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Breeding for dual purpose attributes in sorghum: Identification of materials and associations among fodder and grain yield and related traits

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In view of the pressing need for both grain and fodder of sorghum as source for food and feed, a study was conducted during 2010 and 2011 to investigate the possibility of developing high yielding dual (grain/fodder) sorghum cultivars. A replicated breeding nursery comprising 122 genotypes was screened for dual grain/fodder attributes. 21 sorghum genotypes were selected and tested against 3 checks in Alpha lattice design with 3 replicates. Association study between grain and forage yields and some related traits was carried out. Sorghum genotypes with high capacity for dual grain/fodder production were identified. It was concluded that high levels of grain and fodder yields coupled with some desirable related traits could be incorporated in one sorghum cultivar as suggested by the favorable associations shown in the study.

Key words: Abjaro, Abu Sabein, Ankolib, correlation, shambat, Sudan grass, variability.

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is a crop of world-wide importance, ranking fifth among the important cereal crops (Chantereau and Nicou, 1994). In the sub-Saharan Africa, it is arguably the most important cereal crop. The world production of grain sorghum amounted to 63.4 million tonne resulting from growing an area of about 47 million ha 63% of which in the African continent (FAO, 2009). The major uses of sorghum have been for food, feed, starch, and for fuel alcohol. Initially, sorghum grain is used primarily for food; however, its use as a feed now exceeds its use as food especially in developed countries. In view of the pressing demand for fodder coupled with the fact that grain sorghum is the stable diet for millions of people in the sub-Saharan Africa and India, it is imperative to reconsider the present mono-commodity breeding strategy of sorghum. Kelly et al (1991) questioned the current strategy of strictly adopting grain-yield criteria in evaluating sorghum genotypes arguing that fodder's contribution to the total value of sorghum production has increased considerably.

Being a possible centre of origin, Sudan is endowed with a wealth of genetic variability in sorghum (Yasin, 1978) enabling selection for most economic traits. The sorghum germplasm of Sudan has been utilized extensively all over the world especially in the USA to improve yield of both grain and fodder (Mahmoud et al,,

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1996). In contrast, local efforts to exploit such variability to develop dual sorghum types have been very limited and mostly directed towards developing improved grain types. Simultaneous improvement of sorghum for both fodder and grain attributes will help in meeting the demand for feed and food and allow maximum utilization of the limited farmer's resource. Research efforts of such kind were very few or lacking in the Sudan. The objectives of this investigation were: To assess the magnitude of variability among some local and exotic sorghum for some traits that aid in developing dual forage/grain sorghum cultivars and to investigate associations between the major forage and grain attributes contributing to developing of dual purpose sorghum cultivars.

MATERIALS AND METHODS

The experimental site

The study was conducted in Shambat (lat.15° 39 N; Long.32° 31 E) in the Experimental Farm of Agricultural Research Corporation (ARC) during 2010- 2011. The soil is heavy clay, non-saline, non-sodic with pH 7.8. The climate is hot and dry. Average Min-Max temperature was 14 and 40°C. The rainy season is short extending from July to September with scant and fluctuating precipitation.

Plant materials

The breeding nursery

The source population of materials used in this study was based on a breeding nursery established in 25/11/2010 in the Experimental Farm of Shambat Research Station (Sh. R.S.). The material grown consisted of 122 entries comprising 34 Sudan grass, 33 Abu Sabein, 29 grain sorghum, 17 sweet sorghum and 9 Ankolib genotypes. All materials other than grain sorghum were developed or kept by the Forage Improvement Program (FIP) at Sh. R.S. The grain sorghum genotypes were collected from different parts of the country, or donated by local research programs. Each entry was represented by one 5 m - ridge replicated twice. Sowing was done manually on the eastern side of the ridge by placing 3 to 5 seeds in holes spaced at 20 cm. Nitrogen fertilizer (urea) was added at the second irrigation at rate of 55 kgN/ha..Irrigation water was applied at 10 to 12 days interval. Weed population was kept at minimum by hand weeding.

Selection criteria

The major criteria used to select for dual purpose (fodder/grain) genotypes included but not limited to: Early to semi early flowering time, high regrowth and tillering capacity, medium to tall plant stature, large panicle size (thick diameter), leafiness, stay green, juicy sweet stems, bold white grains with no testa color. Panicle and grain characteristics were evaluated in the laboratory from five heads randomly chosen from each genotype. Based on the above attributes, 21 genotypes comprising 7 Sudan Grass, 5 each Abu Sabin and grain sorghum and 2 each Ankolib and sweet sorghum were selected. Selection was firstly based on high dual grain / forage yield then on related attributes with more emphasis given to earliness, regrowth and leaf to stem ratio (Table 1).

The trial

The 21 selected genotypes plus 3 standard checks (totaling 24) were arranged in α lattice design (Patterson and Williams, 1976) with 12 incomplete blocks (iblock) and 4 complete blocks. The iblock composed of two plots each having two 5 m ridges. Planting date was effected on 11/10/201. Sowing method and planting density were similar to those of the breeding nursery. In each incomplete iblock, forage and grain attributes were evaluated from the two outer and the two inner rows, respectively. Data collected for forage attributes included: Green (GMY) and dry (DMY) matter yields (t/ha), days to 50% flowering, plant height and stem diameter. Leaf to stem ratio: Measured on dry weight basis by dividing the weight of the leaves by the total weight of leaves and stems taken from five randomly chosen plants from each plot. Regrowth (g): Measured two weeks following the date of cutting of each entry, new immerging shoots from 5 competitive plants randomly chosen from each harvested plot were collected, air dried and the dry weight was determined in grams. Data collected for grain attributes included seed yield /plant (g), head circumference (cm), head length (cm), 1000 seeds weight (gm) and seed number/head.

Statistical analysis

The data was subjected to analysis of variance (ANOVA) following the procedure of alpha lattice design (Patterson and Williams, 1976). Correlation between different characters was worked out. The statistical software packages Agrobase Gen II (2008) was used to run alpha lattice whereas GenStat (2011) was used to run correlation analysis.

RESULTS

Agronomic performance

The analysis of variance (Table 2) revealed highly significant differences among genotypes for forage and grain yields and all related traits.

Forage yield

The overall mean for DMY was 7.34 t/ha (Table 3). SG33 gave the highest DMY (11.35 t/ha) followed by Abjaro (9.85 t/ha), S.25Abu70 (9.80 t/ha), SG8 (9.74 t/ha) and S.03Abu70 (9.74 t/ha). The lowest DMY was shown by Abnaffain (3.78 t/ha). The grain checks (WadAhmed, and ArfaaGadamak) and Ankolib types gave below average DMY. The overall mean for GMY was 33.8 t/ha. Generally, the genotypes kept similar trend as in DMY. The highest GMY was shown by S.25Abu70 (47.97 t/ha) and SG33 (47.72 t/ha) whereas the lowest GMY was shown by Abnaffain (17.95 t/ha).

Seed yield per plant

The overall mean for seed yield per plant was 31.61 g

Table 1. The 21 selected sorghum genotypes (Shambat, 2011).

Entry	Genotype	Type	Source	Seed color
1	SG33	Sudan grass	FIP. Shambat	Dark brown
2	SG08	Sudan grass	FIP. Shambat	White
3	SG54	Sudan grass	FIP. Shambat	White
4	SG53-1	Sudan grass	FIP. Shambat	Dark brown
5	SG12-1	Sudan grass	FIP. Shambat	White
6	SG51	Sudan grass	FIP. Shambat	White
7	SG32-1	Sudan grass	FIP. Shambat	White
8	S.25Abu70	Abu sabein	FIP. Shambat	White
9	S.24Abu70	Abu sabein	FIP. Shambat	White
10	S.26Abu70	Abu sabein	FIP. Shambat	White
11	S.134Abu70	Abu sabein	FIP. Shambat	White
12	S.03Abu70	Abu sabein	FIP. Shambat	White
13	ANKSenar	Ankolib	FIP. Shambat	Dark brown
14	ANKNiyala	Ankolib	Nyala Res. Station	Dark brown
15	E-35-1	Sweet sorghum	USDA-ARS U .of Nebraska	White
16	Atlas	Sweet sorghum	USDA-ARS U .of Nebraska	White
17	ArfaaGadamak	Grain sorghum	ARC National Prog.	White
18	HagaBanet	Grain sorghum	Niyala Res. Station	White
19	FakiMustahi	Grain sorghum	ARC National Prog.	White
20	Hemasi	Grain sorghum	FIP. Shambat	Yellow
21	Abjaro	Grain sorghum	FIP. Shambat	White
22	Abnaffain	Grain/Forage (dual check)	U. of Bakht Alrida	White
23	SG32-2A	Sudan grass (forage check)	FIP. Shambat	Dark brown
24	WadAhmed	Grain sorghum (grain check)	ARC National Prog.	White

Table 2. Mean squares from ANOVA for yield and yield-related traits of 24 sorghum genotypes (Shambat, 2011).

Source of variation	DF	Green matter yield (t/ha)	Dry matter yield (t/ha)	Seed yield/plant (g)	Regrowth weight (kg/ha)	Days to flower	Plant height (cm)	Stem diam. (cm)	Leaf/stem ratio
Block	3	113.00*	4.845^{ns}	86.856^{ns}	6.394^{ns}	20.427**	700.260**	0.013^{ns}	0.000^{ns}
Genotype	23	275.862**	15.254**	815.573**	70.534**	75.565**	2757.597**	0.104**	0.004**
Residual†	69	30.428	2.004	67.697	13.352	4.007	129.311	0.009	0.001
iBlock$^{♣}$	44	36.190^{ns}	2.014^{ns}	78.527^{ns}	15.933^{ns}	5.009^{ns}	157.543^{ns}	0.010 ^{ns}	0.001^{ns}
Error‡	25	20.285	1.987	48.63777	8.810	2.244	79.623	0.007	0.001

**, ^{ns}, Highly significant and not significant at 0.01 and 0.05 probability level, respectively; †, RCBD residual; $^{♣}$, incomplete block; ‡, Intra block error.

(Table 3). Abjaro showed the highest seed yield (72.50 g) followed by S.134Abu70 (57.54 g), S.26Abu70 (49.10 g), Hemasi (45.58 g) and S.25Abu70 (44.13 g). S.03Abu70 and E-35-1 averaged 41.85 and 36.92 g, respectively. SG53-1 and SG51 gave the best seed yield among Sudan grass group averaging 30.1 and 28.83 g, respectively. Abnaffain, ArfaaGadamak and WadAhmed gave below average seed yield amounting to 25.65, 23.60 and 21.72 g, respectively. The lowest seed yield was shown by the Sudan grass genotypes SG33 (18.39 g), SG32-2A (13.69 g) and SG32-1(12.89 g).

Growth traits

The genotypes SG12-1 and Abnaffain were the earliest with respective flowering time of 52.3 and 53.2 days (Table 4). In contrast, Abjaro and E-35-1 were the latest taking 71.3 and 66.0 days to flower. The flowering time for Abu Sabein genotypes ranged from 55.9 to 58.7 days. The average performance for plant height was 182 cm. Abjaro was the tallest (217 cm) whereas ArfaaGadamak and WadAhmed showed the shortest stature (122 cm).

Abu Sabein genotypes showed above average plant

Table 3. Green (GMY) dry (DMY) matter yields and seed yield of sorghum genotypes evaluated for dual fodder/grain yield (Shambat, 2011).

Genotype	GMY	DMY		Seed yield		Rank average
	(t/ha)	(t/ha)	Rank	(g/plant)	Rank	
SG33	47.7	11.4	1	18.4	22	12.5
SG08	41.1	9.74	4	24.0	16	10
SG54	36.9	8.85	7	27.1	13	10
SG53-1	30.8	6.73	17	30.1	9	13
SG12-1	32.7	6.66	18	23.9	17	17.5
SG51	31.8	7.08	15	28.8	10	12.5
SG32-1	36.8	7.71	9	12.9	24	16.5
S.25Abu70	48.0	9.80	3	44.1	5	4
S.24Abu70	39.3	7.64	11	37.9	7	9
S.26Abu70	42.4	8.19	8	49.1	3	5.5
S.134Abu70	45.1	8.86	6	57.4	2	4
S.03Abu70	43.7	9.19	5	41.9	6	5.5
ANKSenar	27.8	5.25	21	25.7	14	17.5
ANKNiyala	26.6	5.43	19	19.1	21	20
E-35-1	32.7	7.39	12	36.9	8	20
Atlas	33.1	7.12	14	27.7	12	13
ArfaaGadamak	20.4	4.32	22	23.6	18	20
HagaBanet	30.1	7.67	10	22.5	19	14.5
FakiMustahi	19.0	4.26	23	28.2	11	17
Hemasi	28.6	6.79	16	45.6	4	10
Abjaro	42.1	9.85	2	72.5	1	1.5
Abnaffain	18.0	3.78	24	27.7	15	18.5
SG32-2A	34.0	7.18	13	13.7	23	18
WadAhmed	23.4	5.35	20	21.7	20	20
Mean	33.8	7.34		31.6		
S.E±	2.6240	0.7079		3.9725		
LSD (5%)	7.6429	2.0618		11.5705		
C.V (%)	15.51	19.28		25.14		

height. The average performance for stem diameter was 0.95 cm. Abjaro was the thickest (1.57 cm) whereas SG32-2A was the thinnest (0.65 cm) in stem diameter. Abu Sabein genotypes, apart from S.24Abu70 showed above average stem diameter.

The highest leaf to stem ratio was shown by ArfaaGadamak (0.45), WadAhmed (0.44), FakiMustahi (0.44), Abjaro (0.43) and Atlas (0.43). The highest regrowth weight was given by the Sudan grass genotypes SG32-2A (33.8 g/plant) and SG8 (30.6 g/plant). Abnaffain Fakimustahi and All of the Abu Sabein genotypes gave below average regrowth weight whereas Abjaro gave above average regrowth.

Grain yield components

Mean performance for number of seeds per head was 1098 seeds (Table 4). Abjaro gave the greater number of seed per head (1879). Abu Sabein genotypes gave above average number of seed per head whereas the opposite is true for most of Sudan grass genotypes. Mean performance for 1000 seed weight was 28.5 g. The greater seed weight was expressed by the genotypes: Hemasi, S.26Abu70, S.134Abu70, S.25Abu70, Abjaro and Abnaffain, showing seed weight ranging from 36.8 (for Abnaffain) to 40 g (for Hemasi).

Mean performance for panicle length was 20.5 cm. The largest value for panicle length was shown by ArfaaGadamak (26.9 cm) and FakiMustahi (25.0 cm) whereas the smallest value was shown by Abjaro (15.7 cm) and E-35-1(15.8 cm). Mean performance for panicle circumference was 14.9 cm. Abjaro gave the largest panicle circumference (24.2 cm) whereas the smallest value was shown by SG32-2A (10.9 cm). All of the Abu Sabein genotypes and Abnaffain showed above average panicle circumference ranging from 15.8 to 17.3 cm.

Table 4. Forage and grain yields related traits of different sorghum cultivars (Shambat, 2011).

Genotype	Days to flower	Plant height (cm)	Stem diam. (cm)	Re-growth (g/plant)	Leaf /stem ratio	Panicle length (cm)	Panicle circum. (cm)	No. of seeds /head	1000 seed wt. (g)
SG33	60.2	206	1.02	27.8	0.35	24.47	12.66	734	26.66
SG08	59.3	201	0.96	30.6	0.34	19.18	14.13	850	28.01
SG54	61.0	214	0.97	19.3	0.38	25.82	13.92	1058	25.81
SG53-1	56.6	178	0.94	20.3	0.38	21.63	14.75	1116	27.29
SG12-1	52.3	191	0.82	22.1	0.36	22.94	13.78	731	33.65
SG51	62.5	206	1.00	23.1	0.36	24.15	14.14	1223	23.77
SG32-1	56.2	202	0.94	23.5	0.36	19.01	14.44	458	30.43
S.25Abu70	57.4	195	0.97	18.3	0.38	18.01	16.88	1159	38.64
S.24Abu70	55.9	189	0.93	17.0	0.37	18.60	15.83	1253	31.16
S.26Abu70	56.4	187	0.97	19.5	0.40	16.40	16.05	1232	39.15
S.134Abu70	57.8	201	0.98	17.8	0.37	16.76	17.30	1465	38.73
S.03Abu70	58.7	187	0.97	19.6	0.38	18.94	17.19	1267	33.25
ANKSenar	54.1	167	0.80	19.5	0.40	22.57	11.57	988	25.57
ANKNiyala	56.9	167	0.88	18.9	0.40	24.63	11.05	788	23.26
E-35-1	66.0	154	1.10	22.7	0.41	15.77	15.92	1595	22.71
Atlas	62.3	177	0.95	18.5	0.43	21.39	14.09	1615	17.10
ArfaaGadamak	57.7	122	0.85	23.9	0.45	26.90	11.84	1234	19.46
HagaBanet	64.0	176	0.87	28.0	0.38	16.12	13.88	977	21.61
FakiMustahi	55.3	154	0.82	19.4	0.44	24.96	13.92	931	29.97
Hemasi	58.2	178	1.01	19.1	0.38	17.18	19.05	1127	39.82
Abjaro	71.3	217	1.57	22.3	0.43	15.73	24.16	1879	38.47
Abnaffain	53.2	171	0.89	18.2	0.38	16.65	15.34	719	36.78
SG32-2A	60.7	211	0.65	33.6	0.38	24.09	10.87	744	16.24
WadAhmed	59.5	123	0.92	21.8	0.44	20.92	13.78	1216	16.46
Mean	58.9	182	0.95	21.9	0.39	20.53	14.86	1098	28.50
SE±	0.914	5.315	0.045	1.734	0.012	0.766	0.564	97.993	2.102
LSD (5%)	2.662	15.480	0.136	5.052	0.035	2.232	1.642	285.416	6.121
CV%	3.10	5.83	9.81	15.87	6.19	7.46	7.59	17.85	14.75

Association study

Table 5 shows correlation among different grain and forage sorghum attributes. Positive highly significant correlations were observed between green matter yield (GMY) and each of seed yield (R = 0.402), 1000 seed weight, head circumference, plant height and stem diameter. Negative highly significant correlations were detected between GMY and leaf to stem ratio. GMY has week and insignificant correlation with days to flowering and regrowth. Seed yield has positive highly significant correlation with each of plant height, stem diameter. Correlations were weak and insignificant between seed yield and each of days to flowering and leaf to stem ratio. Plant height was positively and significantly correlated with 1000 seed weight and head circumference but has weak and insignificant correlation with days to flower, regrowth and number of seeds/ head. Plant height has negative significant correlation with leaf to stem ratio. Days to flowering has significant positive correlation with number of seeds/ head, stem diameter, head circumference and leaf to stem ratio, but has negative significant correlations with 1000 seed weight and head length. Weak and insignificant correlation was observed between days to flowering and regrowth.

DISCUSSION

Agronomic performance

Abjaro and the Abu Sabein selections: S.25Abu70, S.134Abu70, S.26Abu70, S.03Abu70 were the best genotypes ranking top in dual forage and grain yields (Table 3). However, of the 4 Abu Sabein genotypes, only S.25Abu70 and S.03Abu70 would be advanced due to their good performance in one or more of other attributes including regrowth, earliness and leaf to stem ratio (Table 4). Among the Sudan grass genotypes, SG08 , SG54 and SG51 averaged the best score for dual grain forage yield,

Table 5. Correlation among different grain and forage attributes in sorghum (Shambat, 2011).

1	Regrowth										
2	Seed No/ head	-0.2173*									
3	Seed yield	-0.3118**	0.7541**								
4	Stem diameter	-0.1078	0.5252**	0.5900**							
5	Plan height	0.1456	-0.0381	0.2765**	0.2593*						
6	1000 seed wt	-0.3134**	0.0998	0.6994**	0.3063**	0.3949**					
7	Days to flowering	0.1359	0.4322**	0.1893	0.4936**	0.0772	-0.2536*				
8	Green matter yield	0.0894	0.1725	0.4018**	0.3506**	0.6901**	0.3732**	0.1038			
9	Head circumiference	-0.3068**	0.6098**	0.8569**	0.6820**	0.2997**	0.6650**	0.3309**	0.3340**		
10	Head length	0.1589	-0.2666**	-0.4711**	-0.3559**	-0.1455	-0.4453**	-0.2226*	-0.2850**	-0.5969**	
11	Leaf to stem ratio	-0.1432	0.2666**	0.0153	0.0436	-0.6258**	-0.2480*	0.2157*	-0.4521**	-0.0087	0.1042
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

*, **, Significantly different from zero at 0.05 and 0.01 probability level, respectively.

however, the former has got brown seed color which is undesirable for food consumption whereas the latter showed the lowest regrowth value among Sudan grass genotypes (Table 4). SG51 has desirable seed color and can be considered for advanced testing. SG51 has been reported to have stable agronomic performance with high forage yield (Mohammed, 2010). E-35-1 was the best among sweet sorghum group showing desirable performance in dual purpose attributes.

Abnaffain is a traditional cultivar grown for dual production of grain and fodder. The literal translation of the Arabic name “Abnaffain” (*Father of two benefits*) implies the dual utility of this cultivar. It was included here as a check for dual fodder / grain production. In this study, all of the advanced materials outperformed the check Abnaffain in dual forage and grain yields. Its low fodder and grain yields could be attributed to its reduced plant height and seed number / head (Table 4). However, none of the studied materials was earlier in flowering than Abnaffain. Earliness is a key factor in dual cultivations systems with limited moisture and other resources of production. ArfaaGadamak and WadAhmed exhibited below average performance in both grain and fodder yields. Their low forage yield could be attributed to their short stature. Both cultivars are the outcome of the national breeding program that emphasizes developing high grain yielding types at the expense of fodder yield, that is, dwarf combinable types suitable for mechanized harvesting. Abjaro belongs to the landraces of Northern Sudan. It was the best genotype combining the highest fodder and grain yields (Table 3). Its high fodder yield could be explained by its unique tallness and stem thickness (Table 4) whereas the high grain yield is attributable to the high number of seeds per head coupled with high weight of the seed (Table 4). Unexpectedly, Abjaro was among the best genotypes in leaf to stem ratio (Table 3). Usually leaf to stem ratio correlates unfavorably with forage yield and plant height as proved by this study (Table 5) or reported by other workers (Rashida and Mohammed, 2012). This trait represents a good measure for fodder quality as the greater part of the nutritive value is stored in leaves which also have better intake potential and digestibility (Mohammed and Zakaria, 2014). Unfortunately, Abjaro was the latest to flower (Table 4). However, being highly productive along with leafiness justify its advancement as a candidate for dual fodder/grain production. Some of Abu Sabein genotypes, that is, S.25Abu70 and S.03Abu70 were comparable to Abjaro in high fodder/grain productivity. Though less leafy, they were however, excelling Abjaro in earliness. Abu Sabein is basically a grain cultivar more probably derived from the palatable ‘Dibekri’ (Kambal 2003). Dibekri is a land race variety widely grown in Northern Sudan (Nile State). Driven by the need for fodder around cities, the farmers opted to Abu Sabein as a dual grain/fodder cultivar. However, Abu Sabein had been gradually devoted to forage production in response to the increasing demand for fodder.

Association study

The highly significant positive correlation revealed by this study between green matter yield (GMY) and grain yield (Table 5) points to the possibility of simultaneously combining high levels of grain and fodder yields in one cultivar. Similar results with grain and stover were reported by a number of workers (Ross et al., 1983; Blümmel et al., 2009; Reddy et al., 2005). Ross et al (1983) reported that grain yield had no extremely strong negative phenotypic correlations with any forage residue trait. They concluded that, the correlations obtained do not suggest any formidable barriers to simultaneous improvement of agronomic, grain, and forage traits. Their results go well with our finding that GMY was positively or favorably correlated with and 1000 seed weight, head circumference and seed number per head. Furthermore, this was strongly supported by the positive and highly significant correlation shown in this study between plant height and each of grain and fodder yields. Positive significant association between grain yield and plant height was also reported by Kumar et al. (2012).

Correlations of days to flower with each of forage and grain yield in this study were weak and insignificant permitting development of early and improved dual grain fodder cultivars. Disagreeing results for week correlation between grain yield and days to flower were reported by Patil et al. (1995).

Conclusion

The study revealed the possibility of selecting sorghum cultivars with high capacity for dual grain/fodder production. Six genotypes were identified as having the best dual grain/fodder excelling the standard checks, these included Abjaro (a land race cultivar), S.25Abu70 and S.03Abu70 (Selections from the land race cultivar Abu Sabein), SG08 and SG51 (Selections from Garawi, traditional Sudan grass cultivar) and E-35-1 an introduced sorghum cultivar.

High levels of grain and fodder yields coupled with some desirable traits could be incorporated in one sorghum cultivar as suggested by the favorable associations shown in the study.

Conflict of Interest

The authors have not declared any conflict of interests.

REFERENCES

Agrobase GII (2008) version 18.5.1 Agronomix software, inc. Canada

Blümmel M, Rao SS, Palaniswami S, Shah L, Reddy BVS (2009). Evaluation of sweet sorghum (*Sorghum bicolor* L. Moench) used for bio-ethanol production in the context of optimizing whole plant utilization. An. Nutr. Feed Technol. 9:1-10.

Chantereau J, Nicou R (1994). Sorghum. The Tropical Agriculturist Series. CTA Wageningen, Netherlands; Macmillan, London PMid:24186186

FAO (2009). FAOSTAT. Available at: http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor

GenStat (2011). Ninth edition, Version – 9.1.0.174. Lawes Agricultural Trust (Rothamsted Experimental Station) VSN International, Hertfordshire. UK.

Kambal AE (2003). Naming Abu sabein sorghum, U.K. J. Agric. Sci. 11:449-452.

Kelly TG, Rao PP, Walker TS (1991). The relative value of cereal-straw fodder in the semi-arid tropics Indian: Implication for cereal breeding programs at ICRISAT. Progress report NO105, ICRISAT, India, p. 33.

Kumar NV, Reddy CVC, Reddy PVRM (2012). Study on character association in Rabi sorghum. Plant Arch. 12:1049-1051.

Mahmoud MA, Khidir MO, Khalifa MA, ElAhmadi AB, Musnad HA, Mohamed EI (1996). Sudan country report to the FAO International Technical Conference on Plant Genetic Resources. Leipzig, pp. 39-40.

Mohammed MI (2010). New Sudan grass forage cultivars selected from the original population (Sorghum Sudanense var. Garawi). Afr. J. Range. Forage Sci. 27:51-55. http://dx.doi.org/10.2989/10220111003703518

Mohammed MI, Zakaria ZA (2014). Quality Attributes In Sudanese Sorghum Improved For Forage Yield. Am. J. Expt. Agric. 4:171-182.http://dx.doi.org/10.9734/AJEA/2014/5480

Patil DV, Makne VG, Patil RA (1995). Character association and path coefficient analysis in sweet sorghum (*Sorghum bicolor* (L.) Monech). PKV Res. J. 19:21-24.

Patterson HD,Williams ER (1976). Anew class of resolvable incomplete block Designs. Biometrica, 63:83 -92. http://dx.doi.org/10.1093/biomet/63.1.83

Rashida AM, Mohammed MI (2012). Evaluation of new locally developed sorghum hybrids. J. Sci. Technol, 1:66-77.

Reddy VSB, Ramesh S, Reddy PS, Ramaiah B, Salimath PM, Kachapur R (2005). Sweet sorghum– A potential alternate raw material for bio-ethanol and bioenergy. Int. Sorghum Millets Newslett. 46:79-86.

Ross WM, Groz HJ, Haskins FA, Hookstra GH, Rutto JK, Ritter R (1983). Combining ability effects for forage residue traits in grain sorghum hybrids. Crop Sci. 23:97-101. http://dx.doi.org/10.2135/cropsci1983.0011183X002300010028x

Yasin TE (1978). Phenotypic variations in local Sorghum in the Sudan Nuba Mountains. Exp. Agric. 14:181-188. http://dx.doi.org/10.1017/S001447970000867X