Original Research Article

Biomass and Dry Matter Yield Potential of Some Early Sweet Sorghum (*Sorghum bicolor var. saccharatum* (L.) Mohlenbr.) Genotypes

ABSTRACT

Sweet sorghum plant is a warm season annual crop. It can be used for animal feeding in the one-cut agricultural system. Sweet sorghum is grown for the purpose of fresh and dry grass and for silage production. Biomass of sweet sorghum is nutritive due to sweet sorghum stalk contains 15-20% sugar. The objectives of the study were to determine biomass, dry matter yield and some agricultural characteristics of some early sweet sorghum genotypes. Research was carried out during the second crop-growing season of 2016 at the Eyyubiye campus of experimental area of the Harran University in Sanliurfa, Turkiye. The experiment was designed as complete randomized blocks design with four replicates. In the study 12 early sweet sorghum genotypes were used as crop material. Some yield characteristics such as cluster formation period, plant height, stalk diameter, stalk ratio, leaf ratio, cluster ratio, dry matter yield and biomass yield were investigated in the experiment. Significant differences were found between the genotypes for tested characteristics ($P \leq 0.01$). Cluster formation period values ranged from 54.25 to 69.00 day, plant height from 252.25 to 340.75 cm, stalk diameter from 19.15 to 25.60 mm, stalk ratio from 75.72% to 86.75%. Leaf ratio values varied between 8.83% and 15.98%, cluster ratio between 4.40% and 10.31%. Dry matter yield values were between 2918.12 and 8456.25 kg da^{-1}, biomass yield values between 9283.5 and 18400.0 kg da^{-1}. It was determined that UNLY-hybrid-4, Rox Orange, Blue Ribben, and Colman sweet sorghum cultivars gave higher values than others in terms of plant height, dry matter yield and biomass yield.

Keywords: Sweet sorghum, plant height, dry matter yield, biomass yield

1. INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is a cereal grain. Sweet sorghum is a multipurpose crop providing food, feed, fiber, and fuel across a range of agroecosystems[1]. It is a C4 crop with low input requirements and accumulates high levels of sugars in its stalks.

Sweet sorghum adapts very well to different environmental conditions [2], obtains reliable yield even in extreme areas [3] and needs less nitrogen for high yield [4].

Sorghum can be grown in a wide range of soil and climatic conditions, and can thrive in arid areas. Sorghum is a multipurpose crop well adapted to environmental conditions ranging from tropical to temperate conditions [5]. Sweet sorghum is also adapted to widely differing soil conditions cause the cultivation of sweet sorghum in large areas.

Sweet sorghum requires less fertilizer and water to produce significant biomass. It also has a higher tolerance to salt and drought, and tolerance to biotic and abiotic stresses [6].

Sweet sorghum requires less water. In hot and dry regions of world, sorghum is a staple food. Its waxy leaves and deep roots are suited for dry climates. It tolerates drought and high-temperature stress better than many crops and has the capability of remaining dormant during the driest periods [7].

Sweet sorghum are very flexible in crop rotation and can be planted after many crops. Sweet sorghum may become more popular as drought-hardy food and fodder crop in the future.

Sweet sorghum has a wide range of uses such as ethanol production, energy production, animal feed, organic fertilizer and cellulosic raw material [8].

Sweet sorghum can be used the production of biofuels in two ways. The stalk and seed are used directly for biomass energy and their high sugar content allows them to be fermented to make ethanol. One of the main products from sweet sorghum is its sweet juice. Sweet sorghum is harvested for its juice before the mature plant forms clusters of grain. Sweet sorghum produces less grain but more biomass than grain sorghum. The stalks are pressed, and the juice is fermented and distilled for the production of biofuels. Forage sorghum is taller and produces more dry matter tonnage than grain sorghum. Because of its coarse stem, it's primarily used for silage.

Sweet sorghum has emerged as a promising target for sugar as well as lignocellulosic biofuel production. Sorghum biomass is burned by fast pyrolysis to produce syngas, bio-oil, and charcoal. In this system, the synthetic gas and bio-oil are used for transportation fuel, and the charcoal is applied to fields to improve soil structure.

Sorghum is also used for human nutrition all over the world [9]. Globally, over half of all sorghum is used for human consumption. Sorghum grain is higher in protein and lower in fat content. Grain sorghum is used for flours, porridges and side dishes, malted and distilled beverages, and specialty foods such as popped grain [10].

The bagasse can be used to or to produce electricity. The residual fiber (bagasse) from sweet sorghum can be used to feed livestock or pelletized to burn for heat in buildings, produce electricity, paper, and cattle fodder. Sweet sorghum is also considered to be a significant crop for animal feeds used as animal feed [11].

The sugar content in sweet sorghum is very high. The most sugar (78.7%) is found in the stem part. It is followed by panicles (2.99%) and leaves (2.54%), respectively. There are more than 14% sugar types on the stems and they are all evenly distributed. The most well-known of these; fructose, glucose and sucrose [12]. Sorghum has a great importance in the nutrition of cattle, sheep and poultry [13]. After the stem and leaves of the sorghum plant are chopped as green, they are used as straw and silage for feeding animals. For this reason, sorghum silage production has gained great importance especially in recent years [14].

The objectives of the study were to determine the biomass yield and some morphological characteristics related fodder of some early sweet sorghum genotypes in semi-arid climatic conditions.

Comment [A1]: Very long Introduction!!!

2. MATERIAL AND METHODS

This study was conducted in the experimental area of University of Harran at Eyyubiye campus as second crop conditions of 2016 in Sanliurfa, Turkiye. The experimental field is located in Harran Plain where the climate varies from arid to semi-arid. Table 1. provides the climatic data obtained at the Sanliurfa City Meteorological Station. As can be seen from Table 1. that the weather is hot and dry in the months of June, July and August where maximum temperatures were all above 40 ^{o}C while the relative humidity was below 50%. Rainfall was not seen from June to August in 2016.

Comment [A2]: This a part of the results

Table 1. Monthly some climatic data during 2016 sweet sorghum growth period in Sanliurfa†

Meteorological observations	May	June	July	August	Sept.	Oct.	Nov.
Av. Temp.^{0}C	22.6	27.1	30.6	29.2	26.9	20.8	14.0
Max. Temp. (°C)	35.5	40.5	41.8	42.2	36.2	31.0	22.4
Min. Temp. (°C)	9.30	13.1	15.4	16.2	14.0	9.2	1.7
Av. Humidity (%)	45.0	42.1	40.5	49.8	48.1	60.0	56.8
Min. Humidity (%)%)	16.0	14.3	13.0	24.2	21.2	16.4	20.2
Rainfall (mm) (kg/m^2)	16.4	0.0	0.0	0.0	1.0	15.8	26.4
Sunshine (hour)	10.8	12.4	12.6	11.5	9.3	6.40	6.2

†Data collected from the Sanliurfa Meteorological Station

The soil of the research field was clay, slightly alkaline, high in lime and very low in salt contents. Field capacity of the soil was 33.8% on dry basis, permanent wilting point was 22.6% and bulk density was 1.41 g cm^3. Some physical and chemical properties of research soil were given in Table 2.

Table 2. Some physical and chemical properties of research soil

Deep (cm)	Organic Matter (%)	Total Salt (%)	pH	$CaCo_3$ (%)	P_2O_5 (kg da^{-1})	K_2O (kg da^{-1})	N (%)	Texture (%)		
								Sand	Clay	Silt
0-20	1.26	0.098	7.65	38.25	3.3	95.3	0.26	2.42	15.12	82.46
20-40	1.68	0.086	7.64	42.61	3.6	93.2	0.35	5.50	8.41	86.08

Twelve early sweet sorghum genotypes (*Sorghum bicolor* (L.) Moench*ssp. saccharatum*) were used as crop material. Land was ploughed and cultivated then prepared for planting with a single pass of a disk-harrow. The experiment was laid out in a randomize block design with four replications. Each plot area was 14 m^2(5 m x 2.8 m) and consisted of four rows of 5 m in length. The plants were grown 70 cm apart between the rows with 15 cm spacing in each row. The seeds were sown in second part of June at a 50-60 mm depth. At sowing, 50 kg ha^{-1} of pure N, P and K, as a 15-15-15 composed fertilizer, was applied to each plot; this was followed by 50 kg ha^{-1} of N as urea when the plants reached 30-40 cm in height.

Irrigation water was first applied to all the plots using a sprinkler irrigation system. After the emergence of plants, plots were irrigated equally by the furrow irrigation system. All tested characteristics were measured on randomly selected 10 plants in the center of each plot. An analysis-of-variance (ANOVA) was performed using Jump statistical package program to evaluate statistically differences between results. Means of the data obtained from research were compared using Duncan test at $P \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1. Cluster Formation Period(day)

According to variance analyses, It was determined that there was a statistically significant difference between sweet sorghum cultivars in terms of cluster formation period (P≤0.01).As seen from table 3. that cluster formation periodvalues were ranged from 54.25 day to 69.00 day. The highest cluster formation period was found at Rex genotype whereas the lowest flowering value was seen at Norkan and Simon genotypes. Some of the genotypes such as Rex, Colman, UNL-Hiybrid 4, Honey and Blue Ribben gave higher cluster formation period value than other genotypes. Norkan, Simon, Mennonite,Rox Orange, Waconia-L genotypes' cluster formation period values were lover than 60 day. Some researchers reported different flowering duration values such as 55-72 day [15]and 69-88 day [16]in sorghum plant. Higher than our findings, Mulayim et al. [17] stated that they observed the earliest cluster formation time of 74 days in Bovital variety.

3.2. Plant Height (cm)

Variance analyses results show that there was a statistical difference at 1% significance level in terms of plant height between the tested cultivars. Plant height values varied between 252.25 cm and 340.75 cm. The longest plant height value was found at UNL-Hybrid-4 genotype whereas the shortest plant height was seen at Norkan genotype (Table 3). Average plant height value was found as 307.41 cm. Most of tested genotypes were over average plant height value. Plant height values of UNL-Hybrid-4, Colman, Early Folger,Blue Ribben, Honey, Rex, Rox Orange and Waconia-L genotypes were over than others whereas plant height values of Norkan, Simon, H. Sugarcane and Mennonita genotypes were lower.

Similar results were obtained by SkermanveRiveros[18]. Researchers reported that plant height values in sorghum were between 350 and 394 cm.Avcioglu et al. [19] stated that the plant height in sweet sorghum varied between 2.5 and 3.5 m. However, some researchers reported lower plant height values at sorghum such as 226 cm [20], 184.9 cm [21], 163.7 cm [22], 170.56 cm[23] and 204.0 cm [24].

It was observed that the plant height of the early flowering genotypes was shorter than the late flowering ones. The reason for the plant height difference may be due to the genetic characteristics of the cultivars.

3.3. Stem Diameter (mm)

According to variance analyses, differences among genotypes were significant (P≤0.01) at stem diameter. Stem diameter values ranged from 19.15 mm to 25.60 mm (Table 3). The highest stem diameter value was seen at Colman genotype whereas the lowest stem diameter value was found at Norkan genotype. Stem diameter values were higher at Blue Ribben, Colman and Early Folger genotypes than others. Manga et al. [25]reported that the stem thickness in sorghum could vary between 20 and 50 mm.

3.4. Stalk Ratio (%)

According to the variance analysis results, it was determined that there was a statistically significant difference at 0.01 level between the stalk ratios of sweet sorghum varieties. Stalk ratio values varied between 75.72% and 86.75% (Table 3). While the highest stem rate value was obtained from Waconia-L variety with 86.75%, the lowest value was determined in UNL-hybrid-4 variety with 75.72. In the studies carried out by some researchers, it has been reported that the stem rate is 87.54% [26] and varies between 60% and 84% [15].

Table 3. Cluster formation period, plant height, stem diameter and stalk ratio values

Genotypes	Cluster formation period (day)**	Plant height (cm)**	Stem diameter (mm)**	Stalk ratio (%)**

1.Blue Ribben	65.25 bc	316.50 abc	24.35 ab	81.72 bcd
2.Colman	68.50 ab	323.50 abc	25.60 a†	84.40 ab
3.Early Folger	60.00 de	327.75 ab	24.10 ab	79.07 cde
4.H.Sugarcane	63.50 cd	287.25 bcd	20.20 de	82.18 bcd
5.Honey	65.25 bc	322.00 abc	20.80 cde	80.48 bcd
6.Mennonite	59.50 ef	284.50 bcd	22.85 bc	81.73 bcd
7.Norkan	54.25 g	252.25 d	19.15 e	78.85 cde
8.Rex	69.00 a	313.00 abc	20.05 de	82.93 abc
9.Rox Orange	56.00 fg	329.00 ab	21.85 bcd	78.36 de
10.Simon	54.25 g	277.50 cd	21.35 cde	82.23 bcd
11.UNL-hybrid-4	65.75 abc	340.75 a	22.55 bcd	75.72 e
12.Waconia-L	59.00 ef	315.00 abc	21.50 cde	86.75 a
Mean	61.68	307.41	1.33	81.20
CV (%)	2.378	6.228	4.695	2.155
LSD	3.64	47.53	1.29	4.34

†There is no statistical difference among values annotated with the same letter in a column
** : denotes P≤0.01

3.5. Leaf Ratio (%)

It was determined that there was a statistically significant difference between tested sweet sorghum cultivars in terms of leaf ratios (P≤0.01). Leaf ratio values varied between 8.83% and 15.98%. While the highest value was obtained from Early Folger variety with 15.98%, the lowest value was found in Waconia-L variety with 8.83% (Table 4). In a similar study, it was determined that the leaf ratio of the cultivars varied between 9% and 14% [27]. Ricaud and Arceneaux[28] reported a lower leaf rate (8.4%) than our findings.

3.6. Cluster Ratio (%)

It was determined that there was a statistically significant difference at 0.01 level among sorghum cultivars in terms of cluster ratio. Cluster ratio values varied between 4.40% and 10.31%. In the research, the highest value was obtained from Norkan variety with 10.31 % (Table 4). This cultivar was followed by Rox Orange, UNL-hybrid-4 and Mennonite cultivars with 10.09%, 8.51% and 7.92%, respectively. The lowest value was found in Waconia-L variety with 4.40%. Similar to our findings; Gul and Basbag[22] stated that the cluster ratio in sorghum varies between 5% and 13%. Yıldızet al. [29] found the cluster rate to be 19.3%-38.6% higher than our findings, and Yılmaz [30] reported that the cluster rates ranged between 11% and 12%.

3.7. Dry Matter Yield (kg da^{-1})

According to variance analyses, sweet sorghum genotypes were significant for dry matter yield (P≤0.01). Dry matter yield values were varied from 2918.12 kg da^{-1} to 8456.25 kg da^{-1} (Table 4). The highest dry matter yield value was obtained from UNL-hybrid-4 genotype whereas the lowest values were seen at Rex genotype. There was a big difference at dry matter yield among tested sweet sorghum genotypes. Differences were 5538.13 kg da^{-1} between the lowest and highest dry matter yield values. UNL-hybrid-4, Waconia-L, Rox Orande and Mennonite genotypes gave higher dry matter yield than others (Fig. 1). As lower than our findings; some researchers reported dry matter yield values between 760 and 1610 kg da^{-1}[31] and between 1001.3 and 1850 kg da^{-1}[22] in sorghum plant.

Table 4. leaf ratio, cluster rate, dry matter yield and biomass yield values

Genotypes	Leaf ratio (%)**	Cluster rate (%)**	Dry matter yield (kg da^{-1})**	Biomass yield (kg da^{-1})**
1.Blue Ribben	11.79 c†	6.48 bcd	3670.00 ef	15600.00 ab
2.Colman	8.84 d	6.74 bcd	4450.00 de	14540.25 bc

3.Early Folger	15.98 a	4.94 cd	3750.00 ef	11196.00 de
4.H.Sugarcane	11.21 cd	6.60 bcd	3017.50 f	9283.50 e
5.Honey	13.10 bc	6.40 bcd	3441.25 f	12240.80 cd
6.Mennonite	10.33 cd	7.92 ab	5520.00 bc	14322.00 bc
7.Norkan	10.83 cd	10.31 a	3127.50 f	9412.50 de
8.Rex	12.23 c	4.82 cd	2918.12 f	9531.00 de
9.Rox Orange	11.53 cd	10.09 a	6301.25 b	16350.00 ab
10.Simon	10.77 cd	6.99 bc	5298.75 cd	9606.00 de
11.UNL-hybrid-4	15.76 ab	8.51 ab	8456.25 a	18400.50 a
12.Waconia-L	8.83 d	4.40 d	5993.75 bc	10864.50 de
Mean	11.77	7.02	4662.03	12612.25
CV (%)	9.549	14.502	8.139	9.233
LSD	2.79	2.79	942.08	2891.13

†There is no statistical difference among values annotated with the same letter in a column
** : denotes P≤0.01

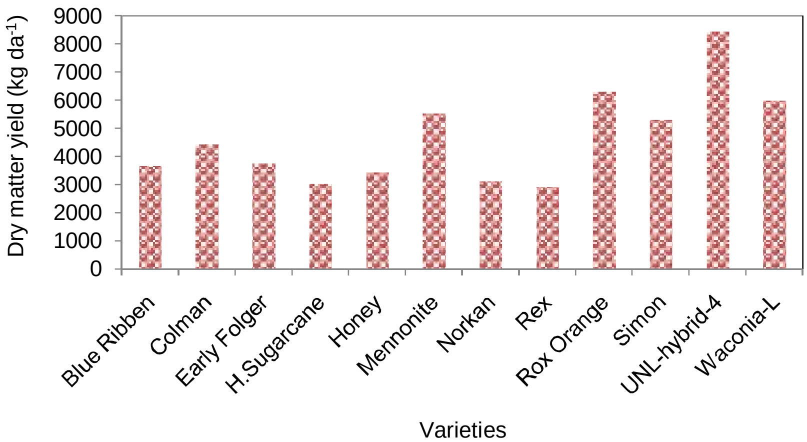

Fig. 1. Dry matter yield values of different sweet sorghum cultivars

3.8. Biomass Yield (kg da^{-1})

Significant differences (P≤0.01) were seen among sweet sorghum genotypes for biomass yield. Biomass yield values ranged from 9283.5 kg da^{-1} to 18400.0 kg da^{-1} (Table 4). It was seen big differences about biomass yield among tested sweet sorghum genotypes. There was 9116.5 kg da^{-1} between the lowest and highest biomass yield.

The highest biomass yield value was seen at UNLY-hybrid-4 genotype whereas the lowest biomass yield value was found at H. Sugarcane genotype(Fig. 2). Some of the genotypes such as Rox Orange, Blue Ribben, Colman, Mennonite, Honey genotypes gave higher biomass yield than other genotypes.

Similar results were reported by Grassi[12] as between 50 and 90 t ha^{-1}. But lower biomass yield values than our findings were reported as 5600 kg da^{-1}[24] and as 6800 kg da^{-1}[20] and

5900 kg da^{-1}[28]. Mahmood and Honermeir[32] stated that there is a significant difference between the varieties in terms of biomass yield and chemical composition. Avcioglu et al. [19] stated that the biomass yield is high in sweet sorghum.

As seen from Table 3 and Table 4 that biomass yield values were higher at some genotypes, which has long cluster formation period. Dogget[5] reported that late maturated genotypes were high yielding than earlier sweet sorghum genotypes.

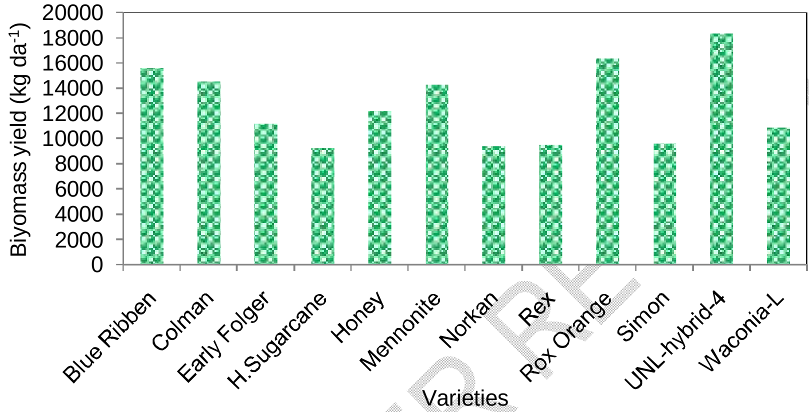

Fig. 2. Biomass yield values of different sweet sorghum varieties

4. CONCLUSION

Among the tested gonotypes, Norkan and Simon were determined as the earliest and Rex as the latest genotypes. UNL-Hybrid-4, Early Folger, Colman and Honey genotypes had longer plant heights. Leaf ratio values, which have an important place in animal nutrition, were found to be higher in UNL-hybrid-4 and Early Folger genotypes. UNL-hybrid-4 and Rox Orange genotypes gave the highest dry matter and biomass yield. Considering the biomass and dry matter yields, it was determined that UNL-Hybrid-4, Rox Orange and Blue Ribben genotypes could be preferred in animal nutrition.

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