



Comparison of Different Sweet Sorghum (*Sorghum Bicolor* L. Moench) Varieties Grown as Second Crop in Eastern Mediterranean Conditions in Terms of Forage Yield and Quality Characteristics

Osman Turgut¹, Asiye Sena Çavdar¹, Recep İrfan Nazlı*^{1*}

¹Department of Field Crops, Faculty of Agriculture, Cukurova University, Adana, Turkey

inazli@cu.edu.tr

Abstract. Sweet sorghum is an important crop for forage production due to its high biomass yield, forage quality, adaptability to adverse environmental conditions, and suitability for cultivation as a second crop. This study was conducted to evaluate the forage yield and quality characteristics of eight sweet sorghum (*Sorghum bicolor* (L.) Moench) cultivars (Dale, ICSV 93046, Erdurmuş, Uzun, Gülşeker, IS 2331, IS 3556, and Umbrella) grown as second crops under the Eastern Mediterranean Conditions during the 2024 growing season. Significant differences were observed among the cultivars in terms of fresh biomass yield, dry matter yield, crude protein, ash, ADF, NDF, and relative feed value (RFV). ICSV 93046 produced the highest fresh biomass yield (55.31 t ha⁻¹) and highest dry matter yield (13.88 t ha⁻¹). Umbrella exhibited the lowest ADF (30.93 %), lowest NDF (47.74 %), and the highest RFV (126.26) among the cultivars, as well as the highest CP content (7.10 %) after Uzun. These results indicate its superior forage quality under second crop conditions. In contrast, Gülşeker recorded the lowest values for most traits. These results indicate that ICSV 93046 and Umbrella cultivars can be primarily preferred for sustainable forage crop production under second crop conditions in the Eastern Mediterranean region of Türkiye.

Keywords: Sorghum, Forage, Mediterranean

1 Introduction

The lack of sufficient roughage production in Turkey remains one of the key challenges facing the livestock sector. Therefore, as the impacts of global warming have started to become more evident, it is crucial to evaluate the current status of forage crop cultivation areas, monitor recent changes in these areas, and develop new strategies to expand forage production [1].

Sweet sorghum (*Sorghum bicolor* (L.) Moench), a member of the *Poaceae* family, is an annual crop with a C4 photosynthetic pathway [2]. Compared with other maize, it demonstrates superior tolerance to drought, soil toxicities, and temperature extremes [3]. Furthermore, sweet sorghum enables multiple cultivation cycles within a single

year, ensuring high productivity and agronomic stability while requiring minimal nitrogen input [4]. Owing to this resilience, sweet sorghum is often referred to as “the camel among crops” and considered “a promising alternative forage to maize” [5]. Currently, it is used mainly as a bioenergy and forage crop in arid and semiarid regions [6].

Sorghum is a suitable forage crop for rotational grazing, hay production, and silage, and under certain conditions it can produce higher forage yield than silage maize [7]. Due to its high biomass habit and high tillering capacity, sweet sorghum produces greater dry matter yield per unit area compared with many other forage crops [8]. In addition to its high biomass productivity, sweet sorghum has high nutritive value, with crude protein and digestibility comparable to or sometimes higher than maize [7]. Furthermore, sweet sorghum accumulates high levels of sugar, making it suitable not only for sugar extraction and the production of various by products, but also as a valuable feed source. Its high sugar content is more easily digested and absorbed by ruminants, which helps mitigate the severity of rumen acidosis [9].

Due to its high yield potential and tolerance to abiotic stresses, sweet sorghum represents a highly valuable option for second crop forage cultivation in regions where high temperatures and drought prevail during the summer months. However, the number of studies examining its forage yield and quality under second crop conditions in the Eastern Mediterranean conditions is limited [10, 11]. That’s why the aim of this study is to compare different sweet sorghum varieties in terms of forage yield and quality under second crop conditions in the Eastern Mediterranean climate, and to identify the varieties best adapted to the region.

2 Material and Methods

2.1 Site Description and Crop Culture

The field experiment was conducted between July 8 and November 1, 2024, over a four month period, at the experimental area of the Agricultural Faculty of Cukurova University in Adana, Türkiye. The soil at the experimental site had a clay texture and was characterized by very low salinity (0.139 mmhos/cm), high lime content (24.3%), low organic matter (1.52%), medium available phosphorus (74.3 kg/ha), high available potassium (1065.4 kg/ha), and a slightly alkaline pH (8.19).

The site is located under Mediterranean climate conditions, where summers are hot and dry, while winters are mild and rainy. Before planting, the soil was plowed to a medium depth (30–40 cm) and harrowed once with a field cultivator to obtain a proper seedbed. According to the soil analysis results, 75 kg ha⁻¹ of phosphorus (P₂O₅) was applied at sowing in the form of a compound fertilizer (20-20-0). The total planned nitrogen (N) application for the field trial was 150 kg ha⁻¹. Of this, 50% was applied at sowing with the same 20-20-0 fertilizer, and the remaining 50% was supplied as urea (46%) when the plants reached the five-leaf stage.

In the experiment, eight sweet sorghum (*Sorghum bicolor* (L.) Moench) cultivars—Dale, ICSV-93046, Erdurmuş, Uzun, Gülşeker, IS 2331, IS 3556, and Umbrella—were used as planting materials. The field trial was arranged in a randomized complete block design (RCBD) with three replications. Sowing was done on July 8, 2024, with a row

spacing of 70 cm and an intra-row spacing of 15 cm. Each plot consisted of four rows, measuring 5 m in length and 2.8 m in width, giving a total plot area of 14 m². The sowing depth was maintained at 2–3 cm.

2.2 Sample Preparation and Analysis

The sweet sorghum cultivars were harvested between October 7 and November 1, 2024, when the plants had reached the soft-dough growth stage [11]. Harvesting was performed manually with a sickle, by cutting the stalks approximately 5 cm above the soil surface. During harvest, ten plants were randomly chosen from each plot and used for subsequent laboratory analyses. The collected stalks were chopped into 1–2 cm pieces using a forage cutter, then dried in a forced-air oven at 60°C until they reached a constant weight. After drying, the samples were ground in a plant mill fitted with a 1 mm sieve to prepare them for chemical analysis. The Kjeldahl method was used to determine the nitrogen (N) content (%) of the samples. The obtained N values were multiplied by 6.25 to calculate the crude protein content. The acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents were determined following the procedure described by Van Soest [12]. The relative feed value (RFV) was calculated using the method proposed by Rohweder et al. [13], according to the formula:

$$\text{RFV} = (\text{DDM} \times \text{DMI}) / 1.29$$

where DDM represents the digestible dry matter percentage and DMI indicates the dry matter intake. The following equations were used to estimate DDM and DMI:

$$\text{DDM} = 88.9 - (0.779 \times \text{ADF})$$

$$\text{DMI} = 120/\text{NDF}.$$

2.3 Statistical Analysis

The data presented in the study were analysed by an ANOVA model using the JMP 7.0 statistical software. Significantly different means were separated at $P = 0.05$ using the least significant difference (LSD) test.

3 Results and Discussion

Cultivars	FBY (t ha ⁻¹)	DMY (t ha ⁻¹)	CP (%)	ASH (%)	ADF (%)	NDF (%)	RFV
ICSV 93046	55.31 a	18.41 a	6.10 b	5.56 d	36.30 b	55.24 bc	102.14 c
Umbrella	43.29 b	13.88 b	7.10 a	5.96 b	30.93 e	47.74 d	126.26 a
IS 3556	36.43 bc	11.62 bc	5.70 bc	6.20 a	32.64 d	53.71 c	109.93 b
Dale	35.45 c	10.27 cd	5.57 c	5.02 e	31.3 e	48.54 d	123.63 a
IS 2331	29.79 cd	8.89 c-e	5.63 c	5.71 cd	36.02 bc	56.93 b	99.43 c
Erdurmuş	25.10 de	8.34 de	5.9 bc	4.78 f	33.42 d	47.00 d	124.63 a
Gülşeker	24.93 de	7.33 e	5.90 bc	5.75 c	37.63 a	59.55 a	93.09 d
Uzun	22.00 e	7.71 de	7.21 a	5.75 c	35.03 c	55.88 b	102.60 c
Mean	34.04	10.80	6.13	5.59	34.16	53.10	110.21
P-Value	**	**	**	**	**	**	**

Table 1. Forage quality and yield parameters of sweet sorghum cultivars

*= $P < 0.05$, **= $P < 0.01$, NS = not significant, FBY = Fresh Biomass Yield, DMY = Dry Matter Yield, CP = Crude Protein Content, ADF= Acid Detergent Fiber, NDF= Neutral Detergent Fiber, RFV= Relative Feed Value.

The ANOVA results showed that FBY, DMY, CP, ASH, ADF, NDF, and RFV varied significantly between the cultivars. (Table 1). FBY ranged from 22.00 to 55.31 t ha⁻¹ in the study. The highest FBY was obtained from ICSV 93046, while Uzun recorded the lowest. Our results were lower than those reported by Göler and Özyazıcı (2024) [14] and Adıyaman et al. (2020) [15], who observed higher fresh biomass yields under second crop conditions in Mardin and Şanlıurfa, Türkiye. The relatively lower yield obtained in the present study may be associated with environmental factors, particularly shorter growing periods and reduced solar radiation, which are known to limit photosynthetic efficiency and biomass accumulation [16].

DMY varied between 7.33 t ha⁻¹ and 18.41 t ha⁻¹ in the study. The highest DMY was obtained from the cultivar ICSV 93046, whereas Gülşeker had the lowest. Our results were lower than those reported by Batog et al. (2020) [17] and Adıyaman et al. (2020) [15], who observed higher DMY values under second crop conditions in Poznan, Poland and Şanlıurfa, Türkiye respectively.

CP content ranged from 5.57 % to 7.21 % in the study. The highest CP content was observed in Uzun, whereas IS 2331 recorded the lowest values. Our results were lower than those reported by Karadağ and Özkurt (2014) [18] and Göler and Özyazıcı (2024) [14], who observed higher CP contents under second crop conditions in Tokat and Mardin, respectively.

Ash content varied between 4.78 % and 6.20 % in the study. The highest ash content was found in IS 3556, whereas the lowest was recorded in Erdurmuş. Our results were lower than those reported by Çiğdem and Uzun (2006) [19], who observed higher ash contents under second crop conditions in Samsun, Türkiye.

ADF content ranged from 30.93 % to 37.63 % in the study. The lowest ADF content was recorded in Umbrella, while the highest was in Gülşeker. Our results were slightly higher than those reported by Öktem et al. (2021) [8], who found lower ADF content under second crop conditions in Şanlıurfa.

NDF contents varied between 47.00% and 59.55 % in the study. The lowest NDF contents were obtained from Erdurmuş, whereas Gülşeker had the highest. Our results were lower than those reported by Göçer and Karadağ (2022) [20], who observed higher NDF values under second crop conditions in Tokat, Türkiye.

RFV ranged from 93.09 to 126.26 in the study. The highest RFV values were obtained from Dale, while Gülşeker had the lowest. Our results were slightly lower than those reported by Öktem et al. (2021) [8], who found higher RFV values under second crop conditions in Şanlıurfa.

4 Conclusion

These results indicate that ICSV 93046 and Umbrella cultivars can be primarily preferred for sustainable forage crop production under second crop conditions in the Eastern Mediterranean region of Türkiye.

Acknowledgment

We are grateful that this study was funded by the Cukurova University (BAP), Adana, Turkey's Scientific study Project Unit (project number FYL-2024-16864).

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article

References

1. Tan, M., Yolcu, H. Current status of forage crops cultivation and strategies for the future in Turkey: A review. *Journal of Agricultural Sciences*, 27(2), 114-121. (2021)
2. Mokariya, L. K., Malam, K. V. Sweet Sorghum: A smart, multipurpose crop. *Agriculture and Environment*, 1(1), 61-68. (2020).
3. Olusola, F. O., Oluwatosin, O. B., Adebowale, F. N. Nutritional potentialities of sweet sorghum plant parts in ruminant production system. *Archiva Zootechnica*, 25(1), 5-23. (2022).

4. López-Sandin, I., Gutiérrez-Soto, G., Gutiérrez-Diez, A., Medina-Herrera, N., Gutiérrez-Castorena, E., Galicia-Juárez, M., Zavala-García, F. Biomass and sugar production dynamics in sweet sorghum variety Roger. *Chilean journal of agricultural research*, 81(1), 92-101. (2021).
5. Zhao, J., Yin, X. J., Li, J. F., Wang, S. R., Dong, Z. H., Shao, T. Effects of developmental stage and store time on the microbial community and fermentation quality of sweet sorghum silage. *Italian Journal of Animal Science*, 21(1), 1543-1557. (2021).
6. Xu, H., Wu, N., Na, N., Ding, H., Sun, L., Fang, Y., ... & Xue, Y. Dynamics of fermentation quality, bacterial communities, and fermentation weight loss during fermentation of sweet sorghum silage. *BMC microbiology*, 24(1), 429. (2024).
7. Qu, H., Liu, X. B., Dong, C. F., Lu, X. Y., Shen, Y. X. Field performance and nutritive value of sweet sorghum in eastern China. *Field Crops Research*, 157, 84-88. (2014).
8. Oktem, A., Yucel, C., Oktem, A. G. Assessment of biochemical forage quality of sweet sorghum (*Sorghum bicolor* (L.) Moench ssp. *Saccharatum*). *Asian Journal of Chemical Sciences*, 9(3), 1-9. (2021).
9. Wang, S., Guo, F., Wang, Y., Dong, M., Wang, J., Xiao, G. Effects of Substituting Sweet Sorghum for Corn Silage in the Diet on the Growth Performance, Meat Quality, and Rumen Microorganisms of Boer Goats in China. *Animals*, 15(10), 1492. (2025).
10. Geren, H., Avcıoğlu, R., Kavut, Y. T., Sakinoğlu Oruç, Ç., Öztarhan, H. İkinci ürün olarak yetiştirilen şeker darısının (*Sorghum bicolor* (L.) Moench var. *saccharatum*) verim ve verimle ilgili diğer bazı özellikleri üzerine bir ön araştırma. *Türkiye*, 4, 14-17. (2011).
11. Nazli, R. I. Effects of harvest time on bioethanol production and bagasse characteristics for combustion and forage in sweet sorghum. *Field Crops Research*, 280, 108464. (2022).
12. Van Soest, P.J. Use of detergents in the analysis of fibrous feeds. 2. A rapid method for the determination of fiber and lignin. *J. Assoc. Off. Agric. Chem.*, 46, pp. 829-835. (1963).
13. Rohweder, D., Barnes, R. F., Jorgensen, N. Proposed hay grading standards based on laboratory analyses for evaluating quality. *Journal of animal science*, 47(3), 747-759. (1978).
14. Göler, M., Özyazıcı, M. A. İkinci ürün olarak yetiştirilen bazı tatlı sorgum [*Sorghum bicolor* var. *saccharatum* (L.) Mohlenbr.] genotiplerinin verim ve verim öğelerinin belirlenmesi. *Ege Üniversitesi Ziraat Fakültesi Dergisi*, 61(1), 87-102 (2024).
15. Adıyaman, C., Erbil, E., Çelik, A., Hatipoğlu, H., Aksoy, M., Acar, M., Dok, M. İkinci ürün tatlı sorgum [*Sorghum bicolor* (L.) Moench]'un Şanlıurfa koşullarında bazı tarımsal ve teknolojik özelliklerinin belirlenmesi. *Journal of the Institute of Science and Technology*, 10(4), 3084-3094 (2020).
16. Ji, Z., Shi, Y., Jiang, L., Wang, X., Zhu, G., Zhou, G. Double-Cropping Systems Based on Maize, Sorghum, and Alfalfa: Impact of Annual Combination on Biomass and Nutritional Yield. *Agronomy*, 15(1), 83 (2024).
17. Batog, J., Frankowski, J., Wawro, A., Łacka, A. Bioethanol production from biomass of selected sorghum varieties cultivated as main and second crop. *Energies*, 13(23), 6291 (2020).
18. Karadağ, Y., Özkurt, M. Effect of different row spacings on the yield and quality of silage sorghum (*Sorghum bicolor* (L.) Moench) cultivars to be second crop grown (2014).
19. Çiğdem, İ., Uzun, F. Samsun İli Taban Alanlarında İkinci Ürün Olarak Yetiştirilebilecek Bazı Silajlık Sorgum Ve Misir Çeşitleri Üzerine Bir Araştırma. *Anadolu Tarım Bilimleri Dergisi*, 21(1), 14-19 (2006).
20. Göçer, E. U., Karadağ, Y. Tokat Koşullarında İkinci Ürün Olarak Yetiştirilen Sorgum (*Sorghum bicolor* L) Çeşitlerinin Verim ve Kalite Özelliklerinin Belirlenmesi. *Journal of Agriculture*, 5(1), 18-24 (2022).

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

