AU-60-282 ⁵	Irrigated	236.53 ^{**}	2.61 ^{ns}	1.46 ^{**}	1.00 ^{**}
	Rain-fed	303.67	2.45	0.94	0.76
Ex Giwa 34 ¹	Irrigated	259.23 ^{ns}	3.11 ^{***}	1.54 ^{**}	0.94 ^{**}
	Rain-fed	257.00	1.45	0.62	0.40

Table 3. (Cont'd)

Cultivar	Season	Plant height (cm)	Base stem diameter (cm)	Middle stem diameter (cm)	Top stem diameter (cm)
AC-313-29 ³	Irrigated	261.93 ^{ns}	2.45 ^{**}	1.40 ^{**}	0.79 ^{**}
	Rain-fed	240.33	1.05	0.64	0.48
Pankeshin JG	Irrigated	204.00 [*]	1.14 [*]	1.78 ^{ns}	0.59 ^{ns}
	Rain-fed	240.67	1.56	0.57	0.47
2QQ 17 ¹	Irrigated	257.93 ^{***}	2.98 ^{***}	1.75 [*]	0.66 ^{ns}
	Rain-fed	338.00	1.87	0.98	0.61
Cuba 19 ³	Irrigated	266.87 [*]	2.52 ^{ns}	1.32 ^{**}	0.69 [*]
	Rain-fed	318.33	2.47	0.69	0.54
AU-2452 ⁵	Irrigated	291.57 [*]	2.64 ^{ns}	1.39 ^{ns}	0.81 ^{***}
	Rain-fed	329.67	2.62	1.26	0.53
AU-719 ²	Irrigated	245.07 ^{ns}	2.64 ^{ns}	1.43 ^{ns}	0.80 ^{ns}
	Rain-fed	276.67	2.62	1.28	0.87
Ifeken 400	Irrigated	265.77 ^{ns}	2.43 ^{ns}	1.53 [*]	0.83 ^{**}
	Rain-fed	289.67	2.43	1.09	0.56
V-100-10 ¹	Irrigated	246.33 ^{**}	2.49 [*]	1.39 [*]	0.68 ^{ns}
	Rain-fed	319.67	2.09	1.09	0.72
V1-400	Irrigated	188.30 ^{***}	2.74 ^{ns}	1.55 ^{ns}	1.05 ^{***}
	Rain-fed	282.00	2.64	1.40	0.63
Cuba 108	Irrigated	244.83 ^{ns}	2.31 ^{**}	1.55 ^{**}	0.95 ^{**}
	Rain-fed	263.67	1.71	0.89	0.44
Tianung 1	Irrigated	239.33 ^{ns}	1.65 ^{ns}	0.86 ^{ns}	0.68 ^{ns}
	Rain-fed	260.67	1.99	0.96	0.58
Tianung 2	Irrigated	264.70 ^{ns}	2.04 ^{ns}	1.41 [*]	0.81 [*]
	Rain-fed	268.30	2.00	1.01	0.53
Ex Shika	Irrigated	236.33 [*]	2.13 ^{**}	0.88 ^{**}	0.46 ^{**}
	Rain-fed	292.50	2.77	1.44	0.75
108/4/47 ^B	Irrigated	243.00 ^{ns}	2.31 ^{**}	1.35 ^{ns}	0.70 [*]
	Rain-fed	260.00	2.97	1.12	0.87

ns, *, **, *** Non-significant or significant at $P < 0.05$ or $P < 0.01$ or $P < 0.001$, respectively, least squares means analysis.

Table 4. Variation in flowering behaviour and seed yield of the 32 cultivars of kenaf evaluated across seasons in forest-savannah transition agro-ecology

Cultivar	Day to first flowering	Day to 50 % flowering	Duration from first to 50% flowering	Seed weight (kg/5m ²)
G 45-2	64.3	79.7	15.3	1.71
2QQ 1 ³	55.7	80.3	24.7	2.37
AU-7541 ⁴	62.7	77.7	15.0	1.66
Ifeken 100	57.3	74.0	16.7	1.74
AU-2452-4 ³	88.0	99.0	11.0	0.61
Ex Shika 24 ²	65.3	72.3	7.0	1.55
A-60-282-5 ¹	55.7	71.7	16.0	1.71
Cuba 19 ²	55.0	73.0	18.0	1.56
AU 2452 ⁴	64.7	89.0	24.3	1.64
AU-60-282 ⁶	62.0	88.3	26.3	0.95
AU-724 ⁸	54.0	78.0	24.0	2.23
2QQ 17 ³	63.0	80.0	17.0	0.79
Cuba Ovate 5 ¹	55.0	72.3	17.3	1.55
AU-2452 ⁶	74.7	91.3	16.7	0.74
AC-313-24 ⁴	49.7	63.7	14.0	2.34
Cuba 19 ¹	55.0	73.0	18.0	1.56
AU-60-282 ⁵	56.3	72.3	16.0	1.49
Ex Giwa 34 ¹	61.0	72.3	11.3	1.56
AC-313-29 ³	57.0	73.0	16.0	0.88
Pankeshin JG	64.0	75.7	11.7	1.62
2QQ 17 ¹	47.3	71.7	24.4	0.99
Cuba 19 ³	63.3	72.3	9.0	1.55
AU-2452-5 ^A	78.7	90.7	12.0	1.06
AU-719 ²	55.7	73.0	17.3	1.66
Ifeken DI 400	75.0	77.0	2.0	1.61
V-100-10 ¹	57.3	64.0	6.7	1.36

Table 5. Variation in the fibre yield components of the 32 cultivars of kenaf evaluated across seasons in forest-savannah transition agro-ecology

Cultivar	Core diameter (cm)	Bast weight (g/plant)	Core weight (g/plant)
G 45-2	2.78	9.84	21.35
2QQ 1 ³	1.96	8.35	21.93
AU-7541 ⁴	2.93	10.26	35.13
Ifeken 100	2.21	11.94	26.96
AU-2452-4 ³	1.93	11.25	25.44
Ex Shika 24 ²	2.50	10.26	18.13
A-60-282-5 ¹	2.72	10.33	20.77
Cuba 19 ²	2.86	12.70	29.04
AU-2452 ⁴	3.54	12.14	35.88
AU-60-282 ⁶	2.03	11.14	32.33
AU-724 ⁸	2.77	11.57	30.27
2QQ 17 ³	1.97	9.59	25.44
Cuba Ovate 5 ¹	2.70	10.39	19.91
AU-2452 ⁶	2.16	8.44	27.06
AC-313-24 ⁴	2.85	12.59	28.76
Cuba 19 ¹	2.41	14.26	30.23
A-60-282 ⁵	2.84	4.90	12.19
Ex Giwa 34 ¹	2.86	6.12	17.48
AC-313-29 ³	2.61	6.75	15.01
Pankeshin JG	2.85	7.06	17.70
2QQ 17 ¹	3.30	13.80	38.86
Cuba 19 ³	2.60	7.33	11.07
AU-2452-5 ^A	2.99	10.93	26.79
AU-719 ²	2.88	8.40	16.49
Ifeken 400	2.95	4.75	11.54
V-100-10 ¹	2.96	7.58	17.76
V1-400	2.99	5.34	16.85

Table 6. Traits relationship of 32 cultivars of kenaf evaluated across seasons in forest-savannah transition agro-ecology

	D50%F	PH	BSD	MSD	TSD	SWT	INLG	NND	CRD	BDWT	CDWT	LLWD	LLGT	PTLT
DTFF	0.89***	-0.17	0.01	-0.01	0.01	-0.26*	0.06	-0.11	-0.22*	-0.12	-0.08	0.48***	-0.04	-0.18
D50%F		-0.21*	0.06	-0.10	0.05	-0.22*	0.07	-0.19	-0.10	0.05	0.18	0.39***	-0.08	-0.11
PH			0.14	-0.25*	-0.07	-0.07	0.16	0.24*	-0.27**	0.03	-0.11	-0.17	0.08	0.07
BSD				0.42***	0.20*	-0.10	-0.34***	0.23*	0.43**	0.05	0.13	-0.17	-0.04	-0.37**
MSD					0.28**	-0.03	-0.12	-0.28**	0.25***	0.05	0.11	-0.06	-0.15	-0.49***
TSD						-0.10	-0.02	-0.20*	0.07	-0.26*	-0.13	-0.03	0.20*	-0.18
SWT							-0.12	-0.01	-0.11	0.10	-0.01	-0.14	0.03	0.19*
INLG								0.03	0.08	0.03	-0.02	-0.18	0.15	0.04
NND									0.29*	-0.08	-0.10	-0.23*	0.27**	0.55***
CRD										0.05	0.10	-0.04	-0.07	0.30**
BDWT											0.73**	0.04	-0.20*	0.05
CDWT												0.06	-0.16	0.06
LLWD													-0.01	-0.30**
LLGT														0.10

ns, *, **, *** Non-significant or significant at $p < 0.05$ or $p < 0.01$ or $p < 0.001$, respectively. DTFF, D50%F, PH, BSD, MSD, TSD, SWT, INLG, NND, CRD, BDWT, CDWT, LLWD, LLGT respectively mean days to first flowering, days to 50% flowering, plant height, base stem diameter, mid-stem diameter, top stem diameter, weed weight, internode length, number of node per plant, core diameter, bast dry weight, core dry weight, leaf width, leaf length and petiole length.

relationship than the PTLT. The CDWT only related to BDWT (about 73%); but BDWT had a negative significant association with TSD and LLGT. The relationships among the other traits of the crop were shown in the Table 6.

Discussion

Progress in any breeding programme of a crop traits depends on the variability in populations and the extent to which the desirable traits are influenced by season. The high variability suggested by the high coefficients of variation and wide range values for growth and yield traits confirms a rich diversity among the crop's cultivars which will provide a strong and effective base for rapid improvement of the crop. Shukla and Chandel (2009) had described that wide ranges, high CVs and high standard errors to imply heterogeneity, inconsistency and instability of series of data sets. Shukor *et al.* (2009) reported that wide variation may exist in the vegetative growth and flowering patterns of kenaf. The finding in this study suggests adequate variability among the cultivars to form efficient gene pool from which germplasm can be drawn for hybridization or improvement of lines or

landraces of the crop. Variability in SWT, BDWT and CDWT further explained by the wide range, higher CVs and standard error indicates that the traits are controlled by additive genes. This may also be due to the fact that the traits are yield related and thus polygenic in nature. Low CV for D50%F compared to DTFF shows that the cultivars were more diverse for DTFF than for the D50%F. Hence, DTFF could be used to distinguish the cultivars, especially at early growth stage. Besides, less power of the D50%F to discriminate the cultivars, is expected as the crops tend to reaching peak of growth at this stage and the effect of seasonal elements on the crop is minimal. Moreover, low CV of D50%F shows that most of the cultivars mature for fibre at a closer range than when first flower emerged. Flowering in plants signifies the commencement of seed formation. Since the kenaf's economic produce is quality fibres, the crop is harvested when the fibre's quality is highest. This period coincides with when not more than half of the plant population density has reached maturity stage. Amaducci *et al.* (2000); Shakhes *et al.* (2008) found that kenaf fibres increases with age of the plant but the quality

decreases as the crop grows older than about D50%F. However, the DTFF may not sufficiently distinguish cultivars because the crop is mainly cultivated for its fibres and not necessarily seeds. Hence, uniformity of plant growth, especially plant height at time of harvest is essential for both high yield and quality of the fibres.

. Knowledge of the response the heritable traits to changes in environmental conditions is required to plan and execute effective breeding strategies for developing improved genotypes. The effect of seasons on the vegetative growth traits of the kenaf cultivars shows variation in the water use efficiency of the cultivars. Generally, the cultivars performed better when rain-fed than when irrigated. The vegetative traits of cultivars Tianung 1, AU-719², AU-60-282⁶ and Ex-Shika 24² were not affected by seasons thus these cultivars may be suitable for fibre production in wet, dry or both seasons. Effect of season on flowering and yield components of the kenaf cultivars was mostly not significant suggesting that vegetative growth of kenaf cultivars is more sensitive to water than flowering and seed production. This means that perennial water source should be available for kenaf production for fibres and water shortage should be avoided during vegetative growth of the crop. The plan should also facilitate the flowering and fruiting period of the crops, when water supply is reduced. This will enable the crops to maximize water use for vegetative growth and dryness for pollination and fruit development. The fact that the fibre weights were not significantly affected by season suggests that variation for plant height and stem girth are due to the differences in moisture contents in the respective season. This may be responsible for the crop's greater performance under rain

than irrigation. Nkaa *et al.* (2007) also reported variation in fibres yield of kenaf due to differential water supply. Ariyo (1993); Ogunniyan and Tairu (2015) found variation in the vegetative performance of okra due to seasonal effects. This finding may be applicable to kenaf which is in the same family with okra.

Flowering pattern in crop determines the crop's seed formation and subsequent production and productivity. The opening of flowers and pollination are therefore expected to be affected by the season. This may provide a premise on which the cultivars are classified. Webber *et al.* (2002) and Alexopoulou (2013) classified kenaf accessions into three maturity groups based on their time of flowering. From this study, it is evident that the kenaf cultivars belong to different maturity groups based on the variation in the number of days to flowering. Mean D50%F of these genotypes fall within the range of 85 days after planting when the fibres have the best quality. The 15 days duration from DTFF to D50%F will provide an efficient platform for breeders to execute their breeding programmes and adequate time for the farmers to harvest kenaf plants for fibres. Attention needs to be paid to those cultivars that had short interval between DTFF to D50%F to plan the crop improvement programmes and for farmers to plan harvesting for its fibres. According to Webber *et al.* (2002), AU-2452-4³, AU-2452⁴, AU-60-282⁶, AU-2452⁶, AU-2452⁵ and V1-400 could be grouped as late maturing and harvested later than AC-313-24⁴, V-100-10¹, Tianung 1 and Tianung 2 because the former set of cultivars had higher D50%F. Ifeken DI-400 had the least days interval from DTFF to D50%F perhaps due to the cultivar's day insensitivity and so could be grown regardless of the solar

radiation effects.

The seed yield value for each cultivar distributed within a wide range because of the qualitative nature of the trait. Heritability of this type of traits is additive and so variation within a population is bound to be wide. Fibre yield of kenaf is in the form of core and bast. Cultivars AU-2452⁴ and 2QQ 17¹ had high core diameter and can therefore be considered suitable for producing pulp in paper industries or insulating materials in building industries whereas Cuba 19¹, 2QQ 17¹, Cuba 19², AU-2452⁴ and AC-313-24⁴ may be selected as raw materials as bast fibres in packaging industries. In the same vein, AU-2452⁴, AU-754⁴, AU-60-282⁶ and 2QQ 17¹ may be considered along with other industrial attributes for paper and packaging industries because of their high core fibre yields. Dutt *et al.* (2009); Villar *et al.* (2009) in their independent study observed that difference exists in the suitability of kenaf genotypes for industrial purposes.

Information on the relationships among crop traits is useful in germplasm or cultivars selection because the practices saves time and cost in breeding programmes. Performance of one agronomic trait of a genotype of crop may be used to predict another that significantly relates to it (Shukla and Chandel, 2009; Akinfasoye *et al.*, 2011). Thus, both the DTFF and D50%F can be reliably used to predict the seed yield of kenaf. That the DTFF highly positively relates to D50%F is indicative of a trend in the flowering pattern of the crop. Commencement of flowering in a particular kenaf genotype may be used to determine the harvesting time since fibre quality of kenaf is highest when harvested at 50 % flowering stage (Amaducci *et al.*, 2000). Fibre quality begins to depreciate after the crop has attained 50%F. In this study, the LLWD may

also be used to determine harvesting time in the place of the flowering. The PH is inversely related to MSD and CRD, hence very tall kenaf plants are expected to produce thin plants. This can be explained by the positive significant association between MSD and CRD. There was positive significant relationship between PH and NND because taller plant may likely have more leaves which in turn determine the number of nodes per plant than shorter ones. The CWDT may be related to BDWT because they are both fibre yield components. Evidently, BSD and PTLT had association with other traits than any other character suggesting that these two traits deserve attention during cultivation or selection of cultivars as any effect produced by these traits may affect other parts of the crop that are related to them.

Conclusion

The vegetative growth of kenaf cultivars is more sensitive to water supply than flowering and seed production. The vegetative growth of the crop was higher under rain-fed than when irrigated. It can be concluded that the cultivars evaluated belong to various maturity groups based on flowering pattern within season. Cultivars AU-2452-4³, AU-2452⁴, AU-6028-2⁶, AU-2452⁶, AU-2452⁵ and V1-400 were late maturing. Cultivar 2QQ 17¹ is a high seed producer. The AU-2452⁴, AU-754⁴, AU-60-282⁶ and 2QQ 17¹ may be considered for raw materials in paper and packaging industries because of their high core fibre yields.

Acknowledgements: The authors acknowledge the field and technical staff members of Kenaf and Jute Improvement Programme, Institute of Agricultural Research and Training, Ibadan, Nigeria for

cultural management, fibre and seed processing as well as data collection for the study. The management of the Institute is also appreciated for funding this research work.

References

- Akinfasoye, J. A., Ogunniyan, D.J. and Ajayi E.O. (2011). Phenotypic relationship among agronomic characters of commercial tomato (*Lycopersicon esculentum*) hybrids. *American-Eurasian Journal of Agronomy*, 4 (1): 17-22.
- Alexander, F., Robert, L., Jean-pierre, B. and Sylvain, B. (2007). Optimum refining of TMP pulp by fractionation after the first refining stage. Proceedings of the international mechanical pulping conference, May 6-9, Minneapolis, MN., pp.23-34.
- Alexopoulou, E., Christou, M., Mardikis, M. and Chatzianthanassiou, A. (2000). Growth and yields of kenaf varieties in central Greece. *Industrial and Crops Products*, 11, 163-172.
- Amaducci, S., Amaducci, M.T., Benatiand, R. and Venturi, G. (2000). Crop yield and quality parameters of four annual fibre crops (hemp, kenaf, maize and sorghum) in the North of Italy. *Industrial Crops and Products*, 11, 179-186.
- Ariyo, O.J. (1993). Genetic diversity in West African okra (*Abelmoschus caillei* L. (Chev.) Stevels- Multivariate analysis of morphological and agronomical characteristics. *Genetic Resources and Crop Evolution*, 40: 25-32.
- Balogun, M. O., Akande, S.R., Raji, J.A., Ogunbodede, B.A., Agbaje, G.O. and Adeyeye, O.O. (2009). Development of high yielding, late maturing kenaf (*Hibiscus cannabinus*) using gamma irradiation, "In: *Induced Plant Mutations in the Genomics Era*, Shu, Q. Y. (ed.), Food Agric. Org. United Nations, Rome, 395-396.
- Dutt, D., Upadhyay, J.S., Singh, B. and Tyagi, C.H. (2009). Studies on *Hibiscus cannabinus* and *Hibiscus sabdariffa* as an alternative pulp blend for softwood: An optimization of kraft delignification process. *Industrial and Crops Products*, 29: 16-26.
- Keshk, S., Wiwin, S. and Kazuhiko, S. (2006). Physicochemical characterization of different treatment sequences on kenaf bast fiber. *Carbohydrate polymers*, 65: 202-206.
- Kuchinda, N.C. and Ogunwole, J.O. (2000). Effects of dates and row arrangement on crop growth and yield in kenaf/maize mixture in the Northern Guinea Savannah of Nigeria. *Journal of Sustainable Agriculture and Environment*, 2: 251-256.
- Lemahieu, P. J., Oplinger, E. S. and Putnam, D. H. (2003). Kenaf. In: *Alternative Field crops Manual*. <http://www.corn.agronomy.wisc.edu/FISC/Alternatives/Kenaf.htm>.
- Mahapatra, B.S., Mitra, S., Ramasurbramanian, T. and Sinha, M.K. (2009). Research on jute (*Corchorus olitorus* and *C. capsularis*) and kenaf (*Hibiscus cannabinus* and *H.sabdariffa*): Present status and future perspective. *Indian Journal of Agricultural Science*, 79:951-967.
- Nkaa, F.A., Ogbonnaya, C.I. and Onyike, N.B. (2007). Effect of differential irrigation on physical and histochemical properties of kenaf (*Hibiscus cannabinus* L.) grown in the field in Eastern Nigeria. *African Journal of Agricultural Research*, 2(6): 252-260.

- Ogunniyan, D.J. and Tairu, F.M. (2015). Genotypic and season effects on the adaptability of common okra (*Abelmoschus esculentus* L. Moech) in super humid agro-ecology. *Tropical Agriculture (Trinidad)*, 92(2):92-101.
- Saka, J.O., Adeniyani, O.N., Akande, S.R. and Balogun, M.O. (2007). An economic evaluation of intercropping African yam bean, kenaf and maize in the rain forest zone of Nigeria. *Middle-East Journal of Scientific Research*, 2 (1): 01-08.
- SAS (2004). *SAS Institute user's guide: Statistics*, version 9.0. SAS Institute Incorporated, Cary, North Carolina, USA, 1028p.
- Shakhes, J., Dehghani-Firouzabadi, M. R., Rezayati-Charani, P. and Zeinaly, P. (2008). Evaluation of harvesting time effects and cultivars of kenaf on papermaking. *BioResources*, 5(2): 1268-1280.
- Shukla, R.S. and Chandel, P.S. (2009). *Cytogenesis, Evolution, Biostatistics and Plant Breeding*. S. Chand and Company Ltd., New Delhi. 569p.
- Shukor, N. A. A., Hamzah, M.B., Hamid, H.A., Salleh, G. and Nasir, M.F. (2009). Growth and phenology of kenaf (*Hibiscus cannabinus* L.) varieties. *Pertanika Journal of Tropical Agricultural Science*. 32(1), 29-33.
- Villar, J. C., Revilla, E. Go'mez, N. Carbajo, J.M. and Simo'n, J.L. (2009). Improving the use of kenaf for kraft pulping by using mixtures of bast and core fibers. *Industrial Crops and Products*, 29, 301-307.
- Webber, C. L., Bhardwaj, H. L. and Bledsoe, V. K. (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.
- Webber, C.L. III. and Bledsoe, R.E. (2002). Kenaf: Production, harvesting, and products. p. 416-421. In: J. Janick and J.E. Simon. (eds.), New crops. Wiley, New York.