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Performances of Some Sorghum Genotypes Under Eskişehir Ecological Conditions

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Abstract

The research was conducted in the 2023 growing season as a second crop after the wheat harvest, with the aim of determining the yield characteristics of some sorghum genotypes that can be grown under the ecological conditions of Eskişehir. The experiment was established according to the randomized complete block design with three replications. The study examined the number of days to 50% flowering, plant height, number of tillers per plant, stem diameter, leaf ratio, stem ratio in the plant, dry matter ratio, and green forage yield. Significant differences were found among the lines and varieties for all the studied traits. According to the research results, the days to 50% flowering of different varieties and lines ranged from 72.0 to 87.7 days, plant heights from 122.7 to 315.0 cm, the average number of tillers per genotype was 2.6, stem diameter ranged from 7.9 to 18.3 mm, leaf ratios from 10.9% to 22.9%, stem ratio from 77.1% to 89.6%, dry matter ratios from 15.6% to 30.9%, and green forage yields from 2152.0 to 5614.1 kg da^{-1}. It is recommended to cultivate the Greengo and Erdurmuş varieties and the line number 12 in Eskişehir and similar ecological conditions in terms of green forage yield. However, more studies should be conducted, as single-year results do not always yield correct outcomes in agricultural production.

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1. Introduction

The rapidly increasing global population and diminishing agricultural lands make global food production challenging. Increasing the yield of crops per unit area is an important solution to overcome these challenges (Acar et al., 2000). The importance of plant species and varieties with high adaptation capabilities is increasing every day in the agricultural sector.

The livestock sector in Turkey faces challenges due to the lack of quality roughage, which hinders the balanced nutrition of animals, reducing productivity and negatively impacting the national economy (Ayan et al., 2006). The annual quality feed demand for the existing animal cannot be met with the current feed resources, leading to insufficient nutrition and productivity losses for the animals (Anonymous, 2022). The challenges in animal nutrition are particularly evident in arid and semi-arid regions where limited vegetation and water sources make it difficult to meet roughage needs (Akbudak et al., 2004). Research to increase the production of fodder plants is strategically important to bridge the gap in roughage. The scarcity of water in arid and semi-arid regions exacerbates this problem. Therefore, cultivating plants with drought and heat resistance in these regions will not only solve the problem but also ensure efficient and sustainable use of resources. Sorghum and its hybrids play a critical role in agriculture due to their adaptability, regrowth abilities, and high nutritional values (Acar et al., 2001). Its greater tolerance to drought conditions compared to corn, ability to grow in saline soils, and resistance to diseases and pests (Almodares and Hadi, 2009) make it significant. Moreover, sorghum-sudangrass hybrids stand out for their lower sensitivity to water stress compared to corn, their ability to be harvested multiple times in different periods, various usage options (green fodder, dry fodder, or silage), and their yield potential (Acar et al., 2001).

Changing climate and ecological conditions have become significant factors affecting the agricultural sector. The need for drought-resistant plant species that efficiently use water is increasing every day for sustainable agriculture in the Central Anatolia region, where water is scarce. Cultivating sorghum varieties with high yield and quality traits that are resistant to adverse environmental factors will make this plant an alternative resource, contributing significantly to the regional and national economy. This study was conducted to determine the performance characteristics of some sorghum genotypes under Eskişehir ecological conditions.

2. Materials and Methods

In the experimental fields of Eskişehir Osmangazi University Faculty of Agriculture, the study was conducted as a second crop after the wheat harvest during June-August 2023, using 22 sorghum lines and varieties (8, 12, 32-1, 104, 301, 302, 304, B305, G310, K311, Aldarı, Beydarı, Öğretmenoğlu, Uzun, Erdurmuş, Gözde-80, Greengo, Haybuster, E:Sumoc, Rox, Leoti, Nes). The 22 sorghum genotypes used were obtained from the West Mediterranean Agricultural Research Institute and Uludağ University. The soil of the experimental area is clay-loam, slightly calcareous (14.61%), slightly alkaline (7.68%), salt-free (0.07%), deficient in organic matter (1.62%), rich in potassium (168.80 kg da^{-1}), and has an adequate phosphorus content (6.16 kg da^{-1}). The climatic characteristics of the ecology where the research was conducted are given in Table 1. Eskişehir, where the continental climate prevails, has an average total annual precipitation of 291.7 mm, with the highest monthly rainfall occurring in June (62.0 mm). The average temperature reaches its highest at 21.5°C in July and 21.4°C in August, and the lowest at -0.2°C in January. The relative humidity in 2023 (66.4%) was higher than the long-term average relative humidity (61.7%) (Table 1).

Table 1. Some climate data of the area where the experiment was conducted between long term average (LTA) 1928-2024 and 2023

	Precipitation		Temperature		Relative Humidity	
	2023	LTA	2023	LTA	2023	LTA
January	16.5	40.0	3.5	-0.2	77.8	75.2
February	15.0	32.8	2.5	1.4	70.3	71.0
March	115.7	35.3	7.4	5.0	76.1	65.0
April	41.1	38.4	10.7	10.2	64.8	62.4
May	59.6	44.9	14.5	15.0	71.9	59.9
June	62.0	33.6	19.4	18.9	67.3	55.0
July	0.6	13.2	23.6	21.5	50.6	51.8
Agust	0.1	8.7	25.9	21.4	49.9	52.9
September	21.2	15.9	19.9	17.4	59.2	58.4
October	24.8	28.9	15.3	12.9	76.4	65.2
Total/Av.	356.6	291.7	14.3	12.4	66.4	61.7

The experiment was established according to the randomized complete block design with three replications. Each plot was 5 meters long and consisted of 5 rows. The planting area was prepared for sowing after the wheat harvest by harrowing and tilling, and sowing was done by hand on 15 June 2023 at a rate of 2.5 kg da^{-1} in rows spaced 0.6 m (Açıkgöz, 1995). In the experimental area, 2 kg da^{-1} of nitrogen and 5 kg da^{-1} of phosphorus were applied as basal fertilizer in the form of diammonium phosphate. Weed control in the study was done by hand when the sorghum plants were approximately 10-15 cm tall. After weed control, 15 kg da^{-1} of nitrogen fertilizer (Ammonium sulfate) was applied. Plants were irrigated with sprinklers until the soil reached field capacity whenever needed. Harvesting was done by hand with a sickle on 29.08.2023 when the plants reached 50% flowering, after removing one row from the edge of the plot and 50 cm from the edge effect (head and end rows). After harvesting, the fresh weights were weighed and recorded. From each plot, 10 plants were randomly selected and taken to the laboratory for necessary observations and measurements (plant height, number of tillers, stem thickness, leaf ratio, stem ratio). Samples weighing 500 g taken from the fresh weighed samples were dried in an oven at 105°C until they reached a constant weight, then weighed and proportioned to determine the dry matter ratio. The data obtained from the research were subjected to variance analysis using the StatView package program (SAS Institute, 2011), and the means were compared with Scheffe's multiple comparison test.

3. Results and Discussion

3.1. Days to 50% flowering

The results for the days to 50% flowering and averages of sorghum genotypes grown under Eskişehir conditions are presented in Table 2. The average days to 50% flowering ranged from 72.0 to 87.7 days, with an average of 78.6 days. Significant differences were observed among genotypes ($p<0.001$). The 302 line was the latest to flower (87.7 days), while the B305, 304, and G310 lines were the earliest, flowering at 72.0 days.

The duration of flowering and the extension of vegetation and maturation allow for more efficient use of resources, resulting in higher yields. This leads to an increase in dry matter production and yield (Öktem et al., 2021). Since the genotypes used in the study have different purposes and genotypic characteristics, it is expected that their days to flowering will vary. Bhale and Borikar (1982), Dogget (1988), and Çeçen et al. (2005) have reported differences in the days to flowering among sorghum genotypes with different characteristics in their studies.

3.2. Plant height

Significant differences were found in plant height among the genotypes ($p \leq 0.01$). The plant heights of sorghum lines and varieties ranged from 122.7 to 315.0 cm, with an average plant height of 209.5 cm (Table 2). The tallest plant height was measured at 315.0 cm in the K311 line, while the shortest plant heights suitable for grain production were measured in the Aldarı (122.7cm) and Öğretmenoğlu (127.0 cm) varieties (Table 2).

Table 2. Average 50% number of flowering days, plant height, number of tiller per plant and stem thickness values and statistical analysis of sorghum genotypes

Sorghum varieties/lines	50% Number of days to flowering (days)	Plant height (cm)	Number of tillers (per plant)	Stem thickness (mm)
104	78.67 abc	258.00 A-C	2.67 a-d	7.93 D
12	74.00 bc	201.00 A-E	3.00 a-d	18.23 A
301	79.67 abc	282.67 AB	1.33 d	12.87 A-D
302	87.67 a	269.00 A-C	1.67 cd	16.97 A
304	72.00 c	265.00 A-C	1.67 cd	14.03 A-D
32-1	78.33 abc	255. 00 A-C	2.00 b-d	13.67 A-D
8	81.00 abc	208.67 A-E	2.00 b-d	11.33 A-D
Aldarı	78.67 abc	122.67 E	2.67 a-d	15.00 A-C
B305	72.00 c	252.33 A-D	3.67 abc	9.33 B-D
Beydarı	76.33 bc	139.00 DE	2.33 a-d	17.80 A
E: Sumoc	83.00 ab	185.00 B-E	3.33 a-d	16.27 A
Erdurmuş	80.67 abc	220.00 A-E	2.67 a-d	17.60 A
G310	72.00 c	269.33 A-C	2.33 a-d	15.50 AB
Gözde 80	80.67 abc	222.67 A-E	3.33 a-d	8.70 CD
Greengo	78.67 abc	179.33 B-E	4.00 ab	17.00 A
Haybuster	74.00 bc	213.67 A-E	4.00 ab	11.83 A-D
K311	83.00 ab	315.00 A	1.67 cd	14.50 A-C
Leoti	80.67 abc	204.33 A-E	2.33 a-d	17.63 A
Nes	76.33 bc	157.67 C-E	2.00 b-d	16.50 A
Öğretmenoğlu	79.67 abc	127.00 E	3.00 a-d	16.20 A
Rox	83.00 ab	169.00 B-E	4.33 a	18.00 A
Uzun	78.33 abc	137.00 DE	2.00 b-d	16.00 A
Overall Average	**78.56**	**209.45**	**2.64**	**14.68**
Variance of analysis	**1.840***	**6.052****	**2.123***	**5.798****

Plant height is a morphological property that emerges under the influence of genetic structure and ecological factors. Differences among genotypes grown under the same environmental conditions, with the same care and other procedures, are due to the genetic structure of the plant (Tanrıkulu et al., 2020). The difference among the genotypes used in the study is inevitable due to their characteristics. Since the genotypes used are suitable for grain, syrup, and fodder production, their plant heights are expected to differ. The plant heights of the selected genotypes are similar to those obtained in studies conducted in different geographies around the world (Bhale and Borikar, 1982; Karataş, 2011; Afzal et al., 2012).

3.3. Number of tillers

The average number of tillers per plant was determined to be 2.6. The highest number of tillers was observed in the Rox silage sorghum variety (4.3 tillers/plant), followed by Haybuster and Greengo varieties (4.0 tillers/plant). The lowest number of tillers was observed in line 301 (1.33 tillers/plant) (Table 2). The number of tillers showed differences at the 5% level.

The number of tillers is an important property affecting the forage yield and quality of cereal forage plants. Tillering is influenced by cultivation (planting density, planting time, planting depth), climate, and soil properties, as well as the genotypic characteristics of the variety (Açıkgöz, 1995). Gençkan (1983) reported that the sorghum plant has a high tillering ability. The study also showed that sorghum genotypes suitable for different purposes exhibited differences in the number of tillers per plant, which is attributed to genetic differences among the genotypes.

3.4. Stem diameter

The stem diameter of the genotypes varied from 7.9 to 18.2 mm, with the highest stem diameter measured at 18.23 mm in line 12, and the lowest at 7.9 mm in line 104 (Table 2). The stem diameters of sorghum lines and varieties were found to be statistically significant at the 1% level.

The amount and stem diameter of the main stem in the sorghum plant are important factors in both plant cultivation and animal feeding. The diameter of the main stem can vary depending on the plant type and growing conditions (Öktem et al., 2021). While a diameter main stem in the plant may increase yield, if the sorghum varieties are not used for silage, it is desired that the stem be thin for the fodder to dry and be preferred by animals. Indeed, the study also showed that sorghum genotypes suitable for different purposes exhibited differences in stem diameter. This difference is due to genetic differences among genotypes and different usage purposes. Similar results have been found in studies conducted, showing differences in stem diameter among sorghum genotypes (Özmen, 2017; Çoban and Acar, 2018; Başaran, 2011).

3.5. Leaf ratio

The highest leaf ratio among the evaluated sorghum genotypes was 22.9% in sweet sorghum (Uzun), the lowest was 10.9% in line 8, and the average leaf ratio was recorded as 15.8% (Table 3). Statistically significant differences were found among genotypes at the 1% level.

Table 3. Average leaf ratio, stem ratio, dry matter ratio, fresh yield values and statistical analyses of sorghum genotypes

Sorghum varieties/lines	Leaf ratio (%)	Stem ratio (%)	Dry matter ratio (%)	Green forage yield (kg da^{-1})
104	13.98 B-D	86.02 A-C	21.94 C-G	3760.80 B-E
12	12.28 C-D	82.72 AB	19.40 D-K	4205.57 B
301	17.23 A-D	82.77 A-D	22.72 C-F	2297.43 G-K
302	16.21 B-D	83.79 A-C	17.76 F-K	3469.40 B-G
304	15.57 B-D	84.43 A-C	27.96 AB	2922.93 C-K
32-1	14.48 B-D	85.52 A-C	26.64 A-C	3607.77 B-E
8	10.94 D	89.06 A	24.40 B-D	3881.10 B-D
Aldarı	14.41 B-D	85.59 A-C	23.27 B-E	2386.27 F-K
B305	12.94 B-D	87.06 A-C	29.33 A	3253.57 B-K
Beydarı	16.85 B-D	83.15 A-C	20.75 D-H	2580.60 E-K
E: Sumoc	15.35 B-D	84.65 A-C	17.36 G-K	3393.93 B-H
Erdurmuş	16.43 B-D	83.57 A-C	16.69 G-K	5614.07 A
G310	16.01 B-D	83.99 A-C	23.48 B-E	2152.07 K
Gözde 80	16.18 B-D	83.82 A-C	30.85 A	4033.33 BC
Greengo	18.45 A-C	81.55 B-D	18.78 E-K	5190.53 A
Haybuster	14.60 B-D	85.40 A-C	20.48 D-K	3373.30 B-H
K311	18.45 A-C	81.55 B-D	30.53 A	3517.03 B-F
Leoti	13.29 B-D	86.71 A-C	17.53 F-K	4060.37 BC
Nes	18.83 AB	81.17 CD	16.17 H-K	2864.40 C-K
Öğretmenoğlu	17.78 A-C	82.22 B-D	15.36 K	2270.77 HK
Rox	16.25 B-D	83.75 A-C	18.76 E-K	3259.57 B-K
Uzun	22.89 A	77.11 D	18.86 E-K	2737.53 D-K
Overall Average	**15.88**	**83.89**	**21.77**	**3401.47**
Variance of analysis	**4.612****	**4.612****	**20.748****	**14,907****

The leaf ratio is influential in the quality of fodder plants grown for fodder. A higher leaf ratio increases fodder quality and palatability, encouraging animals to consume the fodder more eagerly (Budak and Budak, 2014). A high leaf ratio in the sorghum plant increases photosynthesis capacity and nutritional value. Therefore, more nutritious and productive material is obtained from plants with a high leaf ratio, and yield increases with increased photosynthesis rate (Budak and Budak, 2014). Significant differences in leaf ratio among genotypes are observed. Differences among genotypes grown in the same environment are the result of genetic differences and different production purposes of the genotypes (Tanrıkulu et al., 2020). Similar results have been obtained in studies (Mülayim et al., 2009; Salman and Budak, 2015; Çoban and Acar, 2018).

3.6. Stem ratio

The average stem ratio of sorghum genotypes was determined to be 83.9%. The highest stem ratio was 89.06% in line 8, and the lowest was 77.1% in the sweet sorghum variety Uzun (Table 3). Significant differences were found in the stem ratios among sorghum genotypes ($p<0.001$). A low stem ratio in the sorghum plant indicates higher fodder quality (Budak and Budak, 2014). As the plant height increases, the leaf ratio decreases, while the stem ratio increases (Küçüksemerci and Baytekin, 2017). Indeed, significant differences were found among genotypes in the study. Similar results have been obtained in studies conducted in different ecologies in our country (Salman and Budak, 2001; Mülayim et al., 2009).

3.7. Dry matter ratio

Significant differences were observed in the dry matter ratio among genotypes ($p\leq0.001$), ranging from 15.4% to 30.9% (Table 3). The lowest dry matter ratio was observed in the Öğretmenoğlu variety (15.4%), suitable for grain production, and the highest in the Gözde-80 variety (30.9%). The average dry matter ratio was determined to be 21.8% (Table 3). Lines suitable for silage, such as B305 (29.33%), 304 (27.96%), 32-1 (26.6%), 8 (24.4%), and G310 (23.5%), were notable for their dry matter ratios.

The variation in dry matter production among plant genotypes is due to a variety of factors (Castanho et al., 2015). A longer generative period leads to prolonged maturation, which positively affects yield. Genotypes with longer vegetation periods benefit from climate, soil, and sunlight for longer periods, resulting in higher dry matter production and yield (Öktem et al., 2021). The characteristics of genotypes, genetic differences, and different usage purposes affect the dry matter ratio. The study expected that genotypes with different usage and genetic characteristics would have different dry matter ratios. Some studies have reported that differences in dry matter yield or ratio among sorghum genotypes are expected (Atış et al., 2012; Atalay, 2019; Bilen and Türk, 2021).

3.8. Green forage yield

Significant differences were found in the green forage yields of sorghum lines and varieties ($p<0.001$). In Eskişehir conditions, the highest green forage yield was observed in the Erdurmuş variety (5614.1 kg da^{-1}), and the lowest in the G310 line (2152.0 kg da^{-1}) (Table 3). The Erdurmuş variety stands out in terms of green forage yield. Factors such as plant species and variety, the number of plants per square meter, maturation period of the plants, harvest time, and cultivation methods influence the green forage yield (Öktem et al., 2021). Significant differences in green forage yield among genotypes are observed. The difference among genotypes grown in the same environment is due to genetic differences and the different purposes for which the genotypes are produced (Tanrıkulu et al., 2020). Studies conducted in our country have reported that sorghum genotypes show different performances in varying ecologies in terms of yield (Hosaflıoğlu, 1998; Acar et al., 2000; Çelik and Türk, 2021).

4. Conclusions

According to the research results; the days to 50% flowering in sorghum genotypes ranged from 72.0 to 87.7 days, plant heights from 122.7 to 315.0 cm, the number of tillers 2.6 (per plant), stem diameter from 7.9 to 18.3 mm. The leaf ratios of genotypes ranged from 10.9% to 22.9%, stem ratio from 77.1% to 89.6%, dry matter ratios from 15.6% to 30.9%, and green forage yields from 2152.0 to 5614.1 kg da^{-1}. When the results of the one-year study are examined, it is determined that sorghum has high adaptation capabilities in Eskişehir province and similar ecological conditions, can be easily cultivated in similar ecologies, and can yield high yields. Cultivating these genotypes in Eskişehir ecological conditions will provide the silage material needed in dry conditions. However, the varieties and lines to be used must have usage characteristics that will not harm animals according to their purpose. Since single-year results are not preferred in field trials, it is recommended to increase the number of sorghum genotypes cultivated and conduct trials for a few more years to provide healthier results for recommendations.

Declaration of Author Contributions

The authors declare that they have contributed equally to the article. All authors declare that they have seen/read and approved the final version of the article ready for publication.

Declaration of Conflicts of Interest

All authors declare that there is no conflict of interest related to this article.

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