Evaluation of Bioethanol Yield Potential of Different Sweet Sorghum Cultivars Grown as a Second Crop Under Eastern Mediterranean Conditions

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Abstract. Sweet sorghum has a high potential for bioethanol production due to its high fermentable sugar content and biomass yield. This research was carried out to evaluate bioethanol yield potential of six sweet sorghum cultivars (ICSV 93046, ICSV 700, Black Amber, White African, Gülşeker, and Red's Red) during summer growing season of 2022 under eastern Mediterranean conditions. Cultivars were significantly differed for brix degree, green herbage yield, juice yield, and juice ethanol yields in the study. ICSV 93046 produced the significantly highest fresh stem yield (58811 kg/ha), juice yield (16105 kg/ha), and juice ethanol yield (1194 L/ha) and followed by ICSV 700. On the other hand, the significantly lowest brix degree (10.5 °Bx) and juice ethanol yield (322 L/ha) were achieved by Gülşeker. These results suggested that ICSV 93046 was the most suitable cultivar to be grown as a second crop for bioethanol production under eastern Mediterranean conditions.

1 Introduction

Rapid depletion of fossil fuel reserves and concerns about climate change have led to an increasing demand for biofuels in recent years [1]. Bioethanol, which is currently the most used biofuel type in the global transportation sector, not only reduces dependence on fossil fuels but also mitigates greenhouse gas emissions [2,3] Today, bioethanol is mostly produced from sugarcane and maize that have a high sugar or starch content through different industrial processes such as hydrolysis, fermentation and distillation. However, global bioethanol production requires the use of non-food resources as a raw material rather than these crops to avoid food – fuel competition [4] In this context, sweet sorghum *(Sorghum bicolor* L.) has gained considerable interest in recent years as a bioenergy crop due to its high biomass yield, fermentable sugar content (10 – 25%), resource use efficiency, and drought tolerance [5-6]. Additionally, sweet sorghum can produce higher bioethanol yield per unit area than both maize and sugarcane with low input [7] The aim of this study was to evaluate bioethanol yield potential of six sweet sorghum cultivars (ICSV 93046, ICSV 700, Black Amber, White African, Gülşeker, and Red's Red) under second cropping conditions in a semi-arid Mediterranean environment.

2 Material and Methods

The field experiment was carried out at the experimental area of the Agricultural Faculty of Cukurova University in Adana during summer growing season of 2022. The location is under Mediterranean climate conditions, with hot and dry summers and temperate and rainy winters. In order to form a suitable seedbed before planting, the soil was first ploughed at a medium depth (30–40 cm) and immediately harrowed once with a field cultivator. 75 kg ha^{-1} of P2O5 and N were distributed to the all plots as pre-plant fertilizer in the form of compose fertilizer (20- 20-0), but potassium was not applied during the study because the soil was rich in K. On the other hand, the
rest of N (75 kg ha–1) was applied in the form of Urea (46%) when the plants reached the 5-leaf stage. Six sweet sorghum cultivars (ICSV 93046, ICSV 700, Black Amber, White African, Gülşeker, and Red's Red) were used as a planting material in the study. The field experiment was arranged according to a randomized complete block design with 3 replicates. The size of each sub-plot was 21 m2 (5 x 4.2 m). Sweet sorghum seeds were sown in 70 cm rows with a 10 cm inter-row spacing at approximately 2–3 cm depth in

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10 plants were randomly selected from each plot for juice extraction. In the plant samples, the roots, leaves, sheathes, and panicles were removed by hand, and then the stems were weighed to determine the stem ratio. Thereafter, stems were crushed at least five times to extract the juice through a sugarcane two-roller press. After extraction, the juice samples were weighted to determine the juice extraction ratio (JER). Brix degree (◦Bx) was recorded using a digital refractometer (HI 96801, Hanna instruments). Fresh stem yield (FSY), juice yield (JY), sugar content (SC), sugar yield (SY), and theoretical ethanol yield (TEY) were calculated according to the following equations [8,9]:

FSY (t ha–1) = stem ratio (%) × fresh biomass yiel (tha–1) (1)

JY (kg ha–1) = JER (%) × FSY (t ha–1) (2)

SC (%) = Brix (%) × 0.75 (3)

SY (kg ha–1) = SC (%) × JY (kg ha–1) (4)

TEY (L ha–1) = SY (kg ha–1) × conversion factor (0.581 L per kg of sugar) (5)

Analysis of the data was performed based on a randomized complete block design by an analysis of variance (ANOVA) model using JMP 8.0 (SAS Institute, Cary, NC, USA) statistical software. Statistical significance was determined as P = 0.05 via use of the least significant difference test.

3 Results and Discussion

Table 1. Theoretical ethanol yield and yield parameters of sweet sorghum cultivars

Cultivars	FSY ($t\ ha^{-1}$)	JY ($kg\ ha^{-1}$)	Brix (°Bx)	TEY (L ha^{-1})
ICSV 93046	58.81 a	16105 a	17.30 ab	1194 a
ICSV 700	52.61 a	9931 b	19.03 a	819 b
Gülşeker	28.39 b	7087 bc	10.50 d	322 d
Black Amber	28.25 b	7761 bc	16.17 bc	540 c
White African	27.70 b	7844 bc	14.40 c	489 cd
Red's Red	21.04 b	5825 c	19.93 a	509 c
Mean	36.13	9092	16.22	646
P-Value	0.0001	0.0007	0.0002	0.0001

ANOVA detected that FSY, JY, Brix degree, and TEY were significantly differed among the cultivars in the study. FSY ranged from 21.04 to 58.81 t ha–1 These results were similar to those reported in Guatemala [10] but were considerably higher than those reported in Virginia, USA [11] ICSV 93046 achieved the highest FSY followed by ICSV 700 with slight difference, while the lowest FSY was obtained from Red's Red.

JY ranged between 16105 and 5825 kg ha–1 in the study. Our results were comparable to those reported by [12] in central Missouri, USA but were considerably lower than those reported by [13] in Columbia city of Missouri, USA. As with FSY, ICSV 93046 exhibited the significantly highest JY, whereas the lowest was in Red's Red.

Brix degrees varied from 19.93 to 10.50 ◦Bx in the study. These results were considerably higher than those reported in semi-arid tropics [14] central Missouri, USA [12], Nebraska, USA [15], and Virginia, USA [16]. The highest brix degree was obtained from Red's Red followed by ICSV 700 with slight difference, while Gülşeker attained the lowest value.
TEY varied between 1194 and 322 L ha–1. Our results were higher than those reported by [17] in semi-arid tropical Indian condition, while they were markedly lower than those reported by [18] in Maryland, USA, [13] in Missouri, USA, [9] in Arizona, USA. As with FSY and JY, ICSV 93046 provided the significantly highest TEY in the study, while the lowest was obtained from White African.

4 Conclusion

The results obtained from the study indicated that ICSV 93046 was the most suitable cultivar to be grown as a second crop for sustainable bioethanol production under eastern Mediterranean conditions.

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