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RESEARCH ARTICLE

Bagasse Yield and Quality Traits of Silage Made From Juice-Extracted Sweet Sorghum (*Sorghum bicolor* var. *saccharatum* (L.) Mohlenbr.) Stalks

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ABSTRACT

This study was conducted to investigate possible use of juice-extracted sweet sorghum stalks (bagasse) as a quality roughage source through silage making. A total of 21 different sweet sorghum (*Sorghum bicolor* var. *saccharatum* (L.) Mohlenbr.) genotypes supplied from different sources were used as the primary material of the study. Field experiments were conducted in a randomized blocks design with 4 replications on the experimental fields of Eastern Mediterranean Agricultural Research Institute under 2nd crop conditions during the growing seasons of 2016 and 2017 years. Plants were harvested for bioethanol production at milk-dough stage of panicle grains. Plant leaves and panicles were stripped and remaining stalks were extracted through squeezing. Juice-extracted stalks (bagasse) were ensilaged for 60 days and quality traits were analyzed at the end of silage period. As the average of two years, bagasse yields varied between 42.6-113.9 t ha^{-1}, silage DM yields varied between 11.6-40.0 t ha^{-1}. In addition, crude protein (CP) content, acid detergent lignin (ADL), neutral detergent fiber (NDF) and acid detergent fiber (ADF) values varied between 29.79 - 50.84 g/kg DM, between 49.3 - 91.4 g/kg DM, between 525.1-694.8 g/kg DM and between 351.2-486.8 g/kg DM, respectively. It was concluded based on present findings that silages made from juice-extracted stalks of sweet sorghum grown under 2nd crop conditions of Cukurova region could be used as quality roughage source for livestock.

Keywords: Bagasse yield; Genotype; Silage quality; Sweet sorghum

INTRODUCTION

Effects of climate change and global warming have distinctive effects on many sectors and it is assumed that the possible effects of climate changes on agriculture will gradually increase. Together with increasing human population, arable lands are continuously decreasing, thus spreading of new plant species and varieties to be produced in marginal conditions has become necessary to meet the nutritional needs of the increasing human population. In this sense, it is important to know the potential of remaining stalks or agricultural residues of some biomass plants after being used for energy purposes as roughage. Periyasamy et al. (2022) reported that approximately 998 million tons of agricultural waste was generated annually by agricultural practices and therefore, converting lignocellulosic waste into energy, chemicals and the other products was an important goal for the future circular economy. As in the world, it is necessary to reveal the potential of using industrial or agricultural residues for different purposes in Turkey. It was reported that sweet sorghum bagasse could be used as cellulose raw material for energy purposes (Belayachi and Delmas, 1995), cellulosic ethanol production (Jacques et al., 1999; Sipos et al., 2009) and as a source of energy in pellets (Dok et al., 2021a, 20021b) and ethanol production from the bagasse.

In many countries, as in Turkey, the search for alternative roughage sources continues in recent years, especially to overcome the quality roughage deficits. Higher protein content of sorghum bagasse than sugar cane makes it more suitable as animal feed (Eggleston et al., 2013). Whitfield et al. (2012) reported that the sugars present in the bagasse after pressing the biomass should be sufficient to allow the ensiling process and indicated that the bagasse remaining after the extraction of juice from pearl millet (*Pennisetum*

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glaucum (L.) R.Br) and sweet sorghum biomass will have sufficient sugar to produce good quality silage. Bernardes et al. (2016) indicated that the bagasse left after removing the juice from its biomass for ethanol production could be preserved as silage and used in animal feedstock, but the nutritional and protective properties of bagasse silage from sweet sorghum (*Sorghum bicolor* (L.) Moench) are not well known. It was reported that sweet sorghum bagasse could be used as a roughage by ensilage (Yucel, 2020) and used in animal feeding (Jafarinia et al., 2005). Additionally, the bagasse could also be pelletized and used in animal feeding. Pelleting is known to be an effective technical method for improving feed intake, digestibility, feed efficiency and livestock performance (Zhang et al., 2019). Physical processing (mash, pellet, and block) of sorghum stover-based complete rations increased the nutrient utilization and growth performance of sheep compared to conventional chopped form (Raju et al., 2021).

Sweet sorghum (*Sorghum bicolor* var. *saccharatum* (L.) Mohlenbr.) is a C4 plant in the Poaceae family and has a high photosynthetic activity (Dolciotti et al., 1998; Shinde et al., 2013). It is able to survive under arid and harsh climate conditions (Ritter et al., 2007), has a wide adaptation capability. It can grow fast, accumulates high sugar in its stems and has high biomass production capacity in semi-arid tropics (Smith et al., 1987). It has a high water and nitrogen use efficiency as well as highly adapted to high temperature and arid conditions (Reddy et al., 2005; Prasad et al., 2007; Almodares and Hadi, 2009). Sweet sorghum exhibits high mineral absorption and, has a low water requirement (500-600 mm). It is tolerant to saline and alkaline soils (pH 5.0 - 8.5), has a minimum tolerated temperature of 7-10 °C and optimum growth temperature of 27-30 °C (Cocchi, 2008). It has high carbon assimilation ratio (50 g/m^2/day) and high ability to accumulate extractable sugars in the stems (Jingshan et al., 1997).

Southern coastal regions of Turkey, where the Mediterranean climate prevails, have an important ecological potential in terms of total temperature. In these regions, especially after wheat harvest, warm season plants with a short vegetation period have a significant potential as second crop. This study was conducted to reveal the potential use of stalks (bagasse), which were juice-extracted for ethanol production in the industry, of some sweet sorghum genotypes as a source of roughage by making silage.

MATERIALS AND METHODS

Experimental materials

The names and origins of sweet sorghum genotypes tested in the study were given in the Table 1.

Table 1: The names and origins of sweet sorghum genotypes tested in the study

Genotype Name	Origin
Cowley	University of Nebraska, Lincoln, USA
Dale	University of Nebraska, Lincoln, USA
Grass1	University of Nebraska, Lincoln, USA
M81-E	University of Nebraska, Lincoln, USA
Mennonita	University of Nebraska, Lincoln, USA
Nebraska sugarcane	University of Nebraska, Lincoln, USA
P1579753	University of Nebraska, Lincoln, USA
Ramada	University of Nebraska, Lincoln, USA
Roma	University of Nebraska, Lincoln, USA
Rox Orange	University of Nebraska, Lincoln, USA
Smith	University of Nebraska, Lincoln, USA
Sugar Drip	University of Nebraska, Lincoln, USA
Theis	University of Nebraska, Lincoln, USA
Topper 76	University of Nebraska, Lincoln, USA
Tracy	University of Nebraska, Lincoln, USA
UNL-hybrid -3 (26297×M81 E)	University of Nebraska, Lincoln, USA
Williams	University of Nebraska, Lincoln, USA
No2	USDA-China
No91	USDA-Taiwan
No5	USDA- South Africa
Gulseker	Local check Gulseker/Turkey

Soil and climate characteristics of the experimental site

Field experiments were conducted on the experimental fields of Eastern Mediterranean Agricultural Research Institute (36° 51' 35" N and 35° 20' 43" E). Experimental soils are Arıklı series (Dinc et al., 1988). Soil samples taken from 0-15 and 15-30 cm depth revealed that soil pH varied between 7.0-7.50, total salt between 0.22-0.27%, N content between 0.10-0.19%, organic carbon (OC) content between 0.63-0.90%, phosphorus (P) content between 063-0.90 mg kg^{-1}, lime content (CaCO3) between 32.5- 35.0%, sand content between 24-28%, silt content between 41-43 % and clay contents between 30-33%. Soil texture was identified as clay-loam (CL) (Yucel et al., 2018).

In the experimental site, in June – October of the experimental years 2016 and 2017, the average air temperatures were respectively measured as 25.1 °C and 24.8 °C, the average relative humidities as 79.0% and 79.6%, and the total precipitations as 46.2 and 48.2 kg/m^2 (Yucel et al., 2018). Since the precipitations of this period were not sufficient for plant growing, irrigation was practiced as needed.

Method

Field experiments were conducted in randomized blocks design with 4 replications during the second crop growing seasons of 2016 and 2017 years. Sowing was practiced in mid-June, which coincides with the period after the wheat harvest, as a second crop. Before sowing, base fertilizer

was applied as to have 50 kg nitrogen and phosphorus per hectare. Each cultivar was sown manually in 4 rows of 5 m long, with 70 cm row spacing and 15 cm inter-row spacing. After sowing, irrigations were initiated, and the experiment were irrigated as needed during the growing period. When the plants reached 40-50 cm height, 50 kg ha^{-1} pure nitrogen was applied manually between the rows as dressing fertilizer. At harvest, outermost rows from each side of the plot and 0.5 m from the top and bottom of the plots were omitted as to consider side effects. The plants in the net harvest area of each plot were cut by a hand sickle at a cutting height of 5 cm. The fresh material cut in each plot was weighed and plot yield was determined. Then fresh biomass yield per ha was calculated by the necessary transformation of plot yield. While the harvest was completed in October in the first year of the study, due to the continuous rainfall in the second year, the harvest of late varieties was completed in the first week of November.

Following the harvest, 10 plants with panicles were randomly selected from each plot and selected plants were transported to the laboratory (Fig. 1). In the laboratory, stalks, leaves and panicles of each plant were separated. Stalks were squeezed in a specially designed machine to extract the juice and bagasse yield was determined based on juice ratio. About 1000 g squeezed and juice-extracted bagasse samples were taken, leaves/branches were chopped in 4-5 cm long pieces, placed into specially prepared 1 kg vacuum bags and vacuumed in the vacuum device (95% air-removed). Vacuumed silage material was labeled, stored at room conditions and kept for 60 days for silage quality analysis. All of the opened silages were dried at 60 °C until a constant mass to get dry matter (DM) ratios and then to calculate dry matter yields (DY). Dried samples were then ground to pass 1-2 mm sieves and prepared for analysis. (Fig. 1).

The Kjeldahl method was used to determine the nitrogen (N) content of the samples. Crude Protein ratio was determined by the formula of Nx6.25 (AOAC, 1990). The % NDF, ADF and ADL contents of silage samples were determined with the use an ANKOM 200/220 Fibre Analyzer (Ankom Technology Corporation). in accordance with the principles specified in Van Soest et al. (1991).

Experimental data were subjected to a combined variance analysis according to the randomized blocks design (Steel at al., 1997) by using JUMP software. The means related to the statistically significant characteristics were compared with the use of Tukey's test.

RESULTS AND DISCUSSION

Bagasse Yield (t ha^{-1}): Genotype (G), year (Y) and genotype x year interactions had significant effects on bagasse yield (Table 2). While the averaged bagasse yield of all genotypes was 60.9 t/ha in the first year of the study, this value was 88.5 t/ha in the second year. The difference in bagasse yield between the examined years was found to be significant (Table 2). Significance of year x genotype interactions in terms of bagasse yield revealed that years affect bagasse yields differently in different genotypes. Although Grass1, N sugarcane, Ramada, Roma, Smith and Theis genotypes had significantly higher bagasse yields in the second year as compared to the first year, bagasse yields of the other tested genotypes did not show a significant variation with the years (Table 2). As the average of two years, bagasse yields of the genotypes varied between 42.6 -113.9 t/ha and this variation was found to be significant. UNL-hyb-3 genotype had significantly higher bagasse yield than the other cultivars, except for Grass1, Roma, Topper 76 and No91 genotypes. Mennonita genotype had significantly lower bagasse yield than the other genotypes, except for No2, Gulseker, Rox Orange, Sugar Drip, Williams and N Sugarcane genotypes (Table 2).

In previous studies conducted with different sorghum genotypes and under different ecologies, bagasse yields of sweet sorghum genotypes were reported as between 40 - 60 t ha^{-1} (Negro et al., 1999; Korpos et al., 2008; Kumar

Fig 1. Silage making phases of sweet sorghum plants.

Table 2: Bagasse and bagasse dry matter yields of sweet sorghum genotypes

Genotypes	Bagasse Yield (t ha^{-1})			Dry Matter Yield (t ha^{-1})		
	2016	2017	Mean	2016	2017	Mean
Cowley	61.1 g-o+	74.6 d-l	67.9 d-h*	22.0 c-o+	17.4 j-q	19.7 efg*
Dale	67.6 f-n	90.3 a-g	79.0 c-f	20.1 f-p	19.0 h-q	19.5 efg
Grass1	74.1 e-l	112.8 a	93.4 abc	23.1 c-n	29.0 b-ı	26.1 b-e
M81-E	77.8 b-j	88.2 a-h	83.0 b-e	33.1 bc	24.8 b-l	29.0 b-c
Mennonita	29.7 o	55.5 h-o	42.6 j	8.11 q	15.0 k-q	11.6 h
N. Sugarcane	39.0 mno	86.8 a-ı	62.9 e-j	13.4 m-q	25.9 b-k	19.7 efg
P1579753	55.1 ı-o	72.3 e-l	63.7 e-ı	18.5 h-q	21.1 e-p	19.8 efg
Ramada	66.7 f-n	108.5 abc	87.6 bcd	24.4 b-m	31.2 b-e	27.8 bcd
Roma	77.2 c-k	110.3 ab	93.7 abc	30.9 b-f	28.9 b-ı	29.9 b
Rox Orange	44.7 k-o	70.0 f-m	57.4 g-j	12.4 n-q	22.0 c-o	17.2 fgh
Smith	46.5 j-o	112.8 a	79.6 c-f	17.1 j-q	35.4 ab	26.3 b-e
Sugar Drip	53.3 j-o	68.7 f-n	61.0 f-j	20.7 e-p	18.1 ı-q	19.4 efg
Theis	44.1 l-o	107.1 a-d	75.6 c-g	14.8 l-q	28.0 b-j	21.4 d-g
Topper 76	87.6 a-ı	117.2 a	102.4 ab	29.6 b-h	30.2 b-g	29.9 b
Tracy	61.6 g-o	86.3 a-ı	73.9 c-h	19.6 g-p	24.9 b-l	22.3 c-f
UNL-Hyb-3	109.5 abc	118.2 a	113.9 a	44.6 a	35.5 ab	40.0 a
Williams	48.3 j-o	76.9 c-l	62.6 e-j	16.9 j-q	20.9 e-p	18.9 fg
No2	36.3 no	52.4 j-o	44.3 ıj	11.9 opq	16.6 k-q	14.3 gh
No91	97.4 a-f	104.7 a-e	101.0 ab	32.6 bcd	26.2 b-k	29.4 bc
No5	64.0 g-n	74.6 d-l	69.3 d-h	21.7 d-o	17.4 j-q	19.6 efg
Gulseker	38.2 mno	70.1 f-m	54.2 hıj	9.98 pq	18.8 h-q	14.40 g-h
Mean	60.9 B[1]	88.5 A		21.2 B[1]	24.1 A	
CV (%)		15.47			17.37	
F Genotype (G)		**			**	
F Year (Y)		**			**	
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 of different year-genotype combinations with the same lower case letters are not significantly different according to the Tukey test at P≤0.05
[1)]The means indicated with the same capital letter in the same row are not significantly different at P≤0.05

et al., 2010; Khalil et al., 2015). It was reported that bagasse yields varied between 51.9 - 86.7 t ha^{-1} under Sanlıurfa conditions (Tas et al., 2021). It was indicated that different water levels affected bagasse yields in Adana province and yields varied between 68.9 - 50.5 t/ha (Dundar et al., 2020). Present bagasse yields were generally greater than the values reported in previous studies and such higher values were mostly attributed to more favorable conditions of the present research site for sorghum growing and differences in sorghum genotypes.

Dry Matter Yield (t ha^{-1}): Genotypes, years and genotype x year interactions had significant effects on DM yields. The averaged dry matter yield over the genotypes was 21.2 t/ha in the first year and 24.1 t/ha in the second year, and the difference in average dry matter yield of the years was found to be significant (Table 2). As it was in bagasse yields, DM yields were also higher in the second year as compared to the first year. The significant and positive correlations between fresh herbage yield and DM yield (De Almeida et al., 2019) supported this finding.

Significance of year x genotype interactions in terms of dry matter yield revealed that years affect dry matter yield differently in different genotypes. Although N Sugarcane and Theis genotypes had significantly higher dry matter yields in the second year than in the first year, there was no significant variation in dry matter yields of the other genotypes with the years (Table 2).

As the average of two years, dry matter yields of the genotypes varied between 11.6 - 40 t/ha (Table 1). As it was in bagasse yields, UNL-HYb-3 genotype had the highest dry matter yield, while Mennonita genotype had the lowest dry matter yield. However, unlike the bagasse yields, UNL-HYb-3 genotype had significantly higher dry matter yield than all other cultivars tested. This result showed that UNL-Hyb-3 genotype had higher dry matter content than the genotypes with statistically similar bagasse yields. Mennonita genotypes had significantly lower dry matter yield than the other genotypes, except for Rox Orange, No2 and Gulseker genotypes. Lower dry matter yield of Mennonita genotype than N sugarcane, Sugar Drip and Willams genotypes, which had statistically similar bagasse yields, indicated that this genotype had lower dry matter content than the aforementioned genotypes. Although varied with the genotypes, dry matter yields of sorghum genotypes were reported as between 16 - 23 t ha^{-1} (Mamood

et al., 2013). Tas et al. (2021) conducted a study with similar genotypes under GAP conditions and reported DM yields of sorghum genotypes as between 12.1 - 21.7 t ha^{-1}.

Crude Protein (g/kg DM); The factors of year and genotype as well as year x genotype interactions significantly affected the crude protein ratio of silage from the bagasse of sugar sorghum. The average crude protein ratio over the genotypes in the first year was significantly higher than that in the second year. Reason of the higher averaged crude protein ratio in the first year could be due to lower biomass yield in that year compared to that in the second year and negative relationship between biomass yield and crude protein ratio of biomass (Linn and Martin, 1999).

Significant effects of year x genotype interactions on crude protein content indicated that effects of years on crude protein ratio varied with the genotypes. Although the average crude protein content in bagasse silage dry matter of N sugarcane and Rox Orange genotypes were significantly higher in the first year than in the second year, there was no significant variation in crude protein content of bagasse silages of the other genotypes with the years. Feed composition of sweet sorghum varies with the genotype, ripening level and environmental conditions (Serna-Saldivar and Rooney, 2014).

As the average of two years, crude protein concentrations of bagasse silages of the tested genotypes varied between 29.79 - 50.84 g/kg and such a variation was found to be statistically significant (Table 3). Bagasse silage of Ramada genotype had significantly higher protein content than those of the other genotypes, except for Mennonita, Roma, Rox Arnage, Smith and No2 genotypes. Bagasse silage of M81-E genotype had significantly lower crude protein content than those of the other genotypes, except for Theis, and No91 genotypes.

In previous studies, crude protein ratios of juice-extracted sweet sorghum bagasse silages were reported as between 3.9 - 7.26% (Mosali et al., 2010; Kumari et al., 2013; Naeini et al., 2014; Gomes-Rocha et al., 2018). Tas et al. (2021) reported CP ratios of bagasse silages of different sweet sorghum genotypes as between 35.39 - 45.61 g kg DM under Sanlıurfa conditions. Dundar et al. (2020) reported crude protein ratio of silages of sorghum genotypes grown at different water levels as between 2.71-3.95%. Ozkan (2022) determined the two years averaged crude

Table 3: Crude protein and acid detergent lignin contents of silages from bagasse of sweet sorghum genotypes

Genotypes	Crude Protein (g/kg DM)			Acid Detergent Lignin (g/kg DM)		
	2016	2017	Mean	2016	2017	Mean
Cowley	37.28 e-m+	41.55 c-k	39.41 c-f	71.4 a-h+	53.9 d-h	62.6 c-f
Dale	36.57 f-m	43.53 a-k	40.05 cde	41.1 h	57.6 d-h	49.3 f
Grass1	44.17 a-j	38.53 d-l	41.35 cd	53.3 d-h	66.6 c-h	59.9 ef
M81-E	26.94 m	32.63 klm	29.79 g	66.9 c-h	95.8 abc	81.4 a-d
Mennonita	48.81 a-d	39.60 c-l	44.20 a-d	64.1 c-h	47.3 gh	55.7 ef
N. Sugarcane	49.86 abc	36.34 f-m	43.10 bcd	50.7 e-h	60.6 d-h	55.6 ef
P1579753	46.06 a-h	35.57 g-m	40.82 cde	73.1 a-g	57.6 d-h	65.4 c-f
Ramada	46.95 a-f	54.74 a	50.84 a	64.6 c-h	82.4 a-e	73.5 a-e
Roma	45.17 a-ı	53.77 ab	49.47 ab	54.6 d-h	69.1 b-h	61.8 def
Rox Orange	53.98 ab	39.06 c-l	46.52 abc	62.3 d-h	51.9 e-h	57.1 ef
Smith	42.83 b-k	45.45 a-ı	44.14 a-d	62.8 d-h	69.9 b-h	66.4 c-f
Sugar Drip	37.24 e-m	40.66 c-l	38.95 def	50.4 fgh	65.0 c-h	57.7 ef
Theis	30.30 lm	34.93 h-m	32.61 fg	65.8 c-h	98.9 ab	82.4 abc
Topper 76	37.42 e-m	38.54 d-l	37.98 def	47.8 gh	84.2 a-d	66.0 c-f
Tracy	37.84 d-m	40.13 c-l	38.98 def	54.7 d-h	53.8 d-h	54.2 ef
UNL-Hyb-3	43.30 b-k	38.98 c-l	41.14 cde	61.5 d-h	80.0 a-f	70.7 b-e
Williams	37.98 d-m	36.44 f-m	37.21 def	50.5 fgh	56.4 d-h	53.5 ef
No2	47.99 a-e	40.66 c-l	44.32 a-d	56.5 d-h	64.7 c-h	60.6 e-f
No91	34.48 ı-m	33.67 j-m	34.07 efg	77.4 a-g	98.9 ab	88.1 ab
No5	35.58 g-m	43.04 b-k	39.31 c-f	62.1 d-h	66.6 c-h	64.4 c-f
Gulseker	46.32 a-g	36.66 f-m	41.49 cd	80.9 a-f	101.9 a	91.4 a
Mean	41.29 A[1]	40.21 B		60.6 B[1]	70.6 A	
CV (%)		9.71			17.02	
F Genotype (G)		**			**	
F Year (Y)		**			**	
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 of different year-genotype combinations with the same lower case letters are not significantly different according to the Tukey test at P≤0.05
[1)]The means indicated with the same capital letter in the same row are not significantly different at P≤0.05

protein ratio of silage from sorghum-sudangrass hybrid as 7.62% under Mediterranean conditions. The silage and bagasse silage CP values of aforementioned studies were higher than the present values. Such differences were mainly attributed more favorable conditions of the present research site for sorghum cultivation, thus increased biomass yields and decreased quality traits such as CP. On the other hand, also genotypes tested account for differences in carbohydrates content and crude protein (CP) (Pastierik et al., 2017).

Acid Detergent Lignin (g/kg DM): Genotype, year and genotype x year interactions had significant effects on dry matter ADL content of the silage made from juice-extracted sorghum stalks. Average ADL content (70.6 g/kg) was significantly greater in the second year than in the first year (Table 3). Due to the high yield values in the second year of the study (Table 2), ADL values were also found to be high. As it is known, high biomass yield results in more substances such as lignin due to the more development of plants.

Significant effects of year x cultivar interactions on silage ADL contents indicated that effects of the years on ADL content of bagasse silage varied with the genotypes. Although Theis and Topper 76 genotypes had significantly greater ADL content in the second year as compared to in the first year, there was no significant variation in ADL contents of bagasse silages of the other genotypes with the years.

As the average of two years, average ADL contents of bagasse silages of the genotypes varied between 49.3 - 91.4 g/kg and such a variation was found to be significant. Bagasse silage of Gulseker genotype had significantly higher ADL content than those of the other genotypes, except for M81-E, Ramada, Theis and No91 genotypes. Bagasse silage of Dale genotype had significantly lower ADL content than those of the other genotypes, except for M81-E, Ramada, Theis, UNL-Hyb-3, No91 and Gulseker genotypes.

It was reported that the ADL values of sweet sorghum bagasse silages varied between 8.79 - 8.95% (Kumari et al., 2013) and the ADL value of silages made with leafy squeezed sweet sorghum stalk varied was 9.05% (Vidya et al., 2016). Khalil et al. (2015) reported the lignin content of fresh sweet sorghum bagasse as between 5.34 - 11.30%. Tas et al. (2021) reported ADL values of sweet sorghum bagasse samples as between 40.58 - 78.88 g/kg DM under GAP conditions. Dundar et al. (2020) reported silage ADL values of sweet sorghum genotypes grown at different irrigation levels under second crop conditions of Adana province as between 6.89-9.36%. Present ADL values were similar with the values reported in aforementioned studies.

Neutral Detergent Fiber (g kg DM): Genotype, year and genotype x year interactions had significant effects on NDF content of the dry matter of silage made from sugar sorghum bagasse. Averaged NDF content of bagasse silage over the genotypes was significantly higher in the second year than in the first year (Table 4). It can be said that the bagasse yield of the second year of the study was higher than in the first year and accordingly, the plants developed more and the NDF ratio increased due to the increase in the rate of indigestible substances. It was reported that there were significant and negative relationships between NDF content and stalk and bagasse yields (Kumar et al., 2010). However, significant effects of year x genotype interactions revealed that the change in NDF content of bagasse silage depending on the year varied with the genotypes. While NDF contents of bagasse silage of Dale, Theis, Topper 76, Trachy and UNL-Hyb-3 genotypes were significantly higher in the second year than those in the first year, the NDF contents of bagasse silage of the other genotypes did not show a significant variation with the years.

As the average of two years, silage NDF contents of bagasse silages of the genotypes varied between 525.1 - 694.8 g/kg and such a variation was found to be significant. Gulseker genotype had significantly higher bagasse silage NDF content than Dale, Mennonita, N Sugarcane, Rox Orange, Williams, No2 and No5 genotypes. N Sugarcane genotype had significantly lower bagasse silage NDF content than M81-E, Theis, UNL-Hyb-3 and No91 genotypes.

In previous studies, silage NDF values of the juice-extracted sweet sorghum pulp bagasse were reported as between 75.4-62.2% (Mosali et al., 2010; Ávila et al., 2013; Kumari et al., 2013; Vidya et al., 2016). Dong et al. (2020) reported the average NDF content of sorghum bagasse silage as 803.23 g/kg DM, while Tas et al. (2021) reported the NDF contents of bagasse silage of the sorghum genotypes as between 473.0 - 653.0 g/kg DM. Naeini et al. (2014 reported NDF content of maize, sorghum and sorghum bagasse as 526, 447 and 491 g/kg/DM, respectively. The present NDF values were similar with the values reported in aforementioned studies.

Acid Detergent Fiber (g kg DM): Genotype, year and genotype x year interactions had significant effects on bagasse silage ADF content of sweet sorghum. Averaged value of ADF content of bagasse silage in the first year was significantly lower than that in the second year (Table 4). Parallel to low NDF values of the first year, ADF values were also low in the first year of the study. This is an expected result, because there is an important and positive

Table 4: Neutral detergent fiber and acid detergent fiber contents of silages from bagasse of sweet sorghum genotypes

Genotip No	Neutral Detergent Fiber (g kg DM)			Acid Detergent Fiber (g kg DM)		
	2016	2017	Mean	2016	2017	Mean
Cowley	602.5 b-m+	614.3 b-l	608.4 a-e	410.9 d-k	414.7 d-j	412.8 b-f
Dale	468.4 lmn	671.9 a-h	570.1 cde	322.8 klm	439.1 b-h	380.9 efg
Grass1	557.5 f-n	670.3 a-h	613.9 a-e	388.3 e-m	437.1 b-h	412.7 b-f
M81-E	598.8 b-m	664.4 a-ı	631.6 a-d	411.3 d-k	524.3 ab	467.8 ab
Mennonita	601.3 b-m	478.3 lmn	539.8 de	411.2 d-k	308.5 m	359.9 fg
N. Sugarcane	461.6 mn	588.6 c-n	525.1 e	333.5 ı-m	401.9 d-l	367.7 fg
P1579753	646.6 a-j	573.0 e-n	609.8 a-e	449.7 a-g	334.2 ı-m	392.0 efg
Ramada	511.5 j-n	710.6 a-e	611.0 a-e	319.5 lm	449.2 a-g	384.3 efg
Roma	551.3 f-n	681.2 a-g	616.2 a-e	373.3 f-m	431.9 c-h	402.6 d-g
Rox Orange	583.3 d-n	547.2 g-n	565.2 cde	383.8 e-m	367.2 g-m	375.5 efg
Smith	522.8 ı-n	640.4 a-k	581.6 b-e	371.1 f-m	413.3 d-k	392.2 d-g
Sugar Drip	578.7 d-n	646.1 a-j	612.4 a-e	393.8 d-m	427.2 c-h	410.5 b-f
Theis	517.2 j-n	764.3 a	640.7 abc	369.8 f-m	531.3 a	450.5 a-d
Topper 76	474.9 lmn	732.3 abc	603.6 a-e	331.4 ı-m	483.7 a-d	407.5 c-g
Tracy	445.2 n	651.6 a-j	548.4 cde	319.5 lm	439.2 b-h	379.3 efg
UNL-Hyb-3	559.1 f-n	720.8 a-d	639.9 abc	386.6 e-m	472.0 a-e	423.3 a-e
Williams	528.1 h-n	549.8 f-n	538.9 de	333.5 ı-m	368.9 f-m	351.2 g
No2	497.5 k-n	631.9 a-k	564.7 cde	328.4 j-m	387.3 e-m	357.9 fg
No91	645.1 a-j	694.1 a-f	669.6 ab	419.7 d-ı	511.0 abc	465.3 abc
No5	540.8 g-n	654.2 a-j	597.5 b-e	356.5 h-m	444.9 a-h	400.8 d-g
Gulseker	652.6 a-j	737.0 ab	694.8 a	459.0 a-f	514.5 abc	486.8 a
Mean	549.7 B[1]	648.7 A		374.9 B[1]	433.4 A	
CV (%)		8.62			7.93	
F Genotype (G)		**			**	
F Year (Y)		**			**	
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 of different year-genotype combinations with the same lower case letters are not significantly different according to the Tukey test at P≤0.05
[1)]The means indicated with the same capital letter in the same row are not significantly different at P≤0.05

relationship between NDF and ADF (Kumar et al., 2010). However, significant effects of year x cultivar interactions indicated that effects of years on ADF content of bagasse silage varied with the genotypes. Thusly, silage dry matter ADF contents of Dale, M81-E, Ramada, Theis, Topper 76, Tracy and No91 genotypes were significantly higher in the second year than those in the first year, whereas bagasse silage dry matter ADF contents of Grass1, Mennonita and P1579753 genotypes were significantly lower in the second year as compared to those in the first year. In other genotypes, silage dry matter ADF contents did not show a significant variation with the years.

As the average of two years, the silage dry matter ADF contents of the tested genotypes varied between 351.2 - 486.8 g/kg and such a variation was found to be significant. Gülseker genotype had higher ADF content of bagasse silage than the other genotypes, except for M81-E, Theis, UNL-Hyb-3 and No91 genotypes. Williams genotype had significantly lower ADF content of bagasse silage than Cowley, Grass1, M81-E, Sugar Drip, Theis, UNL-Hyb-3 and No91 genotypes. In previous studies, ADF contents of juice-extracted sweet sorghum bagasse samples were reported as between 41.4 - 46.82% (Ávila et al., 2013; Kumari et al., 2013). Mosali et al. (2010) reported the ADF content of bagasse silage as 39.2% for M81-E genotype and 37.5% for Topper 76 genotype. Vidya et al. (2016) reported the ADF content of silages made from leafy squeezed sweet sorghum bagasse as 46.75%. Naeni et al. (2014) reported the ADF content of sorghum bagasse as 258 g/kg and Dong et al. (2020) as 558.7 g/kg. Tas et al. (2021) reported the ADF contents of sorghum genotypes as between 273.3 - 431.6 g/kg. Naeini et al. (2014) reported ADF content of maize, sorghum and sorghum bagasse as 263, 213 and 258 g/kg, respectively. Dundar et al. (2020) reported ADF contents of sorghum genotypes grown at different water levels as between 39.79 - 43.32%.

CONCLUSION

Silage was made from juice-extracted sweet sorghum stalks (bagasse) and bagasse yield and silage quality traits were investigated. Two-year averaged values revealed that bagasse yields and silage quality traits varied significantly with the genotypes; some genotypes had DM yields being

greater than 25 t ha^{-1}, the same genotypes had lower NDF and ADF values than the other genotypes; especially Ramada, Roma, Topper 76 and No91 genotypes were superior to the others in bagasse yield and silage quality traits. It was concluded based on present findings that silages made from juice-extracted stalks of sweet sorghum grown under 2nd crop conditions of Cukurova region could be used as quality roughage source for livestock.

Authors' contributions

Celal Yucel and Rustu Hatipoglu: Research hypothesis, methodology and experimental procedures, analysis, data collection, statistical analysis, manuscript writing.

Ilker Inal and Feyza Dondu Bilgin: methodology and experimental procedures, analysis, data collection.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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