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STABILITY ANALYSIS OF KENAF (*Hibiscus cannabinus* L.) FIBER YIELDS USING GGE BI-PLOTS

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Abstract

High yield and stability are prerequisites for crop improvement and adaptation. Genotype + genotype × environment has been used to study G × E interaction in multi-environments, thus, this trial addressed selection for bast and core fibres yields and yield stability of kenaf. Fourteen kenaf genotypes were assessed in six diverse locations in Nigeria in a randomized complete block design with three replications for two years. Fibres weight data were pooled across the two years and subjected to GGE bi-plot analysis. Significant differences existed among the bast and core fibre yields of the genotypes in the locations. Genotype SAU75-441 produced the highest mean bast fibre yield (2.80 t ha^{-1}) while GS14-52 and AEHC-3 were also promising with respect to bast fibre production across locations. Core fibre yields of SAU75-441, GS14-52, AEHC-3, AU75-452 and AU 24524 were greater 4.00 t ha^{-1}. Hence, SAU75-441, GS14-52 and AEHC-3 are identified for further consideration for their yield potentials. Orin Ekiti and Ikenne had higher bast yields (2.55 t ha^{-1}) and (2.52 t ha^{-1}), respectively with core fibre yields (4.48 t ha^{-1}) and (4.29 t ha^{-1}), respectively. The bi-plot identified Ikenne, Ilora, Iwo and Orin Ekiti as a mega-environment where genotype SAU75-441 was the vertex for both bast and core fibres. Genotype GS14-52 was the vertex genotype in the Kaduna and Kisi mega-environment for the fibres. Genotypes SAU75-441, GS14-52 and AEHC-3 were therefore considered most suitable for the respective environments. Genotypes SAU75-414 and GS14-52 were highest bast and core fibres yields, and most stable with broadest adaptation in the two fibre types, hence, they are best recommended for future crop improvement programme.

Keywords: Bast fibre, Core fibre, GGE bi-plot, G × E interaction, *Hisbiscus*, Kenaf.

Introduction

Kenaf (*Hibiscus cannabinus* L.), the third largest fibre crop of economic importance after cotton and jute, belongs to the family Malvaceae. The crop has the potential to serve the dual purposes of cash and food crops. It is currently attracting the interest of both farmers and industrialists in Nigeria because of its food, environmental, industrial and economic benefits (Balogun *et al.*, 2009). Two types of fibres, namely bast and core fibres, exit for different uses. The bast fibre is obtained from the bark while the core fibre is from the inner (pith) core of the plants. Despite the greater adaptability and easy of cultivation and handling of

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kenaf than other fibre crops (Lemahieu *et al*. 2003), fitness into farming systems of the tropics especially intercropping; its multipurpose food potentials, economic and environmental benefits as well as increasing farmers' awareness, cultivation and productivity of the crop is still limited in sub-Saharan Africa and Nigeria in particular (Keshk *et al.*, 2006). The potential dry matter yield averages of about 6 to 10 t ha^{-1} of the crop is realizable in Africa (Masnira *et al*., 2015; Ogunniyan *et al.,* 2016).

Multi-environment yield trials are used to select favourable genotypes based on the mean yield and performance stability. Same genotype responds differently to different environments thus displaying the diverse phenotypic expression in all environments. The variation in the genotypic response to a specific environment is attributed to genotype × environment (G × E) which constitutes difficulty in selecting varieties based on the mean performance alone. The G × E is important in crop improvement through plant breeding programmes and introduction of new improved cultivars (Neacşu, 2011; Mulugeta *et al.,* 2013). Numerous statistical methods have been employed to explain G × E and its relationship with adaptability and stability in crops. However, Genotype + Genotype × Environment (GGE) models have been emphasized for multi environment trial data. The GGE bi-plot for mega environment analysis, genotype evaluation and test environment evaluation has been useful to visualize the pattern of G × E in multi environment genotype evaluation of different crops (Yan *et al*., 2000; Yan *et al*., 2007; Brar *et al*., 2010).

The fibre yield of kenaf in the sub-Sahara Africa is low, with a mean combined bast and core fibre yield of 5.5 t ha^{-1} in Nigeria. A strategy to increase production and productivity in a crop is to select for higher yielding varieties that have broad adaptability. This will widen the production base in terms of time and locations. There is the need to improve the crop's yield in relation to agro-ecological conditions. Therefore, the aims of this study were to evaluate 14 advanced kenaf genotypes for bast and core fibres yield and yield stability across locations with the intention to select promising and suitable for recommendation to farmers.

Materials and Methods

A total of 14 selected genotypes of kenaf were evaluated in six locations (Kisi, Kaduna, Orin, Ekiti, Ikenne, Ilora and Iwo) in Nigeria for bast and core fibres yields during the rainy season in 2017 and 2018. The 14 genotypes consisted of 12 accessions and two existing commercial varieties of the crop in Nigeria. The test locations cut across Rain Forest, Derived savannah and Guinea Savannah agro-ecologies of the country (Table 1). The trial was laid out in randomized complete block design with three replications in each location. Plants of each genotype were established in a four-row plot, 5 m each, at a spacing of 20 cm within row and 50 cm between rows in each location.

Table 1. Description of the six locations where the kenaf genotypes were evaluated

Location	Latitude (° N)	Longitude (° E)	Altitude (m asl)	Agro-ecology
Kisi	08.59	003.56	364	Guinea Savanna
Kaduna	09. 29	007. 22	252	Guinea Savanna
Orin Ekiti	07 50	005.14	456	Rainforest
Ikenne	06. 52	003.04	061	Rainforest
Ilora	07.49	003.49	269	Derived Savanna
Iwo	07.63	004.18	231	Derived Savanna

Four seeds were sowed per hill and thinned to two plants per stand to adjust the population density to 80,000 plants ha^{-1} at 3 weeks after planting. About 60 kg ha^{-1} NPK fertilizer was applied at four weeks after planting (IAR & T, 2015). The plots were kept weed free throughout the study by hoeing twice and slashing one. The hoeing was done with hoe during the vegetative growth stage while cutlass was used to slash during the flowering stage.

Forty randomly selected plants from each plot were cut at 5 cm above ground when the crops were 80 days old. The freshly cut kenaf bundles were sorted by plot, tagged and soaked in a running stream for 14 days after which the bast fibres were stripped from core manually. Both the bast and core fibres were washed in clean water to ensure fibre quality. The fibre was dried by direct sunshine for five days. The fibre dryness was taken by hand feeling. The bast and core fibres were weighed separately for each genotype. Data collected were pooled across 2017 and 2018 and means were tested by using Least Significant Difference before GGE bi-plots were used. The GGE bi-plot was also used to identify high yielding and adapted kenaf genotypes.

Relative magnitude and direction of genotypes along the abscissa and ordinate axes in a biplot were used to understand the response pattern of genotypes across environments according to Yan and Kang (2003). Best genotypes were those which combined high fibre yield with stable performance across locations. An ideal genotype was taken according to Mitrovic *et al*. (2012) as the highest yielding across test environments that was absolutely stable in performance. Concentric circles were used to visualize the distance between each environment and the ideal environment. The centre of concentric circles was regarded an ideal test environment for being the most representative of the overall environments and the most powerful to discriminate genotypes (Yan and Rajcan, 2002). In the "mean vs. stability" of the GGE bi-plot view, the average yields of the genotypes were determined by the projections from the positions of the genotypes onto the average tester ordinate (ATC ordinate) while the stability of genotypes was measured by their projections from the average tester coordinate abscissa (ATC abscissa) or the horizontal line. The further the genotype from the ATC ordinate, the higher the bast fibre yield. In addition, the shorter the length of the projection to the ATC abscissa, the more stable the genotype.

Results and Discussion

Significant differences existed among the bast fibre yields of the kenaf genotypes evaluated in six locations in Nigeria in 2017 and 2018 (Table 2). The effect of the Genotype × year interaction on the bast fibre yield was also significantly different ($p \leq 0.05$). Genotype SAU75-441 (G11) produced the highest mean bast fibre yield (2.80 t ha^{-1}) across the locations while the least mean bast fibre yield of 1.74 t ha^{-1} was recorded in SLE 14-1 (G12). It was also found that mean bast fibre yields of genotypes SAU75-441 (G11), GS14-52 (G8), AEHC-3 (G3) and IFEKEN DI-400 (G10) were significantly higher than the mean across the locations. IFEKEN 400 (G9) had bast yield that was statistically similar to the mean grand bast fibre yields. Each of the five genotypes produced greater than 2.5 t ha^{-1} bast fibre. Yields of bast fibre in Orin Ekiti (2.55 t ha^{-1}) and Ikenne (2.52 t ha^{-1}), had highest than those of other four locations. The mean bast fibre yields of the genotypes in Ilora and Iwo locations were close to the overall mean (2.27 t ha^{-1}) for the six locations while the least yield was obtained in Kisi with 2.00 t ha^{-1}.

Table 2. Bast fibre yield of kenaf genotypes evaluated in six locations in Nigeria over 2017 and 2018

Entry	Genotype	Bast fibre yield (t ha^{-1})						
		Kisi	Kaduna	Orin Ekiti	Ikenne	Ilora	Iwo	Mean
G1	2GQQ 13	1.72	1.85	2.53	2.48	2.13	2.03	2.12
G2	ACG33-293	1.89	1.84	2.23	2.32	1.80	2.06	2.02
G3	AEHC-3	2.35	2.49	3.07	3.09	2.69	2.76	2.74
G4	AU 24524	2.33	2.13	2.44	2.57	2.44	2.46	2.40
G5	AU2452-43	1.88	2.22	2.57	2.36	2.31	2.17	2.25
G6	AU75-192	1.87	2.16	2.35	2.25	2.12	2.15	2.15
G7	AU75-452	1.75	2.06	2.65	2.69	2.58	2.50	2.37
G8	GS14-52	2.45	2.58	3.14	3.14	2.59	2.74	2.77
G9	IFEKEN 400	2.40	2.40	2.97	2.80	2.49	2.42	2.58
G10	IFEKEN DI-400	2.32	2.47	2.97	2.96	2.46	2.53	2.62
G11	SAU75-441	2.25	2.67	3.21	3.11	2.71	2.82	2.80
G12	SLE14-1	1.70	1.45	1.95	2.05	1.81	1.50	1.74
G13	SLE14-13	1.75	1.41	2.11	2.13	2.02	1.90	1.89
G14	SLE14-2	1.76	1.64	2.14	2.00	1.81	1.58	1.82
	Mean	2.00	2.06	2.55	2.52	2.26	2.22	2.27
	LSD (0.05)	0.39	0.30	0.34	0.30	0.32	0.42	
	MS Genotype	3.55	4.04	4.17	4.17	4.13	3.60	
	MS Year	29.07	32.41	32.22	32.83	32.53	31.49	
	MS Genotype × Year	1.25*	1.37*	1.50*	1.29*	1.20*	1.19*	
	CV (%)	22.7	24.6	23.2	23.8	24.0	23.4	

The GGE bi-plot analysis revealed that the first and second principal component axes explained 95% of the total variation in bast fibre yield of kenaf (Figure 1). The polygon revealed AU75-452 (G7), SAU75-441 (G11), GS14-52 (G8), IFEKEN 400 (G9), SLE14-2 (G14), SLE14-1 (G12) and SLE14-13 (G13) as the vertex genotypes. The "which-won-where" view of the GGE bi-plot identified four mega-environments. Ikenne, Ilora, Iwo and Orin Ekiti formed a mega-environment where genotype SAU75-441 (G11) was the vertex. On the other hand, Kaduna and Kisi fell in a sector where GS14-52 (G8) and IFEKEN 400 (G9) were at the vertexes. However, AU75-452 (G7), SLE14-1 (G12), SLE14-13 (G13) and SLE14-2 (G14) were at the vertex in other sectors that were not identified with any of the environments.

The "mean vs. stability" of the GGE bi-plot view showed genotypes SAU75-441 (G11), GS14-52 (G8) and AEHC-3 (G3) occurred on the innermost circle of the GGE bi-plot (Figure 2). The three genotypes were also at the most distant end in the direction of the projection of the AEA, while SLE14-1 (G12), SLE14-13 (G13) and SLE14-2 (G14) were prominent among those that occurred at the farthest end against the AEA projection. According to the Figure 2, genotypes GS14-52 (G8), AEHC-3 (G3), IFEKEN DI-400 (G10), AU2452-43 (5), AU75-192 (G6) and SLE14-13 (G13) had least projections from the AEA on the bi-plot. However, genotypes AU2452-43 (5), AU75-192 (G6) and SLE14-13 (G13) had low PC 1. The core fibre yields of the kenaf genotypes evaluated in six locations in Nigeria in 2017 and 2018 were presented in Table 3. The effect of the Genotype × Year interaction on the core fibre yield was also significantly different ($p \leq 0.05$). The least core fibre yield (2.92 t ha^{-1}) was recorded on SLE14-2 (G14) followed by SLE14-1 (G12) (2.93 t ha^{-1}) while SAU75-441 (G11) had the highest core fibre yield of 4.96 t ha^{-1}. The core fibre yields of SAU75-441 (G11), GS14-52 (G8), AEHC-3 (G3), IFEKEN 400 (G9) and IFEKEN DI-400 (G10), AU75-452 (G7) and AU 24524 (G4) were greater than 4.0 t ha^{-1}. The results also showed that 3.52 t ha^{-1} which was the lowest average by location was obtained in Kisi while Orin Ekiti had the highest average core fibre yield of 4.48 t ha^{-1} among other test locations. Only Orin Ekiti and Ikenne had core fibre yields that were higher than the grand mean.

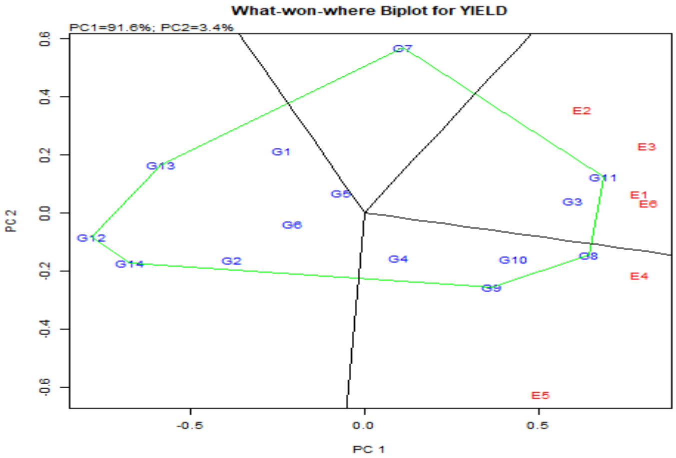

Fig. 1. The GGE bi-plot showing the 'which won where' for bast fibre yield of kenaf genotypes, 2GQQ 13 (G1), ACG33-293 (G2), AEHC 3 (G3), AU 24524 (G4), AU2452-43 (G5), AU75-192 (G6), AU75-452 (G7), GS14-52 (G8), IFEKEN 400 (G9), IFEKEN DI-400 (G10), SAU75-441 (G11), SLE14-1 (G12), SLE14-13 (G13) and SLE14-2 (G14), evaluated in six locations, Ikenne (E1), Ilora (E2), Iwo (E3), Kaduna (E4), Kisi (E5) and Orin Ekiti (E6), in Nigeria over 2017 and 2018.

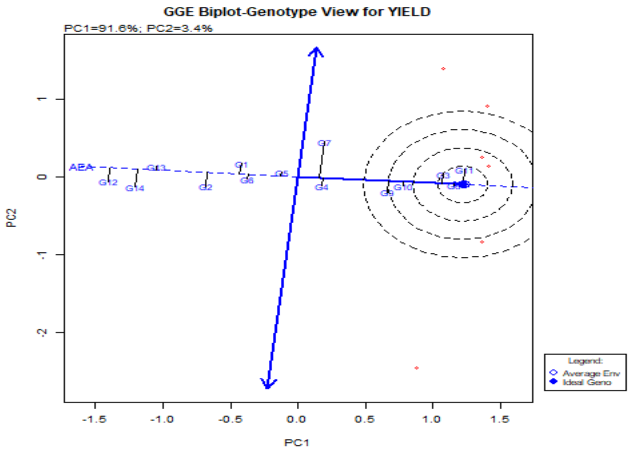

Fig. 2. The GGE bi-plot showing the mean versus stability for bast fibre yield of kenaf genotypes, 2GQQ 13 (G1), ACG33-293 (G2), AEHC 3 (G3), AU 24524 (G4), AU2452-43 (G5), AU75-192 (G6), AU75-452 (G7), GS14-52 (G8), IFEKEN 400 (G9), IFEKEN DI-400 (G10), SAU75-441 (G11), SLE14-1 (G12), SLE14-13 (G13) and SLE14-2 (G14), evaluated in six locations, Ikenne (E1), Ilora (E2), Iwo (E3), Kaduna (E4), Kisi (E5) and Orin Ekiti (E6), in Nigeria over 2017 and 2018.

Table 3. Core fibre yield of kenaf genotypes evaluated across six locations in Nigeria over 2017 and 2018

Entry	Genotype	Core fibre yield (t ha^{-1})						
		Kisi	Kaduna	Orin Ekiti	Ikenne	Ilora	Iwo	Mean
G1	2GQQ 13	2.99	2.92	4.04	3.85	3.63	3.26	3.45
G2	ACG33-293	2.73	3.01	3.74	3.82	3.51	3.57	3.40
G3	AEHC-3	4.00	4.43	5.53	5.51	4.81	4.40	4.78
G4	AU 24524	3.65	3.99	4.67	4.35	3.99	3.86	4.08
G5	AU2452-43	3.41	3.71	3.90	4.06	3.41	3.18	3.61
G6	AU75-192	3.14	3.98	4.02	4.00	3.23	3.06	3.57
G7	AU75-452	3.13	3.82	4.91	4.81	3.98	4.44	4.18
G8	GS14-52	4.75	4.38	5.62	5.55	4.95	4.25	4.92
G9	IFEKEN 400	4.25	4.22	5.12	5.14	4.41	4.19	4.55
G10	IFEKEN DI-400	3.98	4.10	5.18	5.04	3.85	4.54	4.45
G11	SAU75-441	4.48	4.46	5.57	5.43	5.28	4.58	4.96
G12	SLE14-1	2.96	2.45	3.37	2.65	3.04	3.12	2.93
G13	SLE14-13	2.91	3.03	3.85	3.13	3.23	3.03	3.20
G14	SLE14-2	2.83	3.18	3.17	2.75	2.61	3.01	2.92
	Mean	3.52	3.69	4.48^{*}	4.29^{*}	3.85	3.75	3.93
	LSD	0.51	0.41	0.50	0.42	0.60	0.67	
	MS Genotype	5.32	4.85	7.14	5.76	5.10	5.46	
	MS Year	62.39	61.36	84.09	71.56	62.23	65.89	
	MS Genotype × Year	2.46^{*}	2.72^{*}	3.63^{**}	3.80^{**}	2.60^{*}	2.40^{*}	
	CV (%)	22.21	23.00	24.09	25.25	23.01	22.56	

The 'which-won-where' for the core fibre yield of kenaf was presented in Figure 3. The first and second principal component axes explained 94.7% of the total variation in core fibre yield. The polygon had five sectors, out of which only two identified with the test environments Genotype GS14-52 (G8) was the vertex in the sector where Kaduna and Kisi were identified, and GS14-52 (G8) and IFEKEN 400 (G9) and AU 24524 (G4) as adaptable genotypes. Other genotypes in the mega-environment included AEHC-3 (G3) and IFEKEN DI-400 (G10) while AU75-452 (G7)

(2.55 t ha^{-1}) and Ikenne (2.52 t ha^{-1}), had highest than those of other four locations. The mean bast fibre yields of the genotypes in Ilora and Iwo locations were close to the overall mean (2.27 t ha^{-1}) for the six locations while the least yield was obtained in Kisi with 2.00 t ha^{-1}. The SAU75-441 (G11) was the vertex genotype in a sector where Ikenne, Ilora, Iwo and Orin Ekiti were identified as a mega-environment. The SLE14-2 (G14), ACG33-293 (G2), SLE14-1(G12) and AU75-192 (G6) were the vertex genotypes in other sectors where no environment was identified.

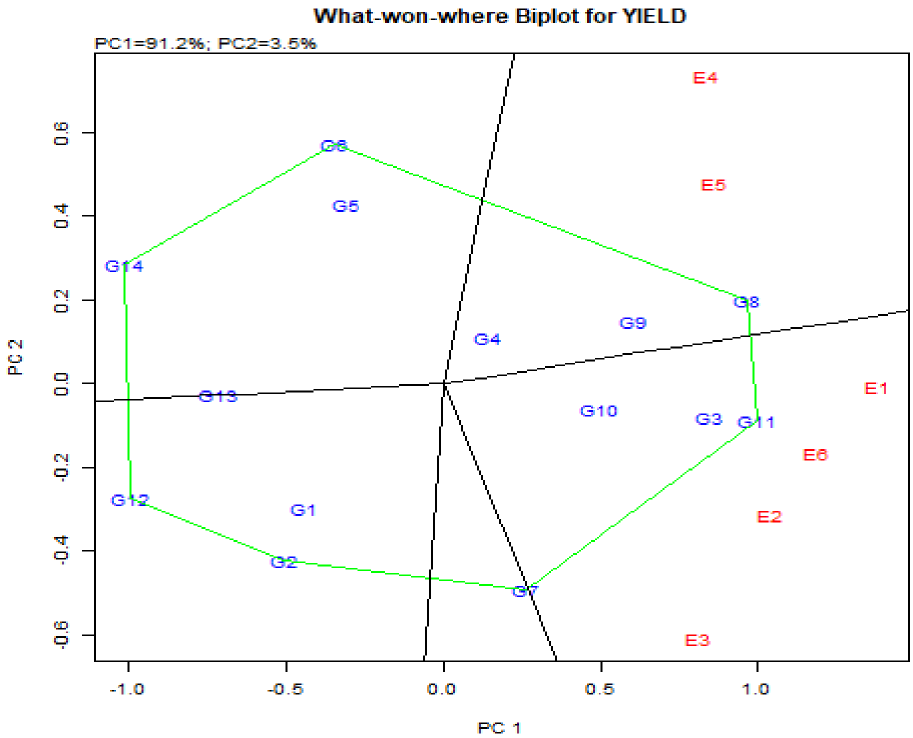

Figure 3. The GGE bi-plot showing the 'which won where' for core fibre yield of kenaf genotypes, 2GQQ 13 (G1), ACG33-293 (G2), AEHC 3 (G3), AU 24524 (G4), AU2452-43 (G5), AU75-192 (G6), AU75-452 (G7), GS14-52 (G8), IFEKEN 400 (G9), IFEKEN DI-400 (G10), SAU75-441 (G11), SLE14-1 (G12), SLE14-13 (G13) and SLE14-2 (G14), evaluated in six locations, Ikenne (E1), Ilora (E2), Iwo (E3), Kaduna (E4), Kisi (E5) and Orin Ekiti (E6), in Nigeria over 2017 and 2018.

The GGE bi-plot showing the genotype view for core fibre of the kenaf genotypes in 2017 and 2018 was presented in Figure 4. Genotypes SLE14-13 (G13), AU 24524 (G4), IFEKEN400 (G9) and GS14-52 (G8) were closer to the AEA than the remaining genotypes, especially the AU75-452 (G7) and AU75-192 (G6) which were projected farther from the axis. Genotypes SAU75-441 (G11) and GS14-52 (G8) had the highest PC1 values while SLE14-2 (G14) and SLE14-1 (G12) had the least. Genotype GS14-52 (G8) was closest to the ideal environment.

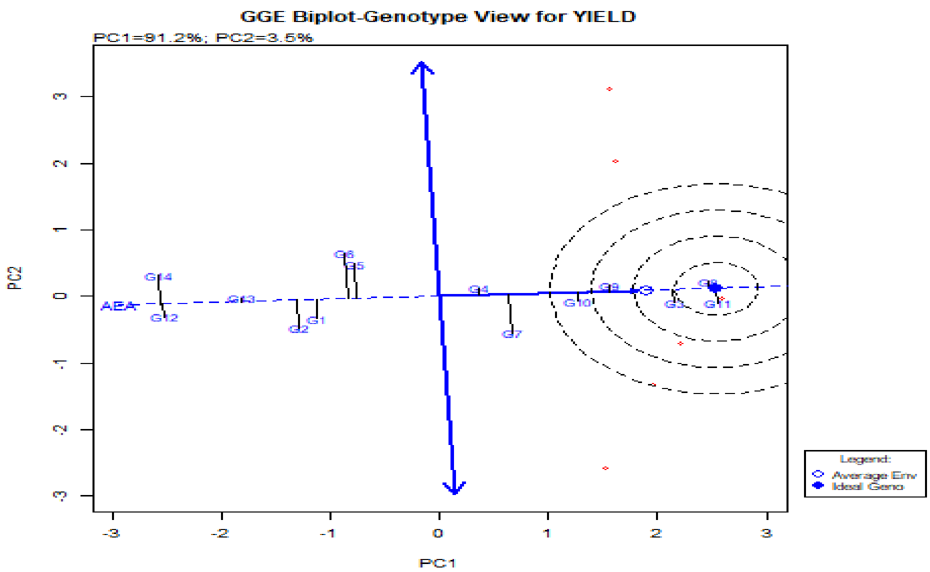

Figure 4. The GGE bi-plot showing the mean versus stability for core fibre yield of kenaf genotypes, 2GQQ 13 (G1), ACG33-293 (G2), AEHC 3 (G3), AU 24524 (G4), AU2452-43 (G5), AU75-192 (G6), AU75-452 (G7), GS14-52 (G8), IFEKEN 400 (G9), IFEKEN DI-400 (G10), SAU75-441 (G11), SLE14-1 (G12), SLE14-13 (G13) and SLE14-2 (G14), evaluated in six locations, Ikenne (E1), Ilora (E2), Iwo (E3), Kaduna (E4), Kisi (E5) and Orin Ekiti (E6), in Nigeria in 2017 and 2018.

There were significant variation in the plant heights of the crop in various locations due to the effect of genotype and G × Y interaction except Ikenne where the effect of the G × Y was not significantly different (Table 4). The stem diameters differed due to genotypic effect in Kaduna only. The effect of year was significant on the plant height of the crop in Kaduna, Ilora and Iwo. The coefficient of variation of the two parameters were low (less than 15 %) in all the locations. Genotypes SAU75-441 (G11), GS14-52 (G8), IFEKEN 400 (G9), IFEKEN DI-400 (G10) and AEHC-3 (G3) were prominent among those with highest plant heights and stem diameters.

Discussion

Significant differences that existed in both the bast and core fibre yields of the kenaf genotypes in the six locations in Nigeria across the two years indicates variation in the response of the crop to the various environments in accordance with the genetic potential of each genotype (Table 1). Wide variation has been observed in agronomic characteristics, and in the fibre yields kenaf genotypes (Ogunniyan, 2016). Yield is greatly influenced by environmental factors such as time of planting, climate or soil status and micro-environment created by the cultural practices applied. Crop genotypes respond differently to the environment factors in each location, and this is the reason the reason for stability analysis to select genotypes that have wide adaptability (Lotan *et al.,* 2012; Hassan *et al.,* 2013; Mulugeta *et al.,* 2013; Ogunniyan *et al.,* 2017).Genotypes SAU75-441 (G11), AEHC-3 (G3), IFEKEN DI-400 (G10) and GS14-52 (G8) were promising with respect to production bast fibre. This is evident in their yields which were higher than the grand mean across the locations. Hence, genotypes SAU75-441 (G11), GS14-52 (G8) and AEHC-3 (G3) are identified for further consideration for recommending for use by farmers. The core fibre yields followed the trend in the performance of the genotypes. Genotypes SAU75-441(G11), GS14-52 (G8), AEHC-3 (G3), IFEKEN 400 (G9) and IFEKEN DI-400 (G10), AU75-452(G7) and AU 24524 (G4) were high core fibre yielders. They had yield potentials greater than the yields of the two existing varieties namely IFEKEN DI-400 (G10) and IFEKEN 400 (G9) in the two fibre types. Highest mean fibre yield obtained in Orin-Ekiti, closely followed by Ikenne suggests the two locations as suitable for production of the crop. Orin Ekiti has been found to be a suitable for kenaf production (Ogunniyan *et al.,* 2017). This may be due to the prevailing weather condition with moderate amount of rainfall and solar radiation required for the growth of the crop as observed by Shukor *et al.* (2009).

Only two of the four mega-environments are congruent to test environments identified by the “which-won-where” view of the GGE bi-plot. Genotypes AU75-452 (G7), SAU75-441 (G11), GS14-52 (G8), IFEKEN 400 (G9), SLE14-2 (G14), SLE14-1 (G12) and SLE14-13 (G13) led in adaptation to the various mega-environments without recourse to their yield because they were at the as the vertices. This reason portrays SAU75-441 (G11), GS14-52 (G8) and IFEKEN 400 (G9) as champions in their various mega-environments. Genotype SAU75-441 (G11) can be nominated for the mega-environment involving Ikenne, Ilora, Iwo and Orin Ekiti. On the other hand, GS14-52 (G8) and IFEKEN 400 (G9) were most promising in Kaduna and Kisi mega-environment. These genotypes were therefore considered most suitable and promising in the respective environments. The remaining vertex genotypes in other sectors that did not identify with any of the environments can be useful in some other environments.

The least projections of genotypes GS14-52 (G8), AEHC-3 (G3), IFEKEN DI-400 (G10), AU2452-43 (5), AU75-192 (G6) and SLE14-13 (G13) from the AEA on the bi-plot means they are stable genotypes. Their locations on the bi-plot which correspond with the direction of the AEA projection show the genotypes are high yielding. They are also closely related to the ideal genotype due to the occurrence in the innermost concentric circle. Therefore, SAU75-441(G11), GS14-52 (G8) and AEHC-3 (G3) have identified as most suitable with respect to bast fibre yield and stability across locations with respect to bast fibre yield.

Table 4. Variation in plant height and stem diameter of kenaf genotypes evaluated across six locations in Nigeria over 2017 and 2018

Entry	Genotype	Kisi		Kaduna		Orin Ekiti		Ikenne		Ilora		Iwo		Mean	
		Plant height (cm)	Stem diameter (cm)	Plant height (cm)	Stem diameter (cm)	Plant height (cm)	Stem diameter (cm)	Plant height (cm)	Stem diameter (cm)	Plant height (cm)	Stem diameter (cm)	Plant height (cm)	Stem diameter (cm)	Plant height (cm)	Stem diameter (cm)
G1	2GQQ 13	264.31	1.82	224.4	2.24	272.47	2.17	279.87	1.73	184.16	1.63	222.55	2.02	241.29	1.94
G2	ACG33-293	263.85	1.74	229.2	2.30	272.32	1.74	264.18	1.64	202.25	1.59	239.99	2.12	245.30	1.86
G3	AEHC-3	257.78	1.85	213.5	2.21	284.00	2.17	273.67	1.79	228.72	1.79	248.87	2.15	251.09	1.99
G4	AU 24524	259.22	1.75	229.0	2.23	288.00	2.01	262.20	1.59	202.67	1.22	231.20	2.07	245.38	1.81
G5	AU2452-43	262.40	1.86	222.9	2.15	267.65	1.96	275.18	1.52	186.70	1.34	245.42	2.04	243.38	1.81
G6	AU75-192	257.46	1.79	223.5	2.22	288.53	2.01	246.83	1.80	211.62	1.73	239.45	2.06	244.57	1.94
G7	AU75-452	264.11	1.90	231.2	2.13	293.33	2.06	290.77	1.62	220.89	1.76	227.43	2.16	254.62	1.94
G8	GS14-52	271.91	2.02	248.2	2.45	293.20	2.21	271.37	1.86	226.73	1.81	246.41	2.29	259.64	2.11
G9	IFEKEN 400	270.90	1.87	230.5	2.24	288.11	2.23	281.32	1.86	221.78	1.81	238.00	2.20	255.10	2.04
G10	IFEKEN DI-400	270.65	1.90	237.7	2.40	288.47	2.16	277.30	1.90	231.61	2.00	243.49	2.15	258.20	2.09
G11	SAU75-441	273.17	2.01	249.4	2.52	305.21	2.32	281.46	1.81	230.70	2.20	248.29	2.28	264.71	2.19
G12	SLE14-1	264.13	1.85	215.4	2.17	269.82	1.92	270.22	1.60	220.68	1.70	250.66	1.97	248.49	1.87
G13	SLE14-13	263.44	1.75	229.6	2.23	273.00	2.05	268.97	1.58	209.78	1.89	232.60	1.82	246.23	1.89
G14	SLE14-2	255.38	1.80	215.1	2.25	277.01	2.15	253.79	1.65	225.97	1.87	231.14	1.78	243.07	1.92
	Mean	264.19	1.85	228.54	2.27	282.94	2.08	271.22	1.71	214.59	1.74	238.96	2.08	250.08	1.95
	LSD (0.05)	24.50	0.29	20.15	0.31	43.14	0.43	26.49	0.36	36.02	0.53	20.87	0.37		
	MS Genotype	445.72*	0.02	540.04*	0.06*	464.89*	0.08	454.52*	0.05	744.91*	0.15	412.33*	0.10		
	MS Year	173.25	0.04	459.50*	0.01	521.62	0.08	126.66	0.02	477.15*	0.27	556.32*	0.11		
	MS Genotype × Year	285.78*	0.05	288.72*	0.05	457.40*	0.08	96.58	0.05	176.33*	0.05	163.15*	0.02		
	CV (%)	5.93	9.89	5.54	8.36	9.35	12.18	6.19	13.10	9.86	18.02	5.49	10.82		

LSD, MS and CV were Least Significant Difference, mean square and Coefficient of Variation, respectively.

Genotypes AU75-452 is high yielding but not stable while AU 24524 (G4) is stable, but had yield not different from the grand mean. Therefore, the two genotype were ranked as not favourable. Unlike for the bast fibre yield, genotypes SLE14-13 (G13), AU 24524 (G4), IFEKEN 400 (G9) and GS14-52 (G8) were closer to the AEA than the remaining genotypes signifying they are stable genotypes but genotypes SLE14-13 (G13) is low core fibre yield. Hence, SLE14-13 (G13) is discarded with AU 24524 (G4). Genotypes SAU75-441 (G11), GS14-52 (G8) and AEHC-3 (G3) which were most desirable had the highest PC1 values and closest to the ideal environment showing that they combined high core fibre yield with stability relative to other genotypes evaluated. They are also associated with the ideal genotypes. According to Yan and Kang, (2003); Mitrovic *et al*., (2012), reported most desirable is highest yielding across test environments and absolutely stable in its performance.

The plant height and stem diameter contributed to the fibre yields of the crop because both the bast and core fibres were derived from the stem. The bark of the crop was processed into bast fibre while the pith was the core fibre. Total fibre yield, therefore, increases with increase in plant height and stem diameter. The plant height and stem diameter have also been reported as major contributors to the fibres yield of kenaf (Ogunniyan *et al*., 2016). The significant variation in the plant height of the genotypes is indicative of the differences in the potential of each genotype. Similarly, the significant differences in the G × Y interaction effects show that each genotype responded differently to change in the environments created by location variables. This finding further supports the identification of genotypes SAU75-441, GS14-52 G8), IFEKEN 400 (G9), IFEKEN DI-400 (G10) and AEHC-3 (G3) with the highest plant heights and stem diameters as most promising owing to their fibre yields.

Conclusion

Genotypes SAU75-414 (G11), GS14-52 (G8) and AEHC-3 (G3) were highest yielding and most stable with respect to the two types of fibres. They were most closely related to the ideal genotypes and perfomed better than existing commercial genotypes. It can therefore be concluded that the genotypes had broadest adaptation, high yield and more stability for both bast and core fibres production, and therefore selected as the most desirable.

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