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EVALUATION OF FORAGE YIELD AND SILAGE QUALITY OF SWEET SORGHUM IN THE EASTERN MEDITERRANEAN REGION

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ABSTRACT

Different sweet sorghum varieties were ensiled and silage quality attributes were determined in the present study. M81-E, Ramada, Roma, Topper-76, UNL Hybrid and No91 sweet sorghum (*Sorghum bicolor* var. *saccharatum* (L.) Mohlenbr.) genotypes were used as the plant material for the study. Field experiments were conducted at the experimental fields of Eastern Mediterranean Agricultural Research Institute (Dogankent-Adana) in the years 2016 and 2017 under second-crop conditions (June-October) in a randomized complete block design with four replications. Average green herbage yield, dry matter yield, crude protein yield, crude protein (CP) ratio, neutral detergent fiber (NDF), acid detergent fiber (ADF), dry matter intake (DMI) and relative feed value (RFV) varied between 151.5-188.7 Mg ha^{-1}; 46.6-61.2 Mg ha^{-1}; 2166-2905 kg ha^{-1}; 4.08-5.22%, 39.11-43.10%, 24.31-28.36%, 2.81-3.11%, and 148.3-168.4. Present findings revealed that M81-E, Topper-76, UNL hybrid and No91 varieties were higher with herbage and DM yield while Ramada and Roma were higher with silage quality attributes. It was observed that the sweet sorghum varieties at second-crop growing period (June-October) under Eastern Mediterranean (Adana) conditions for 100-120 days had green herbage, dry matter and crude protein yields more than 180 Mg ha^{-1}, 50 Mg ha^{-1} and 2300 kg ha^{-1}, respectively. These varieties had RFV of above 150. Such a value was greater than the RFV of several other forage crops.

Key words: Sweet sorghum; silage; cultivar; quality.

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INTRODUCTION

Sweet sorghum has less fertilizer requirements and soil preference, more tolerant to salinity, droughts and high temperatures, and use irrigation water more efficiently, thus can reliably be grown over the agricultural fields of arid and semi-arid regions. Such attributes give sweet sorghum an advantage over the other fodder crops grown under similar conditions (Mastrorilli *et al*., 1999; Gnansounou *et al*., 2005; Tesso *et al*., 2005; Almodares *et al*., 2008). Sweet sorghum is a short-day plant, thus requires high temperatures and exhibit the best growth under high temperature conditions (Reise and Almodares, 2008).

Since sorghum plants have quite high soluble carbohydrate contents (Sankarapandian *et al*., 2013), high nutrient contents and low buffering capacities (Lema *et al*., 2001, Kumar *et al*., 2015), are commonly used for silage production (Brocke *et al*., 2014). Sweet sorghum silage has greater dry matter digestibility (DMD), thus provides a good quality feed source for ruminants. Sorghum varieties have greater potential for silage when they were grown as the second crop (Neto *et al*., 2017). Sweet sorghum stalks are quite rich in fermentable sugars (about 15-18% richer than regular sorghums) (Reddy *et al*., 2005). Such attributes facilitate lactic acid fermentation (Santos *et al*., 2013) and make it suitable crop for 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. Studies about potential use of sweet sorghum of Turkey as a quality forage source are quite limited.

In this study, different sweet sorghum varieties were grown under ecological conditions of Adana province as the summer second crop after wheat, plants were ensiled to determine forage potential and some quality attributes of sweet sorghums.

MATERIALS AND METHODS

Material: Sweet sorghum varieties M81-E, Ramada, Roma, Topper 76, UNL-hybrid (26297xM81E) were supplied by UNL (University of Nebraska, Lincoln, USA) and No91 population (Taiwan-originated and supplied from USDA gene bank) were used as the plant material of this study.

Climate and soil characteristics of the experimental site; Average temperature between the months June-October was 25.1 °C in 2016 and 24.8 °C in 2017. Those values were similar with the long-term averages. Temperatures in June, July and August were around 42-43 °C. Average relative humidity of the same period was 79.0% and total precipitation was 46-48 kg/m^2.

Experimental soils belong to Arikli soil series. Soil samples were taken from 0-15 and 15-30 cm soil profiles. Analyses revealed that soil pH varied between 7.0 and 7.50, total salt varied between 0.22 and 0.27%, N between 0.10 and 0.19%, organic carbon (OC) between 0.63 and 0.90%, phosphorus (P) between 0.63 and 0.90 mg kg^{-1}, lime content ($CaCO_3$) between 32.5 and 35.0%, sand between 24 and 28%, silt between 41 and 43%, clay between 30 and 33% and soil texture was clay-loam (CL).

Experimental Setup: Field experiments were conducted in 2016 and 2017 over the experimental fields of Dogankent Locality of Eastern Mediterranean Agricultural Research Institute (DATAEM) (36° 51' 35" N and 35° 20' 43" E) in a randomized complete block design with four replications. Sowing was performed after wheat harvest in mid-June. Before sowing, 50 kg ha^{-1} of both nitrogen and phosphorus were applied to experimental plots as base fertilizer. Each variety was sown at 70 cm row spacing and 15 cm on-row plant spacing over 5 m long 4 rows. When the plants reached to a height of 40-50 cm, additional 50 kg ha^{-1} pure nitrogen was supplied manually as top-dressing fertilizer and irrigations were initiated then. Plants were harvested at different dates between milk and dough stages. Side rows and 0.5 m sections from the top and bottom of the plots were omitted as to consider the side effects and manual harvest was performed from the remaining sections of middle two rows. Plot yields were determined and then yields per hectare were calculated accordingly.

Sample preparation and chemical analyses: For harvest, five plants were randomly selected from each plot and were used to make silage. The selected five plants (leaf-stalk and panicle) were chopped into 3-5 cm pieces with a chipper-chopper machine and made ready for ensilage. About 1 kg fresh samples were placed into special plastic bags (≥110 µ thickness) in two parallels for each plot and oxygen was removed by 99.9% with the aid of Crompack vacuum device. Bags were automatically sealed to finalize ensilage. Vacuumed silage materials were preserved at room temperature for 60 days. Ensiled materials were dried, weighed and ground to pass through 1-2 mm sieves. Kjeldahl method was used to determine nitrogen (N) content of the ground samples. Crude protein ratio was determined with the aid of equation of Nx6.25 (AOAC, 1990). Of the cell membrane components, ADF, ADL and NDF ratios (%) of the samples were determined in accordance with the method specified by Van Soest *et al.* (1991) with an ANKOM fiber analyzer device. Digestible dry matter ratios (DDM), dry matter intake (DMI) and relative feed value (RFV) of the samples were determined by using the equations provided by Schroeder (1994): DDM=88.9-(0.779 x ADF%); DMI=120/NDF%; RFV=(DDM% x DMI%)/1.29. Net Energy (NE) (Mcal/kg) was calculated by using the equation of NE=1.892-(0.0141*ADF) (Anonymous, 2018).

Experimental data were analyzed using proc mixed procedure in SAS program in accordance with randomized complete blocks design (RCBD). Significant means were compared using TUKEY test at 5% level (Littell *et al.*, 2006).

RESULTS AND DISCUSSION

Biomass Yield (Mg ha^{-1}**):** For biomass yield, also called as fresh biomass or green herbage yield, the varieties and varieties x year interactions were found to be significant. Biomass yields of the years and varieties varied between 129.5 and 206.7 Mg ha^{-1}. M81-E, Topper-76, UNL hybrid and No91 varieties had biomass yields of over 180 Mg ha^{-1}. In previous studies conducted with different genotypes under different ecologies, biomass yields were reported as between 11.5 and 112 Mg ha^{-1} (Turgut *et al.*, 2005; Korpos *et al.*, 2008; Bellmer *et al.*, 2010; Agung *et al.*, 2013; Perazzo *et al.*, 2017). Present biomass yields were greater than those earlier ones and such greater values indicated that present ecology was suitable for sorghum culture.

Dry Matter Yield (Mg ha^{-1}**):** For dry matter yield, means of year and varieties and variety x year interactions were found to be significant. Dry matter yields of the years and varieties varied between 38.8 and 69.0 Mg ha^{-1}. As the average of years, the greatest dry matter yield was obtained from UNL hybrid genotype. In earlier studies conducted with different genotypes at different ecologies, dry matter yields were reported as between 6.59 and 33.9 Mg ha^{-1} (Turgut *et al.*, 2005; Bellmer *et al.*, 2010; Perazzo *et al.*, 2017; Ekefre *et al.*, 2017). As it was in biomass yields, present dry matter yields were also greater than the earlier ones. Significant positive correlations were reported between herbage yield and dry matter yield (Iyanar *et al.*, 2010).

pH: Effects of years, varieties and variety x year interactions on silage pH values were found to be significant (Table 2). The pH values of the years and varieties varied between 3.21 and 3.82. Feed sorghum silage is fermented like as maize silage and generally has a pH of below 4 (Filya, 2003; Contreras-Govea *et al.*, 2010). Junior *et al.* (2015) reported pH of sorghum silage as between 3.60 and 3.68. Present findings comply with those earlier reports.

Crude Protein Ratio (%): There were significant differences in crude protein ratios of the varieties and years. Crude protein ratios of the varieties varied between 4.08 and 5.22% and Ramada variety had greater CP ratios than the others. In previous studies, crude protein ratios of sweet sorghum varieties were reported as between 2.6-8.23% (Lema *et al*., 2001; Madibela *et al*., 2002; Rodrigues *et al*., 2006; Junior *et al*., 2015; Durul, 2016). Present findings were within the earlier reports, greater than some and smaller than the others. Such differences were attributed to differences in varieties, ecologies and growing techniques.

Table 1. Biomass and dry matter yields of sweet sorghum varieties.

Cultivars	Biomass Yield (Mg ha^{-1})			Dry Matter Yield (Mg ha^{-1})		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**
M81-E	181.0 ab	179.2 ab[1]	180.1 AB*	56.6 abc	51.1 bcd[1]	53.8 AB*
Ramada	129.5 b	173.4 ab	151.5 B	43.0 ecd	50.2 bcd	46.6 B
Roma	157.1 ab	182.3 ab	169.7 AB	51.8 bcd	46.1 cd	48.9 B
Topper 76	177.7 ab	185.4 a	181.5 AB	53.6 a-d	47.8 cd	50.7 B
UNLHybrid	193.8 a	183.6 ab	188.7 A	69.0 a	53.4 a-d	61.2 A
No91	206.7 a	170.5 ab	188.6 A	65.9 ab	38.8 d	52.3 AB
Mean	174.3	179.1	176.7	56.7 A+	47.9B	52.3
CV (%)		12.39			12.91	

*)The means indicated with the same capital 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 according to the Tukey test at P≤0.05
1) The means of different year-cultivar combinations with the same lower case letters are not significantly different according to the Tukey test at P≤0.05

Table 2. Silage pH and crude protein ratios of sweet sorghum varieties.

Cultivars	**pH**			**Crude Protein Ratio (%)**		
	2016	**2017**	**Mean**	**2016**	**2017**	**Mean**
M81-E	3.42 bc	3.40 bc[1]	**3.41 AB***	3.54	4.80	**4.08 B***
Ramada	3.46 bc	3.59 ab	**3.52 A**	4.97	5.47	**5.22 A**
Roma	3.36 bc	3.82 a	**3.59 A**	4.46	4.99	**4.72 AB**
Topper 76	3.43 bc	3.53 abc	**3.48 AB**	4.10	5.15	**4.62 AB**
UNLHybrid	3.53 abc	3.54 abc	**3.53 A**	4.54	5.05	**4.79 AB**
No91	3.37 bc	3.21 c	**3.29 B**	3.48	5.40	**4.44 AB**
Mean	**3.43 B**	**3.51 A+**	**3.47**	**4.15 B**	**5.14 A**	**4.65**
CV (%)		**4.05**			**12.70**	

*)The means indicated with the same capital 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 according to the Tukey test at P≤0.05
1) The means of different year-cultivar combinations with the same lower case letters are not significantly different according to the Tukey test at P≤0.05

Crude Ash Content (%): Significant differences were observed in crude ash contents only of the years. Crude ash (CA) contents of the years and varieties varied between 4.87 and 7.48%. Average ash content of the first year (6.73%) was greater than the ash content of the second year (5.83%). Dry matter ratios were also greater in the first year than in the second year (Figure 1). Such a case may be related to leaf-stalk ratio. Madibela *et al.* (2002) reported greater CA content for leaves (115 g kg DM) than for stalks (60.2 g kg DM) of sweet sorghum. Similarly, Elseed *et al.* (2007) indicated that plant stalks tend to have less ash and silica; Monti *et al*. (2008) reported greater ash content for leaves (82 g kg DM) than for stalks (50 g kg DM) of sweet sorghums. Crude ash contents of sorghum were reported as between 2.5 and 4.9% (Lema *et al*., 2001; Trulea *et al*., 2013). Madibela *et al*. (2002) reported crude ash contents of sweet sorghum varieties as between 69.4 and 91.5 g kg DM.

Acid Detergent Lignin (%): The differences in acid detergent lignin (ADL) values of the varieties were not found to be significant (Table 3). ADL values of the years and varieties varied between 4.36 and 6.90%. In previous studies, ADL values of sweet sorghum varieties were reported as between 3.5 and 5.2% (Lema *et al*., 2001) and between 25.5 and 39.8 g kg DM (Madibela *et al*., 2002).

Neutral Detergent Fiber (%): Only the years were found to be significant for neutral detergent fiber (NDF). The NDF values of the years and varieties varied between 35.15 and 46.90%. The varieties Ramada and Roma had lower NDF values than the others. Such a case was attributed to greater leaf ratios of these varieties. Similar findings were also reported by Yucel *et al*. (2018). NDF value of the first year (43.96%) was greater than the second year (38.54%). Such a case was attributed to greater DM yield of the first year (Table 1), thus to greater ripening of the plants and increased cell membrane substances. In previous studies, NDF values of sweet sorghum varieties were reported as between 32.6 and 64.9% (Lema *et al*., 2001; Gomes *et al*., 2006; Mahmood *et al*., 2013; Durul, 2016; Neto *et al*., 2017). Present findings comply with those earlier ones.

Acid Detergent Fiber (%): The differences in acid detergent fiber (ADF) values of the varieties were found to be significant. ADF values of the years and varieties varied between 23.62 and 29.18%. As it was in NDF values, again the varieties Ramada and Roma had lower ADF values. Such a case was attributed to leafy nature of the stalks. In general, ADF, ADL and cellulose contents followed the same trend as NDF (Lema *et al*., 2001). In previous studies, ADF values of sweet sorghum varieties were reported as between 24.4 and 42.0% (Lema *et al*., 2001; Mahmood *et al*., 2013; Durul, 2016) and between 260.0-324.4 g kg DM (Madibela *et al*., 2002).

Table 3. Silage crude ash and ADL values of sweet sorghum varieties.

Cultivars	Crude Ash Content (%)			Acid Detergent Lignin (%)		
	2016	2017	Mean	2016	2017	Mean
M81-E	7.06	4.87	5.97	6.90	5.71	6.30
Ramada	6.25	5.75	5.99	5.13	5.06	5.09
Roma	6.72	5.41	6.06	5.33	4.86	5.10
Topper 76	7.48	6.60	7.04	5.71	4.36	5.04
UNLHybrid	7.32	5.54	6.43	6.05	6.25	6.15
No91	5.58	6.79	6.19	5.75	5.69	5.72
Mean	**6.73 A**	**5.83 B+**	**6.28**	**5.81**	**5.32**	**5.57**
CV (%)		18.49			19.54	

+) The means indicated with the same capital letter in the same row are not significantly different according to the Tukey test at P≤0.05

Table 4. Silage NDF and ADF values of sweet sorghum varieties.

Cultivars	Neutral Detergent Fiber (%)			Acid Detergent Fiber (%)		
	2016	2017	Mean	2016	2017	Mean
M81-E	46.90	39.31	**43.10**	29.18	27.54	**28.36 A***
Ramada	43.07	35.15	**39.11**	25.00	23.62	**24.31 B**
Roma	42.93	35.62	**39.28**	26.56	23.94	**25.25 AB**
Topper 76	44.29	39.53	**41.91**	26.13	26.56	**26.35 AB**
UNLHybrid	42.55	39.57	**41.06**	28.31	28.04	**28.17 AB**
No91	44.05	42.04	**43.05**	26.70	29.13	**27.91 AB**
Mean	**43.96 A**	**38.54 B+**	**41.25**	**26.98**	**26.47**	**26.73**
CV (%)		7.81			10.01	

*)The means with the same capital letter in the same column are not statistically significant different from each other according to the Tukey test at P≤0.05

+) The means with the same capital letter in the same row are not statistically significant different from each other according to the Tukey test at P≤0.05

Dry Matter Ratio (%): For silage dry matter (DM) ratios, varieties, years and variety x year interactions were found to be significant. DM ratios of the years and varieties varied between 24.75 and 38.94%. The DM ratios of the varieties alone varied between 29.68 and 35.34% with the greatest value in UNL hybrid genotype (Figure 1). DM ratio of the first year (35.59%) was greater than the second year (29.33%). Chakravarthi *et al.* (2017) reported DM ratios of sweet sorghum varieties as between 11.82 and 38.19% with an average value of 26.30%.

Digestible Dry Matter Ratio (%): Significant differences were not observed in digestible dry matter (DDM) ratios of the years and the varieties. DDM ratios of the years and varieties varied between 67.15 and 72.18% (Figure 1). Increasing stalk sugar content increase digestibility and feed quality (Poehlman, 1994; Blümmel *et al*., 2009). Digestible dry matter ratios of sorghum were reported as between 56.96 and 70.65% (Junior *et al*., 2015; Karthikeyan *et al*., 2017).

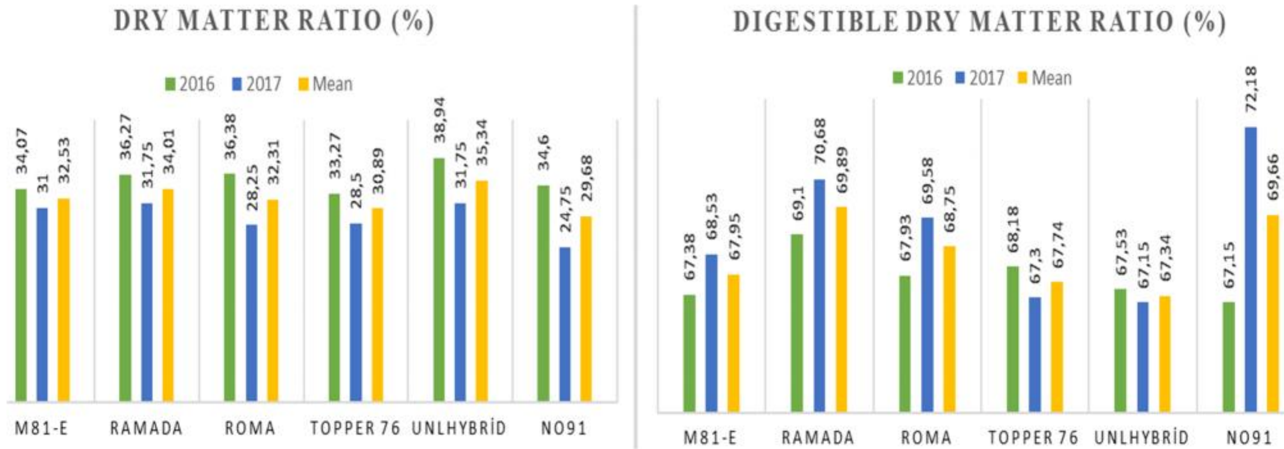

Figure 1. Silage DM and DDM ratios of sweet sorghum varieties.

Dry Matter Intake (%): Years and varieties were found to be significant for dry matter intake (DMI) values. DMI values of the years and varieties varied between 2.56 and 3.37% and DMI values of the varieties varied between 2.81 and 3.11% (Figure 2). The varieties Ramada and Rome had greater DMI values (>3%) than the others. Average DMI value of the second year (3.15%) was greater than the DMI value of the first year (2.74%). Karthikeyan *et al*. (2017) reported DMI values of sweet sorghum varieties as between 1.67 and 2.20% with an average value of 1.93%. Silage fermentation quality had significant effects on feed intake, nutrient use and milk yield of ruminants (Huhtanen *et al*., 2002).

Relative Feed Value: For relative feed value (RFV), both the years and the varieties were found to be significant. RFV of the years and varieties varied between 133.9 and 187.1. RFV of the varieties varied between 148.3 and 168.4 (Figure 2). The varieties Ramada and Rome had greater RFV (>165) than the others. Average RFV of the second year (168.9) was greater than the average RFV of the first year (144.1). The RFV value calculated based on 100% flowering period of alfalfa was assumed to be 100. Durul (2016) reported RFV of sweet sorghum varieties as between 104 and 126.

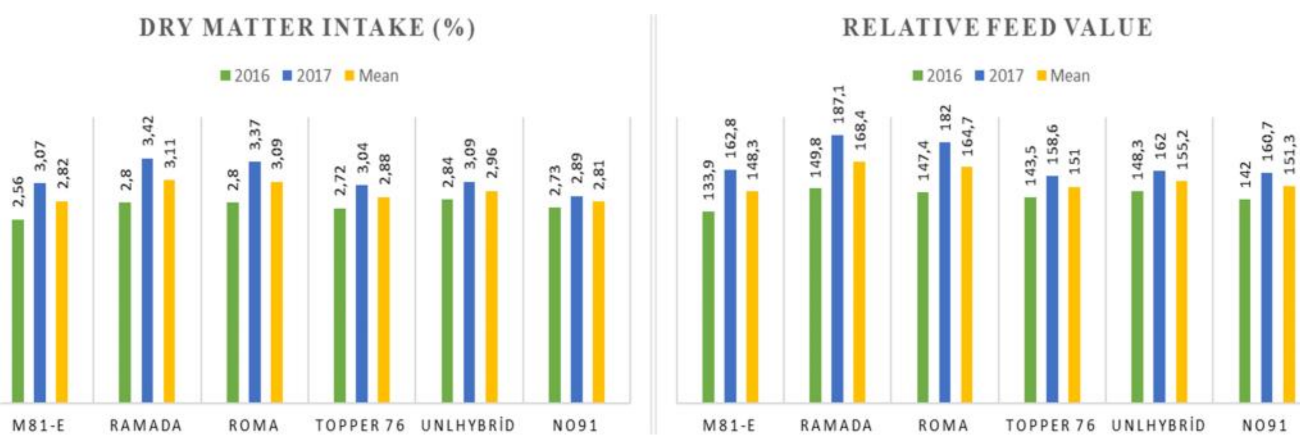

Figure 2. Silage DMI and RFV of sweet sorghum varieties

Crude Protein Yield (kg ha^{-1}): Variance analysis revealed that there were significant differences in silage crude protein (CP) yields of the varieties. The CP yields of the years and varieties varied between 1900 and 3128 kg ha^{-1} (Figure 3). The CP yields of the varieties varied between 2166 and 2905 kg ha^{-1} with the greater value in UNL hybrid genotype than the others.

Net Energy (Mcal kg^{-1}): Significant differences were not observed between the net energy values of the years and the varieties. Net energy values of the years and varieties varied between 1.498 and 1.590 Mcal kg^{-1} (Figure 3). High net energy values of sweet sorghum varieties are generally attributed to high water soluble carbohydrate content of sweet sorghum (Kaiser *et al*., 2004). Cattani *et al*. (2017) reported net energy values of sweet sorghum silage as 1.59 Mcal kg DM.

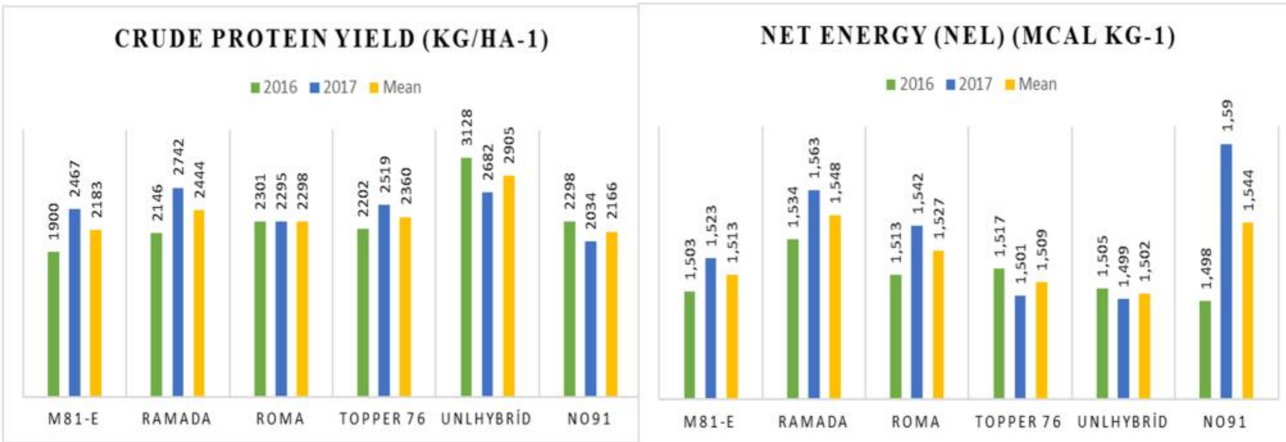

Figure 3. Silage CP yield and NE values of sweet sorghum varieties

Conclusion: Present findings revealed that M81-E, Topper-76, UNL hybrid and No91 varieties were prominent with herbage and DM yield; Ramada and Roma varieties were prominent with silage quality attributes. It was observed in this study conducted at second-crop growing period (June-October) under Eastern Mediterranean (Adana) conditions for 100-120 days that there were sweet sorghum varieties among the investigated plant materials with herbage, dry matter and crude protein yields of above 180 Mg ha^{-1}, 50 Mg ha^{-1} and 2.3 Mg ha^{-1}, respectively. These varieties had RFV of above 150. Such a value was greater than the RFV of several other feed crops. It was concluded based on present findings that sorghum varieties grown in southern coasts of Turkey had 3-4 times greater yields than maize (Korkmaz *et al*., 2015; Yücel *et al*., 2015) and silage quality attributes (NDF, ADF, DMI and RFV) were also better than maize silage. As compared to maize, sorghum is more tolerant to drought and high temperatures, has less fertilizer demands and soil preference. Thus, sorghum can be used as an alternative silage crop to maize and can have great contributions to quality forage supply of the country.

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