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Morphological Characterization of Sorghum (*Sorghum bicolor*) Local Accessions Collected from Southern Nigeria using Qualitative and Quantitative Traits

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Abstract
Sorghum [*Sorghum bicolor* (L.) Moench] is a cereal crop grown mainly for food, feed, fodder, and fuel. Fifty sorghum accessions collected from ten southern States in Nigeria were characterized using qualitative and quantitative markers to identify the extent of variability among the accessions. The experiment was laid in a randomized complete block design with three replicates at FUTA (2019 planting season), FCAI (2018 and 2019 planting seasons) and Ogbomoso ADP (2018 and 2019 planting seasons). Qualitative and quantitative data were collected on 22 morphological traits. Results from the qualitative markers depicted that more than half of the accessions had 75% grain coverage, dull green midrib (52%), medium bloomy waxy bloom (68%), very loose dropping panicle (44%), exerted panicle (76%), good threshability (50%), black glume colour (46%), buff grain colour (48%), intermediate senescence (54%) and low lodging (76%). Analysis of variance for the quantitative traits showed the existence of significant variation among the traits for all the environments, genotype and GEI at $p \leq 0.01$ except for leaf length and leaf width, which were not significant for genotype and genotype*environment, respectively. Accessions RI-17-01, EN-17-03, OS-17-05, AB-17-01, EN-17-01, OG-17-02, OY-17-03, EB-17-01 and AK-17-01, which had the highest mean for the eleven quantitative traits, can be selected for a sorghum improvement programme in southern Nigeria.

Keywords: Sorghum, characterization, accession, qualitative, quantitative

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench; 2n = 2x =20] is a member of the *Poaceae* family and the *Andropogoneae* tribe (ICRISAT, 2009). Cultivated sorghums are categorized into five major races (*Caudatum*, *Bicolor*, *Kafir*, *Durra*, and *Guinea*), and ten intermediate races, based on pairwise comparison using this categorization scheme (Harlan and de Wet, 1972). It is known by several names in Southern Nigeria, including *Oka baba* (South West) and *Okili* (South East). Generally, it is grown mainly for food and feed among the rural dwellers of Southern Nigeria (Obilana, 2012). In Nigeria, there are numerous sorghum accessions that are yet to be characterized. Majority of these accessions are planted by farmers on yearly basis using different parameters for identification (Alade *et al*., 2017).

Sorghum is the most widely cultivated staple cereal, covering 8.5 million hectares in three savannah agro-ecological zones (Guinea, Sudan, and Sahel) from latitude 13°N extending southward to the derived savanna (forest-savanna transition zone) at latitude 7.5°N of the equator (FMARD, 2011). Of all the agro-ecological zones, the Sahel, Sudan, and Guinea savannah (which cut across the three northern geo-political zones of the country, namely: North West (48%), North East (32%), and North Central (19%)) contributed 99% of the total sorghum production, while the remaining 1% is grown in the derived savanna of the South-West zone (FMARD, 2011). The climatic conditions of the aforementioned zones with high sorghum production percentage favour the production of the crop due to its genetically drought-resistant properties, and its ability to grow in hot and dry agro-ecologies, a relative advantage over other food crops such as rice and maize which find it difficult to grow successfully under such conditions (Iorliam *et al*., 2014).

Collection and characterization of existing accessions is a prerequisite for identifying potential germplasm for adaptation, selection, and varietal improvement programmes. Morphological, cytological, biochemical, and molecular markers are commonly used in crop genetic resource characterization. Among these, morphological characterization is the first, easiest, and cheapest step in grouping germplasm, evaluating diversity, and registering cultivars (Rakshit *et al*., 2012). Morphological characterization involves the use of both qualitative and quantitative traits for evaluating and describing genotypes (Adugna, 2014). However, due to the recent interest in sorghum production and utilization in Southern Nigeria, there is a need to carry out morphological characterization and field evaluation of the newly collected accessions using both qualitative and quantitative traits to identify accessions that can be deployed for sorghum improvement and germplasm conservation programs in Southern Nigeria.

Materials and Methods

The experiment was conducted at five different locations in Southern Nigeria; Federal University of Technology Akure (FUTA) (2019), Federal College of Agriculture, Ishiagu (FCAI) (2018 and 2019) and Agricultural Development Centre Ogbomoso (2018 and 2019). Fifty sorghum accessions used for the experiment were collected from different farmers' fields during the 2017 planting season in ten Southern States. The experiment was laid in a randomized complete block design (RCBD) with three replicates and two-row plots of 3 m length. Sowing was done on the 12th, and 15th of July in all the locations with an inter and intra row spacing of 0.75m x 0.25m. In all the locations, weeding was done manually at 4-6 weeks after planting, while the seedlings were protected with insecticide (cypermethrin) at 3-4 weeks after planting against stem borer at the rate of 1 litre per hectare. Urea fertilizer was applied at 6 weeks after planting at the rate of 50kgN per hectare. Morphological data were observed and collected on ten randomly selected plants per plot for twenty-two qualitative and quantitative traits according to IBPGR and ICRISAT descriptor of 1993.

Statistical analysis

Distribution percentages of the eleven qualitative traits were determined using SPSS version 16 software. Likewise, the quantitative data were subjected to ANOVA using General Linear Model (GenStat, 2011). The statistical model for the combined analysis of variance across years is expressed thus:

$$X_{ijk} = \mu + Y_i + R_{ij} + G_k + (RY)_{ij} + (GY)_{ij} + e_{ijk}$$

Where:

X_{ijk} = observation of the i^{th} and j^{th} genotype in the k^{th} replication, μ= general mean, Y_i = the effect of the i^{th} yr, R_{ij} = the effect of j^{th} replication in the i^{th} yr, G_k = the effect of the k^{th} genotype, $(RY)_{ij}$ = replication x year interaction, $(GY)_{ik}$ = the interaction effect between k^{th} genotype in the i^{th} yr, e_{ijk}= experimental error.

Mean of the fifty accessions were compared using critical difference (CD), following Singh and Chaudhary (1985), CD = $(2MSe/r)^{1/2}$ x t; Where; MSe is the error mean square, 'r' is the number of replicates and 't' is the tabulated value at 5% or 1% level of significance for the degree of freedom of error mean square.

Results and Discussion

Results

Phenotypic variability of fifty sorghum accessions using qualitative traits

The variability among the fifty sorghum accessions collected from Southern Nigeria using 11 qualitative traits is presented in Table 1. Among the leaf midrib colours observed, dull green (54%), followed by white (44%), were the most frequent, while yellow had 4%. Waxy bloom on the stalk was recorded as medium bloomy for 68% of the accessions, slightly bloomy for 28%, and mostly bloomy for 4%. Eight classes of inflorescence compactness were observed, which varied from lax panicle to compact elliptic. Very loose, drooping primary branches (44%), and loose, drooping primary branches (32%) had the highest and relative highest primary branches, respectively. Loose erect primary branches (2%), semi-compact elliptic (2%), and compact elliptic (2%) types had the least frequency of occurrence. Seventy-six percent of the accessions were exerted, 22% slightly exerted, while, 2% well exerted. The results obtained with regard to susceptibility to lodging showed that 76% of the accessions had low susceptibility, while, 18% had intermediate susceptibility to lodging. Only three accessions are highly susceptible to lodging. Based on plant senescence, most of the accessions are either intermediate (52%) or slightly senescent (36%). Only 8% of the accessions are mostly senescent at maturity. In this collection, four groups of threshability were observed among the accessions: difficult, intermediate, good, and excellent. About 50% of the accessions had good threshability, followed by 42% that are intermediate, while 4% had both excellent and difficult threshability status. Likewise, the glume colour observed ranges from sienna to a grey colour. Majority of the accessions had black glume colour (46%), followed by sienna (24%), mahogany (24%), red (4%) and grey (2%). The results obtained with regards to grain coverage by glume showed that 80% of the accessions had grains that were covered by 75%, while 14% of the accessions had grains that were fully covered with glume. Only two accessions had glume that was longer than the grain. Grain colour is an important character in sorghum morphological analysis. The dominant colour among the collected accessions was buff (48%), followed by red (38%). The two colours were expressed in more than 80% of the accessions used in the study. Other colours observed include; white (12%) and brown (2%). Awness is an attribute used for selecting accessions against bird invasion among farmers. Fifty-eight percent of the accessions possessed an awn, while 42% were awnless.

Combined analysis of variance for fifty sorghum accessions across five environments

The combined mean squares and CV (%) from the analysis of variance (ANOVA) for 11 quantitative traits evaluated in 5 environments for fifty sorghum accessions are presented in Table 2. The ANOVA for all the environments, genotypes and genotype * environment interaction (GEI) were highly significant (p≤ 0.01) for all the 11 traits evaluated, except leaf length and leaf width, which were not significant for genotype and genotype*environment respectively. With the exception of panicle width (22.20%) and panicle weight (24.10%), the coefficient of variation was between low and moderate, ranging from 3.30% (days to 50% heading) to 24.10% (panicle weight). The mean performance of 50 sorghum accessions evaluated across 5 environments using 11 quantitative traits is shown in Table 3. Using the critical difference, all the 50 accessions differed significantly at p≥0.05. Plant height ranged from 325.30cm (IM-17-01) to 495.10cm (RI-17-01 and EN-17-03) with a mean of 448.98. OS-17-05 had a maximum panicle width of 12.02cm, while, IM-17-03 had a minimum of 7.26cm. At maturity, AB-17-01 gave the highest panicle weight of 82.27g and was significantly different from the other accessions, while, ON-17-04 had the least with 48.16g. Among all the genotypes, EN-17-01 had the longest panicle with a 60.41cm length, while, RI-17-02 had the relative panicle length of 51.71cm. At days to 50% heading, RI-17-02 recorded the highest number of leaves with 19.10 leaves, while, IM-17-01 had the lowest number of leaves (13.90) and panicle length (31.69cm). EK-17-04 had the maximum number of nodes (16.02), while, RI-17-03 had the minimum (11.53). Also, the leaf width ranged from 7.04cm (Ek-17-02) to 9.05cm (OG-17-02). Leaf length increases with OY-17-03 (113.01 cm) and decreases with IM-17-01 (84.70cm). At days to 50% heading and days to 50% anthesis, EB-17-01 recorded the highest mean of 123.50 days and 129.70 days, respectively, while, IM-17-01 had the least number of days to 50% heading with a mean of 99.60 days. IB-17-02 (3.77g) and OY-17-02 (2.89g) gave the highest and the lowest mean for 100 grain weight. The critical mean difference for all the 11 quantitative traits was 3.57 (100 grain weight), 5.69 (leaf width), 6.31 (panicle width), 7.89 (number of nodes), 8.45 (number of leaves), 14.04 (panicle length), 16.72 (panicle weight), 20.43 (leaf length), 21.27 (50% heading), 21.89 (50% anthesis), and 43.06 (plant height).

Discussion

Morphological characterization using qualitative characteristics showed a high occurrence of both buff and red grains. Variable social habits concerning the use of sorghum may lead to variation in the abundance and occurrence of landraces (Adeline *et al*., 2007). In the studied material, more than half of the accessions had 75% grain covering, which is an attribute selected for against bird invasion. Leaf midrib colour among the accessions displayed an ample variation with three different colours; white, dullgreen, and yellow. Similar variations were reported by Durrishahwar *et al.* (2012) among Parkistan accessions. Fifty percent of the accessions in this study had good threshability, followed by 42% with intermediate expression. The most prevalent glume colours among the accessions were black (46%), sienna (24%), and mahogany (24%). One hundred and fifty-seven landraces evaluated in Karnataka, India, showed similar variation, but the majority had more brown glumes (Elangovan and Prablakar, 2007). Darker glumes are known to contribute to grain mould resistance. The variability of glume colour available in the present study may be utilized in screening for grain mould resistance in sorghum (Rajani *et al*., 2017). Glume coverage is inversely related to threshability as threshability becomes poorer with increasing grain coverage. Generally, in grain sorghum, glume coverage is less, and maximum in fodder types. Out of the 50 accessions, eighty percent were covered by 75% glume which was contrary to the findings of Nadjiam (2021) who reported higher occurrence of 25% glume coverage among Chadian sorghum accessions. Likewise, there were more accessions with awns compared to those without awns. According to Richards (1986), the presence of awns may reduce bird damage. Non senescence or stay green is the maintenance of green stems and leaves when water is limited at grain filling and maturity. Non senescence is an important trait related to drought tolerance. Stay green shows the characteristics of green leaves and stems even under limiting condition (Sri Subalakshmi *et al*., 2021). In the present study, 52% of the accessions showed intermediate senescence, while 36% showed slight senescence, hence the selection of the accessions with slight senescence for use in drought prone region. These characters were reported to be used extensively by farmers in naming and identifying sorghum landraces (Dossou-Aminon *et al*., 2014). The mean squares from the analysis of variance showed that significant variation exist among the accessions for all the eleven quantitative traits. This suggests the presence of substantial amount of genetic variability among all the accessions, which shows that there is an opportunity for sorghum improvement using the traits. Alade *et al*. (2017) reported significant variation in 40 genotypes of sorghum evaluated in south-western Nigeria. Furthermore, the highly significant effects of GEI mean squares for all the traits suggest that the environmental conditions in the five environments influenced the performance of the accessions, indicating that some accessions did not behave equally in the expression of the traits in all the environments. This variation may be a result of the differential genetic backgrounds of the accessions (Dossou-Aminon *et al.,* 2014; Alade *et al*., 2017). Generally, the accessions have high height, longer number of days to 50% heading (which is an attribute of long season sorghum), high number of leaves, long panicles, and long broad leaves (as indicated by the head length and leaf size measurements). Similar results were reported on Nigerian sorghum accessions characterized by Obilana (2012), Alade *et al*. (2017), and in Ethiopian sorghum landraces (Adugna, 2014).

Conclusion

Southern Nigeria consists of a heterogenic group of sorghum with high genetic variability, most of which are long season due to the values recorded for their qualitative and quantitative parameters. On the basis of the performance of the accessions for the eleven quantitative traits, superior accessions identified for combined environments were accessions RI-17-01 and

EN-17-03 for plant height, OS-17-05 (panicle width), AB-17-01 (panicle weight), EN-17-01 (panicle length), OG-17-02 (leaf width), OY-17-03 (leaf length), EB-17-01 (longer days to 50% heading and days to 50% anthesis), and AK-17-01 (100 grain weight). These diverse accessions can further be utilized in breeding programs to achieve novel combinations for adaptability and high yield. Hence, the need for further characterization using molecular markers to identify duplicates and initiate sorghum improvement program in the region.

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Table 1: Phenotypic variability of 50 sorghum accessions using qualitative traits

Character	Type	Frequency(%)	Character	Type	Frequency(%)
Midrib colour	White	44	Glume colour	Sienna	24
	Dull green	52		Mahogany	24
	Yellow	4		Red	4
Waxy bloom	slightly bloomy	28		Black	46
	medium bloomy	68		Grey	2
	mostly bloomy	4	Grain covering	50% covering	4
Inflorescence	very lax panicle	8		75% covering	80
Compactness	very loose erect	4		fully covered	14
	very loose drooping	44		glume longer	2
	loose erect	2	Grain colour	White	12
	Loose drooping	32		Red	38
	semi loose	4		Brown	2
	compact elliptic	2		Buff	48
	compact elliptic	2	Senescence	very slightly	4
Inflorescence	slightly exerted	22		Slightly	36
Exsertion	Exerted	76		Intermediate	54
	well exerted	2		mostly senescence	8
Awn	absent	42	Threshability	Difficult	4
	Present	58		Intermediate	42
Lodging	Low	76		Good	50
	Intermediate	18		Excellent	4
	High	6			

Table 2: Mean square of the analysis of variance for the morphological characterization of fifty sorghum accessions collected from south-west Nigeria

Source	DF	PH	PWID	PWEI	PLEN	NOL	NOD	LW	LL	HEADIN	GWEI	ANTH
REP	2	2322.00	19.04	61.10	13.58	0.99	1.82	2.58	240.65	455.06	1.61	480.2
ENVIRON	4	9621.00**	296.08**	63313.80**	1359.55**	437.09**	781.54**	130.41**	4549.65**	10412.60**	21.19**	10399.23**
GENOTYPE	49	11684.00**	12.59**	651.30**	229.37**	12.42**	10.77**	1.87**	307.77	367.91**	0.58**	365.35**
G*E	196	2527.00**	5.46*	456.90**	36.46**	4.97**	5.58**	0.99	86.49**	40.29**	0.41**	41.94**
ERROR	498	1027.00	4.32	206.50	13.73	1.99	1.96	0.67	51.55	14.62	0.12	17.09
CV(%)		7.10	22.20	24.10	8.10	8.00	9.90	10.40	7.10	3.30	10.50	3.40

Significant at P= 0.05 and P=0.01 respectively. PH= Plant height; PAN WID= Panicle width; PAN WEI= Panicle weight; NOL= Number of leaves; NOD= Numbe r of nodes; LW= Leaf width; LL= Leaf length; HEADING= Number of days to 50% heading; GRANW= 100 Grain weight; ANTH= 50% Anthesis

Table 3: Combined mean performance for the quantitative traits of the morphological characterization of fifty sorghum accessions across five environments

Genotype	PH (cm)	PWID (cm)	PWEI (g)	PLEN (cm)	NOL	NOD	LW (cm)	LL (cm)	HEADIN	GWEI (g)	ANTHESIS
OY-17-01	406.70	8.99	52.23	43.03	17.30	13.67	7.87	99.95	105.70	3.10	112.20
IM-17-03	402.90	**7.26**	56.03	34.00	16.24	13.82	7.65	89.44	103.20	3.60	109.20
ED-17-01	472.20	9.04	64.41	46.56	18.66	14.90	7.86	101.65	110.30	3.59	117.10
OY-17-02	485.40	10.34	62.74	40.15	18.74	15.38	8.19	105.23	110.10	**2.89**	117.00
RI-17-01	**495.10**	10.02	62.24	50.82	17.72	14.63	7.60	101.98	115.10	3.30	124.00
OY-17-03	443.50	8.16	45.41	48.19	16.62	13.02	7.75	**113.01**	122.80	2.91	128.90
OY-17-04	474.90	10.12	57.56	53.72	18.49	15.02	7.96	104.82	110.70	3.43	118.30
OY-17-05	471.00	10.88	67.08	45.10	18.63	14.63	8.28	104.91	116.40	2.98	123.30
AB-17-01	459.20	10.11	**82.27**	45.42	17.86	13.93	8.03	100.15	115.00	3.61	122.80
OY-17-06	444.80	9.23	54.01	45.42	18.96	15.18	7.88	101.53	113.00	3.17	119.30
RI-17-07	470.90	10.53	63.40	44.30	**19.10**	14.99	7.76	102.32	116.90	3.68	123.10
ED-17-02	395.00	8.96	50.57	43.34	17.88	14.03	7.95	101.12	114.20	3.22	121.10
OS-17-01	444.40	8.73	44.14	45.39	17.22	12.46	7.75	104.22	121.10	3.08	127.80
RI-17-03	410.50	8.67	57.30	45.54	15.77	**11.53**	7.83	99.21	104.80	3.70	111.40
ED-17-03	426.20	9.04	56.39	43.59	16.53	12.78	7.36	96.99	117.10	3.41	123.70
ON-17-01	454.40	10.13	61.38	47.03	17.55	14.25	7.67	111.00	109.66	3.06	116.20
RI-17-04	455.20	9.53	50.10	43.76	17.29	13.70	7.72	99.10	117.88	3.32	124.20
ON-17-02	447.50	8.73	55.31	43.62	17.47	14.30	8.23	101.33	121.40	3.00	128.00
ED-17-04	445.80	8.60	70.70	47.72	17.20	13.86	8.92	99.94	112.20	3.62	118.70
OG-17-02	448.10	8.14	55.22	49.30	17.79	13.43	**9.05**	106.12	119.70	3.51	126.60
ON-17-03	444.10	9.01	53.48	46.30	19.05	14.84	7.75	96.35	116.00	3.04	122.40
EB-17-01	450.80	9.78	56.27	43.39	18.71	15.16	8.61	99.67	115.80	3.29	122.30
RI-17-05	470.50	9.50	65.90	44.46	17.88	14.45	7.93	99.12	116.40	3.55	123.00
OG-17-01	483.60	8.31	58.47	51.39	19.06	15.96	8.28	107.18	116.20	3.25	123.70
ON-17-04	476.20	8.49	**48.16**	45.13	18.14	14.15	7.05	107.40	121.50	3.36	128.00
EN-17-03	**495.10**	10.89	74.28	45.31	19.05	15.56	8.35	102.80	113.80	3.44	122.50
AN-17-01	440.30	8.93	59.02	43.58	17.24	13.27	7.59	98.32	115.20	3.56	123.00
AN-17-02	476.00	8.58	52.77	43.93	17.77	14.11	7.78	99.03	120.20	3.39	126.90
EN-17-02	404.6	5.96	64.57	36.62	15.96	13.17	7.81	89.17	101.70	3.67	**108.30**
OS-17-01	477.00	9.50	70.80	46.46	18.57	13.30	7.91	98.48	116.90	3.52	123.00
EB-17-02	469.60	9.38	62.48	44.90	18.87	15.20	8.30	99.43	116.50	3.36	122.70
AK-17-01	461.00	9.59	56.44	44.66	18.92	14.97	7.03	102.73	121.80	3.55	128.30
OG-17-03	475.30	10.54	65.74	45.72	18.98	15.23	7.53	103.84	116.80	3.33	124.00
ON-17-05	463.90	8.96	49.23	45.95	16.69	12.91	7.74	108.88	118.00	3.56	124.60
EN-17-04	447.10	8.19	48.98	41.02	18.02	14.13	7.30	99.40	122.40	3.45	129.10
AK-17-02	466.80	9.12	56.33	44.92	17.68	14.21	8.31	106.37	119.30	**3.77**	126.20
EB-17-01	434.20	9.91	62.08	48.45	17.10	13.23	7.87	105.91	**123.50**	3.64	**129.70**
EN-17-01	463.80	10.49	68.20	**60.41**	18.40	14.28	7.87	105.39	122.40	2.90	128.60
RI-17-02	363.80	8.04	75.27	43.83	15.21	12.32	8.01	96.71	101.80	3.04	108.30
OS-17-05	478.70	**12.02**	56.27	44.21	18.74	15.35	7.90	101.13	111.90	3.02	118.20
OY-17-07	465.70	9.44	54.46	44.60	17.04	13.79	8.05	105.80	115.50	3.99	121.70
OS-17-03	470.80	10.22	70.60	51.71	18.94	15.35	8.73	103.40	119.10	3.28	125.90
EK-17-01	436.30	8.98	55.05	47.05	17.99	14.88	7.55	100.48	122.90	3.33	129.10
OS-17-04	465.50	10.00	57.08	51.16	18.34	14.70	8.24	97.87	110.80	3.08	117.70
EK-17-03	387.10	12.20	62.08	55.44	16.57	13.09	**7.04**	99.07	111.50	3.53	118.30
RI-17-06	474.00	9.27	63.15	49.25	17.59	14.65	7.63	97.82	107.60	3.23	114.00
EK-17-03	448.10	8.65	62.78	44.68	17.77	14.77	7.98	101.63	122.70	3.53	128.90

IM-17-01	**325.30**	8.13	53.01	**31.69**	**13.90**	11.60	7.44	**84.70**	**99.60**	3.34	106.40
IM-17-02	400.70	10.99	63.09	42.37	16.61	14.25	7.33	86.24	109.90	3.18	116.10
EK-17-04	476.70	10.23	71.89	50.70	18.47	**16.02**	8.33	107.36	116.30	3.28	123.20
Mean	448.98	9.37	59.73	45.71	17.73	14.17	7.89	101.11	114.82	3.53	119.31
Std error of mean	32.05	2.07	14.37	3.76	1.40	1.39	0.81	7.18	3.82	0.35	4.13
Critical difference	43.06	6.31	16.72	14.04	8.45	7.89	5.69	20.43	21.27	3.57	21.89

PH= Plant height; PAN WID= Panicle width; PAN WEI= Panicle weight; NOL= Number of leaves; NOD= Number of nodes; LW= Leaf width; LL= Leaf length; HEADING= Number of days to 50% heading; GRANW= 100 Grain weight; ANTH= 50% Anthesis