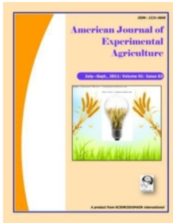

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Quality Attributes in Sudanese Sorghums Improved for Forage Yield

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Authors' contributions

This work was carried out in collaboration between the two authors. Author MIM provided the plant materials, designed and supervised the study, performed the statistical analysis, wrote the protocol and approved the final manuscript. Author ZAZ, conducted the field experiments, carried out laboratory analysis, collected and prepared the data for analysis

Original Research Article

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ABSTRACT

Aims: To investigate quality attributes in forage sorghum at different growth phases and plant parts in relation to some agronomic traits
Study Design: The treatments were arranged in split-plots in randomized complete block design
Place and Duration: Field experiments were conducted in Sudan at two environments: Shambat 2005 and Sennar 2006
Methodology: Quality attributes were studied in two growth phases (boot and dough stages) split over nine genotype with plant part (leaf and stem) further spilt on growth phases. The traits studied included: green and dry matter yields, days to flowering, plant height, crude protein (CP) neutral detergent fiber (NDF) acid detergent fiber (ADF) ash and ether extract (EE).
Results: The growth phases differed significantly for ADF, NDF and CP. The plant parts differed significantly for ADF, CP and ASH. The interaction of growth stage with plant part was significant for all traits other than ADF. Correlation of forage yield with CP was significantly negative, with ADF was significantly positive and with NDF was also positive but insignificant. Correlation of CP with NDF was significantly negative, with ADF, EE and ASH was also negative but insignificant.

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Conclusion: It was concluded that harvesting at boot stage will maximize the benefits gained from forage sorghum. Quality traits might be enhanced by developing cultivars with high leaf to stem ratio. Cultivars improved in protein content, intake potential and digestibility could be developed but concurrent improvement of these aspects with forage yield might be difficult to achieve. Forage yield, but not quality attributes of the selected lines has been improved over their parental population; this has been attributed to the adverse association between forage yield and CP. Screening for both quality and yield attributes in the earlier stages of the breeding program has been suggested.

Keywords: *NDF; ADF; CP; boot; dough; ankolib; sudangrass.*

1. INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is a crop of world-wide importance. It is unique in its ability to withstand a wide array of harsh environmental conditions. Initially, the grain is used primarily for food; however, its use as a feed now exceeds its use as food specially in developed countries. In the Sudan, where the second largest animal wealth in the African continent exists, Sorghum straw has the greater contribution in maintaining the national herd. The major stocks of forage sorghum in Sudan belong to three local populations, namely: 'Abu Sab'in' a dual grain/forage type, 'Garawi' (Sudangrass, *Sorghum sudanense*. Piper Stapf) and 'Ankolib' a sweet sorghum type. A number of improved materials of the three populations have been developed. Of these, Abu Sab'in constitutes the bulk of the area under irrigated fodder in the Sudan. Ankolib, though merited by good forage attributes, is grown not for fodder production, but mostly for chewing the sweet stalks.

The traditional system for forage production in the Sudan favors high yields at the expense of the nutritive value. This is because fodders are mainly produced as low input- cash crops. Such system requires fast growing, highly productive cultivars to minimize costs of production. These requirements are largely met by Abu Sab'in, yet this cultivar is known to have poor quality attributes because the stalks are dry, non sweet and sparsely leafed. On the other hand, a common practice of Abu Sab'in growers is to delay cutting until grain formation to escape the threat of prussic acid poisoning. The grains being produced were eaten by sparrows and the farmer usually ends up with a straw of a lowered feeding value.

Recently, with the increased attention given to dairy and fattening schemes, a new production system (modern system) started to emerge whereby high quality forage types are needed to maximize productivity of milk and live-weight gain. Under such system, the crop is mostly produced rather than purchased from the market and the owner has a chance to appreciate the validity of high quality forage.

Efforts to diversify and improve local types of forage sorghum have just succeeded in developing some improved materials. The objectives of this study were to evaluate the agronomic and quality performance of some of the newly developed genotypes representing the major local stocks of forage sorghums and to assess the effect of growth stage and plant part on some of the quality traits.

2. MATERIALS AND METHODS

2.1 The Experiment

The experiment was carried out in two environments (Shambat, 2005 and Sennar, 2006). In Shambat, the trial was grown in the Experimental Farm of Shambat Research Station (lat.15˚39' N; Long. 32˚31' E. Elevation: 1251 feet). In Sennar, the trial was conducted in the Research Farm of Sennar Research Station (lat. 13°33' N; Long. 33˚37' E. Elevation: 1404 feet). Soils of Shambat are well drained, clay to loamy- clay, non-saline, non-sodic soils with pH 7.8. In Sennar, Soils are heavy clay, moderately drained, non-saline, non-sodic with pH 7.2. In both environments, no rain fall was encountered during the growing season. Temperature degree and relative humidity during the growing season are presented in Figs. 1 and 2, respectively. Unless otherwise indicated, the following materials and methods were applied in both environments.

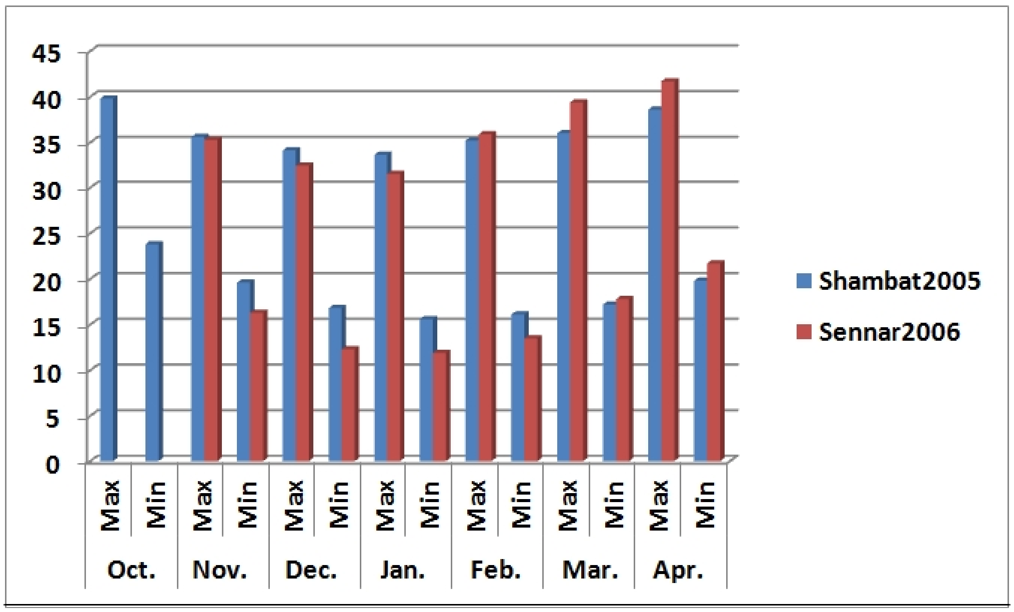

Fig. 1. Monthly mean minimum and maximum temperature (^{O}C) during the growing season in Shambat (2005/06) and Sennar (2006/07).
Source: Meteorological Authority, Ministry of Science and Technology (2006)

2.2 Management

The land was disc ploughed, disc harrowed and leveled by scraper to obtain a flat, fine seed bed. In Shambat the plots were pre watered 3 days before sowing to ensure firm seed bed. Sowing date in Shambat was on 6. Oct. 2005 whereas that of Sennar was on 3.Nov.2006. The plot size consisted of four ridges 0.75 m apart and 6 m long (approximating 27m^2). Sowing was done manually by dribbling the seed in a furrow opened on both sides of the ridge using a seed rate of 48 kg/ha. Nitrogen fertilizer (urea) was added at the second irrigation at a rate of 55 kg n/ha. Irrigation water was applied at 10 to 15 day interval. Weed population was kept at minimum by hand weeding. Harvesting was done manually by cutting the plants at 5 to 7 cm above soil surface.

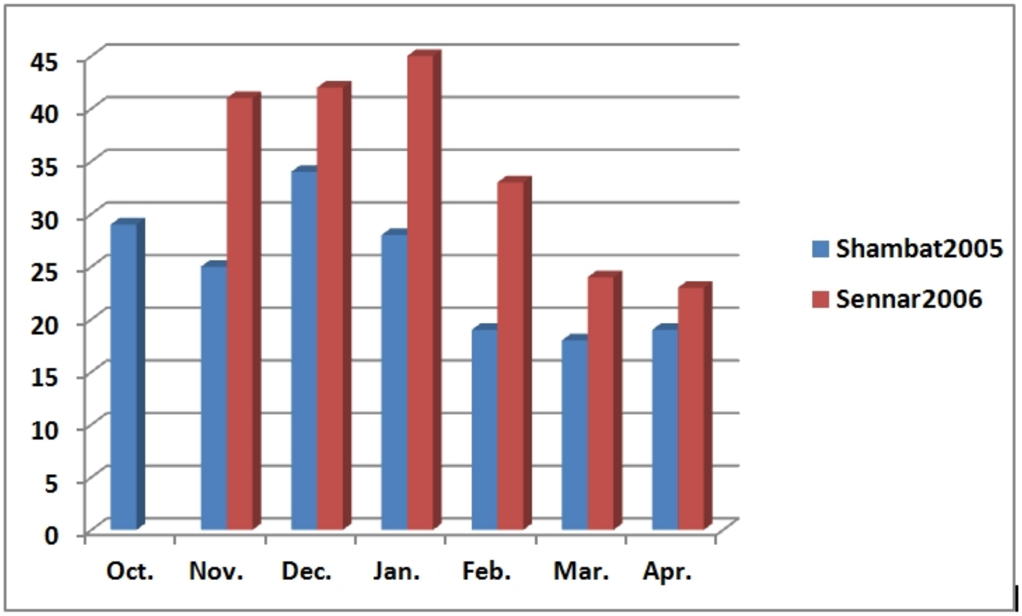

Fig. 2. Relative humidity (%) during the growing season in Shambat (2005/06) and Sennar (2006/07).

Source: Meteorological Authority, Ministry of Science and Technology (2006)

2.3 Plant Materials

The plant materials comprised 9 genotypes developed by individual plant selection within 3 local populations of forage sorghum. The genotypes: S.8, S.126 and Kambal were selected from Abu Sab'in, a dual grain-forage sorghum type. The genotypes: SG32-2A, SG50 and SG18 were selected from 'Garawi', a Sudangrass land race cultivar [1]. The genotypes: ANK40, ANK43 and ANKSSS were selected from 'Ankolib', a local type of sweet sorghum [2]. The selected genotypes were tested against their respective parental populations (Abu Sab'in, Garawi and Ankolib).

2.4 Treatments and Experimental Design

The 12 entries were evaluated for agronomic and quality traits at two growth phases: Booting and dough stages. The quality traits were further investigated in two plant parts: Leaf and stem. The growth stage was imposed on genotype as split in time and the plant part was further split on growth stage. The treatments were arranged in a RCB design with three replicates. The subunits of growth stage were assigned at random in each plot before the onset of the reproductive stage by marking three rows for each stage. In Sennar site only 10 genotypes were evaluated due to seed shortage of the genotypes SG18 and ANKSSS.

2.5 Data Collection

Agronomic data were collected for days to 50 % flowering, plant height, green matter yield (GMY) and dry matter yield (DMY). The GMY was estimated by harvesting the three inner rows specified for each growth stage in each plot. The DMY (not evaluated in Sennar site) was estimated from a random sample of 0.5 kg taken from the fresh materials of the harvested plot and air dried to a constant weight.

The quality traits were measured for neutral detergent fiber (NDF), acid detergent fiber (ADF) crude protein (CP), Ash, and ether extracts (E.E). Proximate analysis for these traits was carried on dry matter basis, using material from two replicates in each experiment. Three plants randomly chosen from the harvested plot at each growth stage were hand- separated into leaves and stems and used for the analysis. The chemical analyses were carried out following the standard procedures [3] in the laboratory of the Faculty of Animal Production, Shambat, Sudan.

2.6 Statistical Analysis

Single analysis of variance was performed for all characters before carrying the combined analysis. Standard procedures of analyzing split plot in RCB design with main effects confounded were followed [4]. Combined ANOVA for the trials conducted in Shambat and Sennar was performed using balanced data sets for characters in common in both environments. Contrast analysis between the three forage types for yield and crude protein was performed. Associations between yield and quality traits were also investigated.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Agronomic performance

Table 1 shows the agronomic performance of the materials studied at both environments. In Shambat, significant differences were detected among genotypes for all agronomic traits whereas in Sennar, differences were significant only for days to flowering. The genotypes SG18, SG32-2A, Kambal and ANK43 significantly outyielded their respective parental populations in GMY in Shambat averaging 32.1, 28.7, 31.1 and 28.6 t/ha, respectively. In Sennar, the genotypes showed short stature and took longer to flower than Shambat with over all mean of 104 cm for plant height and 86 days for flowering period. The combined analysis revealed significant differences among genotypes for forage yield. Kambal ranked first in GMY averaging 21.7 t/ha over the two environments. However, its yield was not significantly different from that of the check Abu Sab'in. ANK43 from Ankolib and SG32-2A from Garawi significantly outyielded their respective parental populations averaging 21.0 and 20.4 t/ha, respectively. The genotype S.8 and the check Garawi gave the lowest GMY averaging 16.6 and 16.8 t/ha, respectively. Kambal, ANK43 and SG32-2A were among the tallest genotypes showing plant height of about 139 cm. The lowest values for plant height were shown by check Ankolib (116 cm) and S. 8 (120 cm). The lowest yielding genotype in Shambat (the check Garawi) significantly outyielded the highest yielding genotype in Sennar (The check Ankolib) which ranked the second lowest in GMY in Shambat. The tallest genotype in Shambat (the check Abu Sab'in) showed the lowest value for plant height in Sennar.

Table 1. Agronomic performance of some forage sorghum genotypes grown in Shambat 2005 (Sh05), Sennar 2006 (Sn06) and combined green matter yield

Genotype	Green matter yield (t/ha)		Dry matter yield (t/ha)	Days to flowering		Plant height (cm)		Combined Green matter yield (t/ha)
	Sh05	Sn06	Sh05	Sh05	Sn06	Sh05	Sn06	
SG(32-2) A	28.7	12.2	4.68	59.0	88.3	176	104	20.4
SG50	24.4	10.6	4.34	66.0	93.0	170	107	17.5
SG18	32.1	-	4.9	61.0	-	168	-	-
Garawi	20.9	12.7	3.16	59.7	83.3	155	108	16.8
Kambal	31.1	12.4	5.04	59.7	83.0	171	109	21.7
S.8	24.4	8.7	4.0	50.0	74.7	142	99	16.6
S.126	26.8	13.2	4.0	59.0	84.0	157	99	20.0
Abu Sab'in	25.4	13.6	4.59	56.3	80.7	177	98	19.5
ANKSSS	26.8	-	4.46	62.0	-	152	-	-
ANK40	27.8	10.2	4.43	54.3	86.0	163	113	19.0
ANK43	28.6	13.3	4.8	58.3	87.3	175	103	21.0
Ankolib	22.2	13.9	3.42	51.0	93.7	128	102	18.0
Mean	26.6*	12.1ns	4.32*	58.4**	85.9**	161**	104ns	19.1*
SE±	1.98	1.16	0.370	0.946	1.489	7.67	4.26	1.00
LSD (0.05)	5.81	-	1.085	2.776	4.425	22.51	-	2.97
CV (%)	14.8	16.5	17.5	2.8	3.0	11.3	7.1	20.0

3.1.2 Quality performance

Table 2 shows mean squares from combined ANOVA for some quality traits of the 10 genotypes evaluated at the two environments. Differences among genotypes were not significant for all quality traits other than NDF (P <0.01). Differences between growth stage were significant for ADF (P <0.05), NDF (P <0.01) and CP (P <0.01). The plant parts differed significantly (P <0.01) in ADF, CP and ASH. The interaction of genotype with each of growth stage, plant part and environment was not significant for most traits. This is also true for higher order interactions. The interaction of growth stage with plant part was significant for all traits other than ADF. The interaction of environment with growth stage and plant part was significant for most quality traits.

Table 3 shows performance of different genotypes for quality traits in each environment and their average performance combined over environments. ANK43 was the best among selected lines in NDF averaging the lowest value (57.8%), yet it was not better than its parental population (the check Ankolib) that showed the lowest NDF value in the whole materials tested (55.9 %). The lines SG(32-2)A and SG50 were better in NDF than their parental population (Garawi) with respective values of 63.5 %, 61.9 % and 65.5 %. The same is true for the lines Kambal (61.5%) and S.8 (63.2 %) which were better in NDF percentage than their parental population Abu Sab'in (66.2%). For crude protein, the line S.8 (Abu Sab'in) gave the highest value for CP (8.97%) among the selected lines. The CP of the other lines ranged from 6.16 % to 8.32 %. With regard to ADF the line SG(32-2)A averaged the lowest value (40.1%) whereas its parental population (Garawi) showed the highest value (48.7%). The EE ranged from 1.53% to 1.93% and Ash from 7.71% to 9.33%.

Table 2. Mean squares from combined ANOVA for acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP), Ash and ether extract (EE) of 10 forage sorghum genotypes grown at two environments (Shambat 2005, Sennar 2006)

Source of variation	d.f.	Mean squares				
		CP	ADF	NDF	ASH	EE
Reps	1	14.799	489.6	107.72	0.439	0.5142
Genotype (G)	9	12.733	96.9	185.37**	3.509	0.2818
Residual	9	7.614	147.8	30.86	3.121	0.8902
Growth Stage (GS)	1	74.311**	540.3*	1383.68**	0.004	0.0117
G x GS	9	5.375	104.3	34.69	1.294	0.3728
Residual	10	4.809	76.8	53.37	2.663	0.3164
Plant Part (PP)	1	179.776**	1424.7**	17.97	723.931**	1.8512
G x PP	9	0.796	90.5	71.04	6.187**	0.1602
GS x PP	1	106.733**	39.6	696.06**	7.167*	3.6512*
G x GS x PP	9	2.983	137.2	64.83	5.718**	0.2735
Residual	20	4.733	92.9	45.93	1.522	0.4669
Environment (e)	1	0.055	1546.7**	47.81	50.846**	25.2413**
G x E	9	10.197	163.6	40.38	6.917**	0.5348
GS x E	1	0.548	1050.8**	440.63**	14.159*	0.8454
PP x E	1	67.392**	1652.8**	1.81	9.573*	0.0061
G x GS x E	9	5.665	55.6	29.29	3.552	0.2180
G x PP x E	9	11.243	49.3	40.29	3.077	0.3573
GS x PP x E	1	133.590**	372.0	650.93**	97.755**	2.9079*
G x GS x PP x E	9	3.502	178.7	45.58	2.577	0.5809
Residual	40	6.707	109.8	43.00	2.220	0.4562

**, **: Significant at 0.05 and 0.01 probability levels, respectively*

Table 4 shows the effect of plant part and growth stage on quality attributes based on data combined over the two environments. Protein content at boot stage was significantly ($P < 0.01$) higher than that obtained at dough stage. The NDF and ADF percentages were significantly lower at boot stage than at dough stage. The percentages of crude protein and ASH in the leaf were significantly ($P < 0.01$) higher than those in the stem. ADF percentage in the leaf was significantly lower than that in the stem.

The performance of the newly developed genotypes (as one group) in contrast to their parental population is shown in Table 5. The two groups differed significantly ($p < 0.05$) in forage yield but not in quality attributes. The selected lines outyielded their parent populations.

Table 3. Crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), ether extract (EE) and Ash obtained by forage sorghum genotypes grown in Shambat 2005 (Sh05), Sennar 2006 (Sn06) and their combined performance (Cmb) over the two environments

Genotype	CP			NDF			ADF			EE			Ash		
	Sh05	Sn06	Cmb	Sh05	Sn06	Cmb	Sh05	Sn06	Cmb	Sh05	Sn06	Cmb	Sh05	Sn06	Cmb
SG(32-2)A	5.95	6.75	6.35	64.6	62.4	63.5	39.3	40.9	40.1	1.39	1.91	1.65	9.17	7.39	8.28
SG 50	6.63	8.09	7.36	59.9	63.6	61.9	49.0	38.0	43.5	1.21	2.13	1.67	9.19	6.77	7.98
SG 18	7.40	-	-	63.1	-	-	54.1	-	-	1.25	-	-	8.72	-	-
Garawi †	9.28	6.69	7.99	62.9	68.1	65.5	54.1	43.4	48.7	1.31	2.55	1.93	8.87	8.25	8.58
Kambal	5.68	6.64	6.16	61.5	61.5	61.5	42.3	44.7	43.5	1.04	2.08	1.56	9.19	6.95	8.07
S.8	8.35	9.60	8.97	62.0	64.5	63.2	50.6	34.3	42.5	1.41	2.04	1.73	8.30	7.12	7.71
S.126	8.56	8.13	8.32	65.7	66.1	65.9	46.9	44.7	45.8	1.34	1.89	1.61	8.98	7.50	8.24
AbuSab'in †	7.65	8.99	8.32	67.3	65.2	66.2	48.2	44.7	46.5	1.45	1.78	1.61	8.67	6.77	7.72
ANKSSS	7.04	-	-	62.6	-	-	44.6	-	-	1.30	-	-	8..32	-	-
ANK40	8.22	6.32	7.27	63.2	59.1	61.1	43.2	42.2	42.7	1.28	1.79	1.53	9.15	7.51	8.41
ANK43	6.60	7.95	7.27	56.2	59.3	57.8	51.3	40.5	45.9	1.16	2.64	1.90	8.45	10.2	9.33
Ankolib †	8.10	6.21	7.15	53.7	58.1	55.9	48.7	38.3	43.4	1.31	2.05	1.68	8.10	8.51	8.30
Mean	7.45	7.54	7.52	61.9	62.8	62.2	47.7	41.2	44.3	1.29	2.08	1.69	8.76	7.7	8.26
S.E±	0.90	0.79	0.69	2.51	2.15	1.39	4.64	3.14	3.04	0.285	0.274	0.236	0.575	0.718	0.442

† = parent population (check)

Table 4. Effect of plant part and growth stage on some quality attributes of forage sorghum based on data combined over two environments (Shambat 2005, Sennar 2006)

Quality attributes[†]	CP	NDF	ADF	EE	Ash
Plant part	....	**P e r c e n t a g e s**	....		
leaf	8.58	61.89	41.28	1.794	10.39
stem	6.46	62.56	47.25	1.579	6.14
S.E±	0.243	0.758	1.078	0.0764	0.138
Growth Stage					
Boot	8.20	59.28	42.4	1.695	8.26
Dough	6.84	65.17	46.1	1.678	8.27
S.E±	0.245	0.817	0.980	0.0629	0.182

[†] : CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber, EE = ether extract

Table 5. Performance of selected forage sorghum genotypes in contrast to their parental population for yield and some quality traits based on data combined over two environments (Shambat 2005, Sennar 2006)

Group	Green matter yield (t/ha)	Quality attributes[†] (percentages)				
		CP	NDF	ADF	EE	Ash
Selected genotypes	19.8	7.36	62.25	43.75	1.665	8.24
Parent Population	18.1	7.82	62.53	46.22	1.740	8.19
SE±	0.42	0.221	0.627	0.936	0.0528	0.161

[†]: CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber, EE = ether extract

Table 6 shows the associations between quality traits and forage yield based on data averaged over the two environments. Negative significant (P <0.01) correlations were detected between GMY with each of CP (r = -0.346) and EE (r = -0.382). Correlation between GMY and ADF was positive and significant (P <0.01) with r = 0.283. Positive non-significant correlations were detected between GMY with each of NDF (r = 0.132) and ASH (r = 0.019). On the other hand CP showed negative significant (p <0.01) correlation with NDF (r = -0.296) and negative but insignificant correlation with each of ADF, EE and ASH. Significant positive correlations were detected between EE with each of NDF (r = 0.267) and ASH (r = 0.192).

Table 6. Correlation among some quality traits and forage yield in sorghum

Characters[†]	GMY	CP	NDF	ADF	EE
CP	-0.346**				
NDF	0.132ns	-0.296**			
ADF	0.283**	-0.156 ns	0.152 ns		
EE	-0.382**	-0.020 ns	0.267**	-0.156 ns	
ASH	0.019ns	-0.013 ns	0.128 ns	-0.072 ns	0.192*

[†] : GMY = green matter yield, CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber, EE = ether extract

3.2 Discussions

The cultivar Kambal ranked first in GMY. Kambal is the recommended Abu Sab'in released in 2004 [5]. The genotype SG32-2A significantly outyielded its parental populations (Garawi). This line has also been officially released under the name Sudan-1 in 2009 [1]. Both cultivars ranked top in forage yield in Shambat (Khartoum State), however they were not leading in Sennar. Such results are not unexpected since Kambal and Sudan-1 have been specifically developed to suit production conditions of Khartoum State [5,1].

The study revealed that protein content at boot stage was significantly higher than that of the dough stage. These results substantiate the previous findings that crude protein in early growth phases is higher than that in the late ones [6,7]. Percentages of NDF and ADF were significantly lower at boot stage than at dough stage. Similar results in forage sorghum, maize and millets were reported [7] where the levels of NDF and ADF increased with the advancing age. These results indicated that quality attributes (protein content, digestibility and intake potential) were enhanced at boot than dough stage suggesting that benefits from forage sorghum could be maximized by harvesting at boot stage. However, the traditional system for forage production in the Sudan favors high yields at the expense of high feeding value. A very common practice adopted by forage sorghum growers is to delay cutting until grain formation. The grains being produced were eaten by sparrows and the farmer usually ends up with a straw of a lowered feeding value.

As shown by this study crude protein and Ash percentages in the leaf were significantly higher than those in the stem. Similar results (specially for Ash) have been reported [8]. ADF percentages in leaves were significantly lower than those in the stem whereas NDF levels were comparable in both plant parts. Such results call for developing forage sorghum cultivars with high leaf to stem ratio. However, some of these results disagree with some workers [8] who reported that leaf had significantly higher ADF and NDF levels than stalk.

The adverse association between forage yield and crude protein shown in this study consolidate the previous findings [9,10]. On the other hand correlation between forage yield and each of ADF and NDF was positive. Similar results have been reported [10]. The ADF measures digestibility. The lower the ADF value the better the digestibility and energy value of the fodder. NDF predicts intake potential; the higher the NDF, the lower the intake [11]. Such results suggest that high yielding cultivars with improved protein content, intake and digestibility are difficult to attain. However, apart from forage yield, the negative association shown in this study between crude protein and each of NDF and ADF was in favor of developing cultivars improved in protein content, intake potential and digestibility. Favorable association between crude protein and ADF have been reported [10,9].

The forage yield of the selected lines has been generally improved over their parental population, however; the newly developed lines showed no improvement over parental populations with regard to quality attributes specially for protein content. This could be attributed to the adverse association between forage yield and CP. The probability for breaking this unfavorable association is greater if simultaneous screening for yield and quality attributes is carried in the earlier stages of the breeding program. Although this will be more expensive, yet it is the only way to achieve tangible improvement in forage quality.

4. CONCLUSION

Assessment of the effect of growth stage and plant part on quality traits in forage sorghum indicated that harvesting at boot stage will maximize the benefits gained from forage sorghum. Quality traits might be enhanced by developing cultivars with high leaf to stem ratio. The correlation study revealed that cultivars improved in protein content, intake potential and digestibility could be developed but parallel improvement of these aspects with forage yield might be difficult to achieve. To break this adverse association, concurrent screening for quality and yield attributes in earlier stages of the breeding program has been suggested.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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