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Evaluation of Sweet Sorghum Bagasse as an Alternative Feed Resource for Livestock in Semi Arid Regions

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Abstract

Production of good quality fodder is of a great importance for the economical livestock. The objective of this proposal is to evaluate the potential of sweet sorghum bagasse as an alternative feed resource for livestock. The research was conducted at Akcakale/Sanlıurfa from June to November in 2016 and 2017 according to randomized complete block design with four replications. Harvest was performed between milk and soft dough stages. After the leaves and panicle of the plant were stripped, sap-extracted plants (bagasse) were ensiled and silage quality attributes were also determined. There were statistically significant differences in sweet sorghum genotypes in terms of bagasse yield and all examined feed quality characteristics. Depending on two-year averages; bagasse yield, dry matter (DM) yield, crude protein (CP) ratio, acid detergent ligin (ADL), neutral and detergent fiber (NDF), and acid detergent fiber (ADF) were ranged from 51.9-86.7 t ha-1, 12.1-21.7 t ha-1, 35.39-45.61 g kg DM, 40.58-78.88 g kg DM, 473.0-653.0 g kg DM, and 273.3-431.6 respectively.It is concluded that the silages of sweet sorghum bagasse which were grown the 2nd production conditions in semiarid region can be considered as roughage.

Keywords: Bagasse yield, dry matter, quality, silage, sweet sorghum

INTRODUCTION

The origin of the sweet sorghum (*Sorghum bicolor* var. *saccharatum* L.) is the continent of North and East Africa. As it is a plant tolerant to marginal areas and extreme climatic conditions, the sweet sorghum plant can be grown easily in different regions and climates of the world (Smith et al., 1987). Sweet sorghum plant can be grown with much less fertilizer and irrigation than corn and sugar cane and sugar beet and found to be more tolerant than these plants (Grassi, 2000). It is also cultivated to extract sweet sap from stalks (Geren et al., 2019). The bagasse remaining after extraction is used in silage and dry forms for animal feeding ((Jafarinia et al., 2005; Kucuksemerci and Baytekin, 2017). Kumari et al. (2013), sweet sorghum bagasse, which is an agricultural byproduct, may constitute a good source of silage without any additives and reliably be used in animal diets. Silage maize has an important production in animal feed in the GAP region, but being more tolerant to heat and water stress sweet sorghum proved a better source for silage than corn. It has been reported that animal health will be protected if sweet sorghum varieties are used as dry grass or silage (Langer and Hill, 1982). The potential use of sweet sorghum as a feed source for ruminants in Turkey is quite limited. Thus, information about potential uses of sweet sorghum plants is not available. This study was conducted to determine the forage quality of 21 sorghum genotypes grown under the ecological conditions of the Southeastern semi arid ecological conditioin of Turkey. İn addition bagasse yield, sap-extracted plants (bagasse) were ensiled and silage quality attributes were also determined in this study.

MATERIAL and METHODS

Experimental materials

Twenty-one sweet sorghum genotypes which obtain from national and international sources was used in the study. The names and source of the genotypes tested in this study were as follows: 1) Corino, Cowley, Grassi, M81-E, N98, Nebraska sugarcane, PI579753, Ramada, Rio, Roma, Smith, Theis, Topper 76, Tracy, UNL-Hybrid - 3 ((26297xM81 E), Williams, Wray; 2) no91 (USDA-Taiwan), no5 (USDA South Africa), no41 (USDA); 3) Local check Gülseker were supplied by UNL (University of Nebraska, Lincoln, USA) and Western Mediterranean Agricultural Research Institute-Antalya/Turkey (supplied from ICRISAT and USDA gene bank) and University of Uludag, Bursa, Turkey), respectively.

Soil and climate characteristics of the experimental site

Soil samples were taken for analysis at the depth of 0-15 and 15-30 cm from the area during 2016 and 2017. The parameters i.e. pH, total salt (EC), Nitrogen (N), organic carbon (OC), phosphorus (P), lime content ($CaCO_3$), sand, silt and clay were ranged from 7.65-7.74, 0.30-0.37%, 0.05-0.08%, 0.34-0.50%, 0.39-0.50 mg kg^{-1}, 44.5-47.0%, 28-30%, 26-27%, 44-45% respectively. During the months of June and July the the temperature was reached above 40 ºC and prominant difference in day and night temperatues was observed. The research was carried out in Akcakele/Sanlıurfa (36° 90′ 23 N″, 389° 20′ 92″E) which is situated approximately at 500 m above sea level under second crop conditions (from June to November) during 2016 and 2017 in randomized complete block design (RCBD) with four replications.

The experiment area was made ready for sowing in the last week of June after the wheat harvest. Nitrogen, in the form of ammonium nitrate (33% N), was applied at the rate of 50 kg N/ha, four weeks after sowing, while, nitrogen and phosphorous was added once with seed bed preparation at the rate of. 50 kg ha^{-1} N and 50 kg ha^{-1} P_2O_5 in the form of mixed fertilizer (20.20.0 % N, P_2O_5). The dimension of the experimental unit was 5 m × 2.80 m. Each was consisted of 4 rows with 5 m in length and 0.7 m of row spacing. Plant population of trial was about 95000 plants ha^{-1}. Trial's plots were irrigated 7 times (about 650 mm) during the growing season. Stalks were harvested for juice extraction when the grains reached to milk/dough stage.The plants were harvested between 15 October and 15 November according to the milk-paste period of genotype seeds and fresh yield per plot was determined. A representative sub sample of approximately 1 kg from each plot was dried at 60 °C until constant weight was reached to determine the dry matter (DM) concentration per plot. Stalks were squeezed by squeezing machine and the and the bagasse collected was converted to bagasse yield (BY) t ha^{-1}. For quality analysis, a bagasse sample of 500 g was chopped into pieces of 4-5 cm length with chopper. Then it was placed in specially prepared 1 kg vacuum bags. Vacuumed silage material was labeled and stored in room conditions. The silage material was left for 60 days for silage quality analysis. After 60 days, all of the silage samples were dried in the drying oven until their weight stabilized at 65 °C, then they were weighed and were calculated dry matter rates (%) and dry matter yields (DMY, t ha^{-1}). All dried silage samples were puverized in a plant mill with a 1-2 mm sieve. Kjeldahl method was used to determine the nitrogen (N) content of the samples. The Crude Protein ratio is determined by the given below formula (AOAC, 1990). Crude protein (%) = N x 6.25 (1). The content of neutral detergent fiber (NDF) % and acid detergent fiber (ADF)% were determined by ANKOM fiber analyzer (Fiber analyzer) (Van Soest et al., 1991). Crude protein (CP) ratio (Equations 1), neutral detergent fiber (NDF) acid detergent fiber (ADF), and acid detergent lignin (ADL) values determined were proportioned to dry matter and the results were converted to g/kg DM. Data obtained were subjected to analysis of variance through the JMP statistics software. Combined variance analysis was applied for years. The comparison of the genotype means was made using the TUKEY test at 5% level.

RESULTS and DISCUSSION

Bagasse yield

The difference between genotypes and genotype × year interaction were found statistically significant (P<0.01) for bagasse yield while the differences between years were found statistically none significant. Bagasse yields ranged from 51.1 t ha^{-1} (Wray) to 86.7 t ha^{-1} (Thesis) in the genotype × year interaction table (Table 1). As the average of two years, bagasse yield of the genotypes varied between 51.9-84.8 t ha^{-1} The varied BY of genotypes may be due to their different genetic structures. It was determined that BY results obtained from the research were far below the results of Yucel et al. (2017) (32.9–133.9 t ha^{-1}) and above results of Khalil et al. (2015) (38.0-58.0 t ha^{-1}). Negro et al. (1999) (50-60 t ha^{-1}). It was determined that different irrigation water levels affect the bagasse yield and the yield varied between 68.9 and 50.5 t ha^{-1} in Cukurova condition (Dundar et al., 2020).

Table 1. Mean of levels of bagasse yield and dry matter yield in the silage of twenty-one sweet sorghum genotypes

Genotypes	Bagasse Yield (t ha^{-1})			Dry Matter Yield (t ha^{-1})		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**
Corina	61.8 f-n[1]	60.6 f-n	61.2c-f*	15.9 f-o	13.5 j-p	14.7 f-ı*
Cowley	59.8 f-n	62.9 f-n	61.3 c-f	18.6 d-j	16.8 f-l	17.7 c-g
Grassi	59.9 f-n	57.4 ı-n	58.7 def	17.3 f-k	11.6 m-p	14.4 ghı
M81-E	74.8 a-f	64.4 f-n	69.6 bc	20.7 b-f	13.8 j-p	17.3 c-g
N98	52.3 mn	66.8 e-m	59.5 def	15.4 g-p	14.7 h-p	15.0 f-ı
N.Sugarcane	55.1 ı-n	67.6 d-l	61.3 c-f	16.9 f-l	15.9 f-o	16.4 d-h
Pı579753	73.2 a-h	56.2 ı-n	64.7 bcd	26.2 a	14.9 g-p	20.5 abc
Ramada	68.8 b-k	74.2 a-g	71.5 b	20.0 b-g	16.0 f-o	18.0 b-f
Rio	63.8 f-n	67.9 c-k	65.9 bcd	22.8 a-d	19.5 c-ı	21.1 ab
Roma	65.2 f-n	63.9 f-n	64.5 bcd	19.7 b-h	14.3 ı-p	17.0 d-g
Smith	81.2 a-e	82.9 abc	82.1 a	**26.9 a**	16.5 f-n	**21.7 a**
Theis	82.3 a-d	**86.7 a**	84.5 a	22.6 a-e	16.7 f-m	19.6 a-d
Topper 76	69.5 b-j	60.7 f-n	65.1 bcd	20.8 b-f	11.9 l-p	16.4 d-h
Tracy	58.4 h-n	62.7 f-n	60.5 c-f	17.2 f-l	12.4 k-p	14.8 f-ı
UNL-hyb-3	83.4 ab	86.2 a	**84.8 a**	24.9 ab	17.5 e-k	21.2 ab
Williams	50.1 n	56.0 ı-n	53.1 ef	12.7 k-p	11.6 m-p	**12.1 ı**
Wray	52.6 lmn	**51.1 n**	**51.9 f**	15.7 f-p	11.1 op	13.4 hı
No91	70.1 b-ı	54.4 j-n	62.3 b-e	20.7 b-f	11.3 nop	16.0 e-h
No5	67.4 d-m	53.9 k-n	60.7 c-f	18.2 d-j	11.3 nop	14.7 f-ı
No41	72.7 a-h	55.4 ı-n	64.0 bcd	24.6abc	13.7 j-p	19.2 a-e
Gulseker	54.3 j-n	59.3 g-n	56.8 def	14.4 ı-p	**10.5 p**	12.4 ı
Mean	**65.6**	**64.3**		**19.6** $^{A+}$	**14.1** ^{B}	
CV (%)	**8.27**			**10.97**		
F Genotype (G)	**			**		
F Year (Y)	**N.S**			**		
F G x Y int.	**			**		

*)The means indicated with the same letter in the same column are not significantly different according to the Tukey test at P≤0.05,
+) The means indicated with the same capital letter in the same row are not significantly different at P≤0.05
1) The means of different year-genotype combinations with the same lower case letters are not significantly different according to the Tukey test at P≤0.05

Dry matter yield

The difference between genotypes, year and genotype × year interaction were found statistically significant for silage of dry matter yield (P<0.01*)*. Dry matter yields ranged between 10.5 t ha^{-1} (Gülşeker) and 26.9 t ha^{-1} (Smith) in the genotype × year interaction table (Table 1). While DMY results obtained from the research taken values below results of Yucel et al. (2017) (7.810–42.620 t ha^{-1}). It was reported that the dry matter yield of sorghum varies between 1.6-2.3 t da^{-1}, although it varies according to the varieties (Mamood et al., 2013). It was seen that the varieties with high Bagasse yields also have high DM yields. Significant positive correlations were reported between herbage yield and dry matter yield (Iyanar et al., 2010). It was determined that the average DM yield of silage (19.6 t ha^{-1}) in the first year of the study was higher than the second year (14.1 kg ha^{-1}).

Table 2. Mean levels of crude Protein and Acid Detergent Lignin in the silage of twenty-one sweet sorghum genotypes

Genotypes	Crude Protein (g kg^{-1} DM)			Acid Detergent Lignin (g kg^{-1} DM)		
	2016	2017	Mean	2016	2017	Mean
Corina*	29.50	50.90	40.20	59.37 c-g1	42.05 e-g	50.70 cd*
Cowley	32.30	47.65	39.98	74.21 a-f	57.93 c-g	66.07 abc
Grassi	31.90	50.53	41.21	67.05 a-g	43.46 e-g	55.26 a-d
M81-E	26.68	46.78	36.73	69.39 a-g	49.67 d-g	59.53 a-d
N98*	33.95	48.18	41.06	47.34 d-g	54.52 d-g	50.93 cd
N. Sugarcane	37.75	43.68	40.71	92.96 abc	48.98 d-g	70.97 abc
P1579753	26.53	45.45	35.99	84.51 a-d	44.94 e-g	64.72 abc
Ramada	35.65	48.98	42.31	38.94 f-g	67.05 a-g	53.00 bcd
Rio*	30.58	48.78	39.68	59.98 c-g	54.31 d-g	57.14 a-d
Roma	41.98	49.25	**45.61**	69.17 a-g	**33.90 g**	51.53 cd
Smith	31.78	49.33	40.55	72.92 a-f	52.48 d-g	62.70 a-d
Theis	**25.23**	45.93	35.58	59.94 c-g	45.24 e-g	52.58 cd
Topper 76	30.23	45.38	37.80	40.84 f-g	40.33 f-g	**40.58 d**
Tracy	31.08	44.30	37.69	62.05 b-g	37.80 f-g	49.92 cd
UNL-hyb-3	32.53	48.45	40.49	68.80 a-g	41.68 f-g	52.24 a-d
Williams	35.98	45.95	40.96	58.65 c-g	67.13 a-g	62.89 a-d
Wray*	30.05	**50.75**	40.40	66.30 a-g	53.45 d-g	59.87 a-d
No91	25.68	45.10	**35.39**	79.48 a-e	56.67 c-g	68.07 abc
No5	28.23	50.58	39.40	65.76 a-g	38.27 f-g	52.02 cd
No41	38.18	45.63	41.90	97.99 ab	56.22 c-g	77.10 ab
Gulseker	29.23	50.00	39.61	**101.13 a**	56.63 c-g	**78.88 a**
Mean	**31.66 B[1]**	**47.69 A**		**68.42 A[+]**	**49.65 B**	
CV (%)	**14.61**			**22.39**		
F Genotype (G)	**N.S**			**		
F Year (Y)	**			**		
F GxY int.	**N.S**			**		

*)The means indicated with the same letter in the same column are not significantly different according to the Tukey test at P≤0.05,
+) The means indicated with the same capital letter in the same row are not significantly different at P≤0.05
[1)] The means of different year-genotype combinations with the same lower case letters are not significantly different according to the Tukey test at P≤0.05

Crude protein

The difference between year were found statistically significant for crude protein (P<0.01). Crude protein ranged from 25.23 g kg^{-1} DM (Theis) to 50.90 g kg^{-1} (Corina) (Table 2). It has been reported that different CP ratios obtained by different researchers came from different environments, variety characteristics, and nitrogen applications (Araújo et al., 2007). Araújo et al. (2007) reported that the protein ratios in sweet sorghum genotypes ranged between 4.09% and 8.02% in harvest at different maturation stages. In previous studies, CP ratios of sweet sorghum bagasse were reported as between 2.59-7.26 (Mosali et al., 2010; Kumari et al., 2013; Naeini et al., 2014; Yucel et al., 2017). Dundar et al. (2020) reported crude protein ratios of sweet sorghum bagasse as between 2.71-3.95%, as between 6.6-11.0% (Mohammed and Mohammed, 2009) Aguiar et al. (2006) reported crude protein ratios of sorghum above-ground biomass as between 4.2-13.3%. Our findings were in the renge of values given in the mentioned reports.

Acid detergent lignin

The difference between genotypes, year and genotype × year interaction were found statistically significant for ADL ($P<0.01$). ADL ranged between 33.90 g kg^{-1} KM (Roma) and 101.13 g kg^{-1} KM (Gülşeker) in the genotype × year interaction table (Table 2). Topper 76 genotype with the lowest ADL value was found to have the best value in terms of digestibility. In addition, according to present findings, there was an inverse proportion between the crude protein ratio and ADL values. It was provided that ADL results obtained from the study were above the results of Yucel et al. (2017) It was reported that lignin content varied depending on plant maturation and weather conditions (Ayaz et al., 2013). Yucel et al. (2017) and Dundar et al. (2020) reported that ADL rates range between 3.83-7.74% and 6.89-9.36%, respectively. ADL values of the study in the second year were found to be low in parallel with the DM yields, thus to greater ripening of the plants and increased cell membrane substances

Neutral detergent fiber

The difference between genotypes, year and genotype × year interaction were found statistically significant for NDF ($P<0.01$). While the highest NDF value of the study was obtained from Rio genotype with 694.1 g kg^{-1} DM, the lowest value was obtained from Ramada genotype with 391.9 g kg^{-1} KM (Table 3). Average of NDF contents in the research were found to be below 60%. Goncalves et al. (2010) and Costa et al. (2016) reported that NDF ratios above 60% had an adverse effect on animal feed quality. NDF values varied in different ecologies and varieties. It was reported that the NDF rate varies between 41.62-75.4% (Kumari et al., 2013; Neto et al., 2017; Yucel et al., 2017). According to the findings of Vidya et al. (2016), The NDF content of the leafy squeezed sweet sorghum pulp silage was 71.81%, both this result was above our finding and above the acceptable limits in terms of feed quality. Naeini et al. (2014) reported the NDF values of the green materials of maize, sorghum and sorghum bagasse respectively as 526.447 and 491 g per 1 kg of DM. It was reported that sorghum and sorghum bagasse without any additives had lower NDF and ADF values than maize (Naeini et al., 2014).

Acid detergent fiber

The difference between genotypes, year and genotype × year interaction were found statistically significant for ADF ($P<0.01$). ADF ranged from 244.6 g kg^{-1} DM (Thesis) to 455.4 g kg^{-1} KM (Batem-7) in the genotype × year interaction table (Table 3). ADF contents in the study were found to be below 40%. Earlier reports were stated that the ADF value of around 30% will increase feed consumption but feeds with high ADF content are difficult to digest and ideal ADF values should not exceed 40% (Van Soest, 1994; Gonçalves et al., 2010). In previous studies conducted with different genotypes under different ecologies, ADF content were reported as between 29.91 and 43.94 (Naeini et al., 2014; Yücel et al., 2017; 2019; Dundar et al., 2020); between 258 and 39.2% (Mosali et al., 2010).

Table 3. Mean levels of neutral detergent fiber and acid detergent fiber in the silage of twenty-one sweet sorghum genotypes

Genotypes	Neutral Detergent Fiber (g kg^{-1} DM)			Acid Detergent Fiber (g kg^{-1} DM)		
	2016	2017	Mean	2016	2017	Mean
Corina	475.7 c-g	568.1a-g	521.9bc*	319.5 c-l	348.4 a-l	334.0 c-f
Cowley	625.5 a-d	626.0a-d	625.7 ab	436.1 abc	396.1a-h	416.1 ab
Grassi	465.7 c-g	605.0a-d	535.4abc	275.6 ı-l	351.2 a-l	313.4 c-f
M81-E	462.1 c-g	590.6 a-e	526.4 bc	328.8 b-l	345.9 a-l	337.3 c-f
N98	409.1 efg	672.7 ab	540.9abc	253.3 kl	368.5a-k	310.9 def
N. Sugarcane	629.1 a-d	532.8a-g	580.9abc	443.6 ab	315.3 d-l	379.5 a-d
P1579753	629.0 a-d	556.1a-g	592.5abc	412.4 a-f	345.9 a-l	379.1 a-e
Ramada	**391.9 g**	575.8a-g	483.8 c	268.3 jkl	347.5 a-l	307.9 def
Rio	538.4 a-g	**694.1 a**	616.3 ab	325.5 c-l	367.0a-k	346.3 b-f
Roma	514.4 a-g	518.5a-g	516.4 bc	291.0 g-l	255.7 k-l	**273.3 f**
Smith	558.3 a-g	592.0 a-e	575.1abc	355.5 a-l	354.9 a-l	355.2 b-e
Theis	400.6 fg	637.5abc	519.1 bc	**244.6 l**	378.4 a-j	311.5 def
Topper 76	444.3 d-g	510.1a-g	477.2 c	256.3 kl	296.9 f-l	276.6 f
Tracy	414.5 efg	531.5a-g	**473.0 c**	306.7 e-l	315.7 d-l	311.2 def
UNL-hyb-3	448.5 c-g	525.7a-g	487.1 c	290.7 h-l	317.7 d-l	304.2 ef
Williams	496.3 b-g	670.2ab	583.3abc	352.7 a-l	424.1a-d	388.4 abc
Wray	540.8 a-g	604.8a-d	572.8abc	334.1 b-l	386.3 a-ı	360.2 a-e
No91	506.0 a-g	583.8a-f	544.9abc	312.3 d-l	377.7 a-j	345.0 b-f
No5	477.9 c-g	530.9a-g	504.4 bc	305.2 e-l	329.9 b-l	317.5 c-f
No41	680.9 ab	625.0a-d	**653.0 a**	**455.4 a**	407.8a-g	**431.6 a**
Gulseker	605.7 a-d	583.4a-f	594.5abc	418.2 a-e	358.4 a-l	388.3 abc
Mean	**510.2 B+**	**587.4 A**		**332.7 B[1]**	**351.9 A**	
CV (%)	**12.16**			**12.04**		
F Genotype (G)	**			**		
F Year (Y)	**			**		
F GxY int.	**			**		

*)The means indicated with the same letter in the same column are not significantly different according to the Tukey test at P ≤0.05, +) The means indicated with the same capital letter in the same row are not significantly different at P≤0.05
[1)] The means of different year-genotype combinations with the same lower case letters are not significantly different according to the Tukey test at P≤0.05

CONCLUSION

The UNL-hybrid-3, Thesis and Smith genotypes can be recommended for bagasse yield, dry matter yield and some silage quality characteristics in the semi-arid region. Due to the low input costs of sweet sorghum plants and its tolerance to extreme weather conditions, it may be more economical than corn silage. Mediterranean climate has hot and dry summers. Cool-season Gramineae species are dominant over the pastures of Mediterranean region and thus they usually get into dormant state in summers and have quite low yield and quality in this season. Therefore, alternative feed crops should be grown in this season. In this case, summer C4 plants with high unit-area yields like sorghum can be grown to meet quality roughage needs of livestock under Mediterranean conditions (Yucel et al., 2020). It was reported that sorghum and sorghum bagasse without any additives had lower NDF and ADF values than maize (Naeini et al., 2014). Thus, sorghum can replace maize for silage and become an alternative feed source in the same ecological conditions.

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