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Determining Forage and Quality Traits of Some Sorghum Genotypes under the Ecological Conditions of Muş

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ABSTRACT

This study was conducted to determine the forage yield and quality of sorghum genotypes to be grown in Muş province. The research was carried out in 2022 in Muş province. The aim of the research was to determine the grass yield and quality of (Akdarı, 26, Mataco, Talisman, Karaca Melez, 305, Uzun, Hulk, Gözde 80, Early Sumac, Rox, 310, Aldarı, Öğretmen Oğlu, 314, Leoti, Erdurmuş, Beydarı) genotypes in some 14 Sorghum and Sorghum Sudan grass hybrids an 4 candidate cultivars under the Muş ecological conditions, The experiment was designed in a randomized block design with three replications. The plants' height ranged from 96.33 to 243.66 cm, single plant weight ranged from 868.33 to 2418.33 g, dry matter yield per decare varied between 345.95 and 1057.18 kg, and crude protein content ranged from 6.08% to 10.02%. According to the results of this study, in terms of quality, the genotypes Leoti, Uzun, and Beydarı stood out, while in terms of yield, the genotypes Gözde 80, Uzun, and Mataco were more prominent. For obtaining good yields in the ecological conditions of Muş and similar regions, it is recommended to grow one of the Gözde 80, Uzun, or Mataco genotypes. Considering both yield and quality, the Uzun genotype, which is in the high statistical groups, would be the most suitable choice for cultivation.

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INTRODUCTION

Sorghum (Sorghum bicolor L.) is an annual warm-season cereal crop that has gained global importance due to its versatility and adaptability (Kumuk and Avcıoğlu, 1986). It ranks fifth worldwide in terms of production and utilization, following barley, maize, wheat, and rice (Ebrahim, 2014). Sorghum is extensively cultivated in the United States, as well as in parts of Africa, Asia, and Central and South America, covering approximately 40 million hectares with an annual production of around 58 million tons. Major producers include the United States, Nigeria, Ethiopia, India, and Mexico. In terms of yield, countries such as Oman, Israel, Jordan, Uzbekistan, Austria, Italy, and Türkiye are among the top performers. According to the Turkish Statistical Institute (Anonymous, 2022a), sorghum production in Türkiye reached 117,093 tons across 29,263 decares.

Traditionally used as animal feed, sorghum has recently gained importance in human nutrition, particularly with the growing demand for gluten-free diets. It is a safe and nutrient-rich option for individuals with celiac disease and is increasingly used in products such as bread, cakes, cookies, breakfast cereals, and alcoholic beverages (Schober et al., 2005, Yousif et al., 2012, Aljobair, 2022). While 75% of global sorghum is used for human consumption, this figure varies significantly between regions. In developing countries, about 56% of sorghum is consumed by humans, compared to just 2% in developed countries, where its use as animal feed is more dominant (Anonymous, 1996; Fageria et al., 1997).

Sorghum stands out due to its drought tolerance, efficient water use, and high biomass production. It can be grown as fresh or dry forage and is suitable for hot, arid climates where irrigation is limited. Its rapid regrowth after cutting, resistance to pests and diseases, and high green fodder yield make it a strong alternative to maize (Çiğdem and Uzun, 2006). New silage-type sorghum cultivars have been developed that are taller, more productive, and comparable in quality to maize. Optimal harvesting time for silage sorghum is at the mid-dough grain stage when plant moisture content is between 65–70% (Undersander et al., 1990, Bulut et al., 2023).

Muş, located in eastern Türkiye, is among the provinces with the highest livestock potential. In 2022, it ranked 15th in registered cattle numbers and 12th in small ruminant population nationwide. However, livestock productivity in the region remains constrained by the high cost of feed, which accounts for 60–70% of total production expenses. Muş's land uses 42% agricultural land, 34% pasture, 11.5% natural meadow, 9% forest, and 3.5% non-arable land—along with its arid climate, presents a suitable environment for sorghum cultivation as an alternative to maize. Furthermore, sorghum can contribute to the rehabilitation of meadows and pastures by providing a cost-effective and locally adaptable roughage source (Anonymous, 1996).

This study was conducted in the ecologically significant Muş Plain to evaluate the forage yield and quality of 18 sorghum and sorghum–Sudan grass hybrid genotypes. The objective was to identify genotypes capable of producing high biomass with efficient water use under local climatic conditions, contributing to the sustainability of livestock farming through low-cost, drought-tolerant, and disease-resistant forage production.

MATERIAL and METHOD

Materials
Experimental Site

The field trial was conducted during the 2022 growing season in Muş Province, Türkiye. The experiment was established in parcel number 3 of block 105, located in Muratgören village, approximately 15 km from the city center (Figure).

Figure. Experimental plant location

Climate Characteristics of the Experimental Site

According to data from the Turkish State Meteorological Service, the average temperature during the trial period from June to September was recorded as 22.38 °C, compared to the long-term average of 22.46 °C. The total precipitation was 40.53 mm, while the long-term total precipitation was 55.80 mm (Anonymous, 2022b) (Table 1).

Table 1. Average precipitation and temperature data for Muş province from 1991 to 2022.

Month	Average Temperature (°C)		Precipitation Amount (mm)	
	1991-2022	**2022**	**1991-2022**	**2022**
June	20.16	19.88	27.10	21.43
July	24.75	24.16	7.70	1.15
August	24.98	25.54	5.40	0.77
September	19.96	19.94	15.60	17.18
Average/Total	22.46	22.38	55.80	40.53

Method

Experiment Implementation

Soil Companent

The soil of the experimental area is classified as clay loam, non-saline, and slightly acidic. It has moderate levels of plant-available phosphorus and organic matter, a medium lime content, and is rich in potassium (Aydeniz and Brohi, 1993).

Planting

In the study, seeds were manually sown in 4 rows with a 70 cm row spacing and a 4-5 cm sowing depth. Planting was done on June 1, 2022, by hand broadcasting, with a seeding rate of 1.5 kilograms per decare. The experiment was designed according to a Randomized Complete Block Design with three replications. The plot area was 5m × 2.8m = 14m² (Fernandez et al., 2012).

Maintenance

Since sorghum seeds are small, thinning and singling were performed after manual planting to achieve the desired plant density. A total of 14 kg of nitrogen (N) per decare (33% Ammonium Nitrate) was applied. Half of the nitrogen (7.0 kg/da) was applied at planting, and the remaining half (7.0 kg/da) was applied when plants reached a height of 40-50 cm. Additionally, 8 kg/da of P_2O_5 (Triple Superphosphate) was applied (Avcı et al., 2018). Weed control was performed by hoeing when the plants reached a height of 15-20 cm and further weed control and root collar filling were carried out when the plants reached 40-50 cm in height.

Irrigation

Irrigation is essential for improving plant productivity. For this purpose, the trial plots were irrigated using furrow irrigation after sprinkler irrigation when the plants reached a height of 100-120 cm.

Harvest

Sorghum varieties were harvested between September 10-11, 2022, during the dough stage. The central two rows and the two rows at the edges of the plot (30 cm from the edge) were excluded from the analysis as border effects. The harvested sorghum plants were weighed for fresh weight, and 10 randomly selected plants from the central two rows of each plot were set aside for observation and measurement.

Traits Measured in the Experiment

Observations on the plants were made on 10 randomly selected plants from the central two rows (Anonymous, 2010).

1. **Plant Height**: The vertical distance from the surface to the tips of 10 randomly selected plants in the central two rows of each plot was measured (Anonymous, 2010).

2. **Dry Matter Yield**: The green biomass of 10 plants randomly selected from the central two

rows of each plot was weighed, then dried and reweighed to determine the Dry Matter Yield (DMY) (Anonymous, 2010).

3. **Single Plant Weight**: Ten plants, cut at a height of 5 cm from the soil surface, were weighed individually to determine their fresh weight (Anomymous, 2010).

4. **Total Plant Crude Protein Content**: For crude protein analysis, 10 plants from the central two rows of each plot were selected, four of which were taken as whole plants, ground, and processed. Protein content was determined using the Kjeldahl method under laboratory conditions. The plants were ground through a 1 mm sieve, and 0.5 grams of the sample were weighed. The total nitrogen content was determined by dry combustion. The total nitrogen value was then multiplied by a factor of 6.25 to calculate the crude protein content (Yavuz, 2011).

Data Evaluation: The data obtained were analyzed using variance analysis according to the Randomized Complete Block Design with the JMP statistical software, and the Duncan test was used to compare differences between the groups (Düzgüneş et al. 1987). study was approved by the Kırıkkale University Animal Experiments Local Ethics Committee (Approval no: 22.07.2024-E.265544).

RESULTS

Plant Height

The differences in plant height among the varieties were statistically significant at the 5% level. The plant heights of the varieties under investigation are presented in the table below (Table 2). As a result of the research, the average plant height was found to be 175.38 cm.

Table 2. Plant height of sorghum varieties in the study.

No	n	Genotypes	Mean±SE Plant Height (cm)
1	10	Akdarı	96.63±19.2^{ı}
2	10	26	128.3321.6^{ghı}
3	10	Mataco	216.00±**26.7**$^{a-d}$
4	10	Talisman	188.33±44^{b-e}
5	10	Karaca Melez	243.66±**39.9**^{a}
6	10	305	229.66±**11.6**^{abc}
7	10	Uzun	125.66±**20.3**^{hı}
8	10	Hulk	221.00±**12.8**$^{a-d}$
9	10	Gözde 80	231.33±**19.2**^{ab}
10	10	Early Sumac	175.66±**14.9**$^{d-g}$
11	10	Rox	153.00±**25.2**$^{e-h}$
12	10	310	226.66±**9.39**^{abc}
13	10	Aldarı	96.33±**5.17**^{ı}
14	10	Öğretmen Oğlu	123.00±**9.81**^{hı}
15	10	314	147.00±**18.9**$^{e-h}$
16	10	Leoti	182.00±**13.5**$^{c-f}$
17	10	Erdurmuş	237.33±**54**^{ab}
18	10	Beydarı	135.00±**27.6**$^{f-ı}$
Overally			175.38±29.68

+: Values marked with similar letters are not significantly different from each other at the P≤0.05 error level according to the Duncan test results.

Dry Matter Yield

As shown in the Table 3, there is a statistically significant difference in dry matter yield (DMY) among the varieties, with a significance level of 1%. The average DMY (dry matter yield) of the examined varieties is presented in the table below (Table 3). As a result of the study, the average dry matter yield (DMY) was found to be 755.37 kg per hectare.

Table 3. Dry matter yield in the study.

No	n	Genotypes	Mean±SE Dry Matter Yield (kg/da)
1	10	Akdarı	345.95±**122**^{h}
2	10	26	711.90±**114**$^{c\text{-}f}$
3	10	Mataco	973.69±**101**^{abc}
4	10	Talisman	811.17±**120**$^{a\text{-}e}$
5	10	Karaca Melez	766.15±**188**$^{b\text{-}f}$
6	10	305	774.90±**106**$^{b\text{-}f}$
7	10	Uzun	758.63±**150**$^{b\text{-}f}$
8	10	Hulk	976.75±**70.2**^{abc}
9	10	Gözde 80	1057.18±**106**^{a}
10	10	Early Sumac	603.84±**163**$^{e\text{-}g}$
11	10	Rox	635.50±**258**$^{d\text{-}g}$
12	10	310	875.77±**70**$^{a\text{-}d}$
13	10	Aldarı	421.26±**63.5**^{gh}
14	10	Öğretmen Oğlu	670.35±**101**$^{d\text{-}g}$
15	10	314	782.31±**352**$^{b\text{-}f}$
16	10	Leoti	884.64±**99.8**$^{a\text{-}d}$
17	10	Erdurmuş	1004.02±**180**^{ab}
18	10	Beydarı	542.82±**198**^{fgh}
Overally			755.37±161.50

+: Values marked with similar letters are not significantly different from each other at the P≤0.05 error level according to the Duncan test results.

Single Plant Weight (g)

When examining the single plant weight in Table 4, statistical analysis indicates a significant difference at the 1% level among the varieties. The single plant weight of the varieties in the study is shown in the table below. Based on the research results, the average single plant weight was found to be 1550.96 g.

Total Plant Crude Protein Content

As seen in the Table 5, there are statistically significant differences in the total crude protein content among the varieties at the 1% level. The crude protein content of the varieties examined is shown in the table below. Based on the research results, the average crude protein content was found to be 7.38%.

Table 4. Single plant weight analyzed in the study.

No	n	Genotypes	Mean±SE Single Plant Weight (gr)
1	10	Akdarı	1864.33±**82**^{bcd}
2	10	26	1683.33±**79**^{cde}
3	10	Mataco	1630.00±**75.5**^{cde}
4	10	Talisman	1531.66±**253**$^{c-f}$
5	10	Karaca Melez	1826.66±**181**^{bcd}
6	10	305	1370.00±**153**$^{d-g}$
7	10	Uzun	1505.00±**286**^{def}
8	10	Hulk	1515.00±**204**^{def}
9	10	Gözde 80	868.33±**127**^{g}
10	10	Early Sumac	2035.00±**190**^{abc}
11	10	Rox	1658.33±**476**^{cde}
12	10	310	1190.00±**123**^{efg}
13	10	Aldarı	911.66±**108**^{g}
14	10	Öğretmen Oğlu	1091.66±**153**^{fg}
15	10	314	2418.33±**497**^{a}
16	10	Leoti	2290.00±**189**^{ab}
17	10	Erdurmuş	1295.00±**253**^{efg}
18	10	Beydarı	1233.33±**304**^{efg}
Overally			1550.96±310.20

+: Values marked with similar letters are not significantly different from each other at the P≤0.05 error level according to the Duncan test results.

Table 5. Crude protein content analyzed in the study

No	n	Genotypes	Mean±SE Crude Protein Content %
1	10	Akdarı	8.83±**0.13**^{abc}
2	10	26	7.51±**0.11**^{cde}
3	10	Mataco	6.54±**0.12**^{def}
4	10	Talisman	6.76±**0.21**^{def}
5	10	Karaca Melez	6.08±**0.16**^{f}
6	10	305	6.77±**0.27**^{def}
7	10	Uzun	10.02±**0.07**^{a}
8	10	Hulk	6.23±**0.113**^{ef}
9	10	Gözde 80	6.52±**0.07**^{def}
10	10	Early Sumac	7.25±**0.09**^{def}
11	10	Rox	7.22±**0.07**^{def}
12	10	310	7.20±**0.09**^{def}
13	10	Aldarı	7.80±**0.17**^{bcd}
14	10	Öğretmen Oğlu	7.22±**0.07**^{def}
15	10	314	7.45±**0.09**$^{c-f}$
16	10	Leoti	7.46±**0.09**$^{c-f}$
17	10	Erdurmuş	6.93±**0.08**^{def}
18	10	Beydarı	9.10±**0.06**^{ab}
Overally			7.38±0.83

+: Values marked with similar letters are not significantly different from each other at the P≤0.05 error level according to the Duncan test results.

DISCUSSION

Statistically, the highest plant heights were obtained from varieties such as Karaca Melez 310,305, Erdurmuş, and Gözde 80, which formed the same statistical group. The lowest plant heights were recorded from varieties such as Akdarı, Aldarı, Öğretmen Oğlu, and Uzun (Table 2). Comparing the plant heights of different sorghum varieties: Malik et al. (2007) reported the highest plant height as 234 cm in Pakistan, Büyükburç et al. (1997) found plant heights between 157-213.9 cm in Tokat, Gül and Baytekin (1999) recorded the highest plant height as 114.60-135 cm, Geren and Kavut (2009) reported plant heights between 147.8-330 cm in Bornova, Karadaş (2008) observed heights of 210-218 cm in Konya, Bhale and Borikar (1982) found the highest plant heights between 93-132 cm, İptaş (1993) recorded a maximum of 198 cm in Tokat conditions, Blümmel et al. (2003) found plant heights ranging from 133-333 cm, Başaran (2011) reported the highest height as 189 cm, Uygur (2011) in Tokat found plant heights ranging from 215-281.7 cm, Güneş and Acar (2005) reported heights between 260-285 cm, Gül and Başbağ (2005) observed heights ranging from 139-248 cm, Özköse et al. (2014) found heights between 83-155 cm, Geren and Kavut (2009) reported heights between 148-330 cm, and Salman and Budak (2015) reported the highest plant height as 345 cm. The variation in these results may be attributed to differences in the varieties used in the trials, as well as factors such as temperature, total precipitation, ecological conditions, and irrigation.

Statistically, the highest yields were observed in the varieties Mataco, Gözde 80, Erdurmuş, and Hulk. The lowest dry matter yields were obtained from the varieties Akdarı, Aldarı, Beydarı, and Early Sumac. In studies by Acar and Yıldırım (2001), the dry matter yield was 2093 kg per hectare, while Çakmakçı et al. (1999) reported a yield of 2093 kg per hectare in Antalya. Kır and Şahan (2017) found the dry matter yield to range from 1352 to 2848 kg per hectare under the conditions of Kırşehir, and Çeçen et al. (2005) reported a range of 1248-1654 kg per hectare in Antalya. Kara et al. (2019) found a dry matter yield of 1334 kg per hectare, while Dündar et al. (2019) reported a range of 6006-3661 kg per hectare. The differences in these results may be attributed to the use of different varieties in the trials, as well as variations in temperature, total rainfall, ecological conditions, and irrigation practices.

Statistically, the highest single plant weights were observed in the varieties 314, Leoti, Early Sumac, and Akdarı. The lowest single plant weights were recorded in the varieties Gözde 80, Aldarı, 310, and Öğretmen Oğlu. In terms of single plant weights, Uygur (2012) reported the highest values of 385-457 g in Tokat, while Yılmaz et al. (2003) found a single plant weight of 599 g under the conditions of Hatay. Güneş and Acar (2005) determined the highest single plant weight to be 266 g in Karaman. The differences in these results may be attributed to the use of different varieties in the trials, as well as variations in temperature, total rainfall, ecological conditions, and irrigation practices.

Statistically, the highest crude protein content was observed in the varieties Uzun, Beydarı, Akdarı, and Aldarı. The lowest crude protein content was recorded in the varieties Karaca Melez, Hulk, Gözde 80, and Mataco (Table 5). In terms of total plant crude protein content, Parlak and Sevimay (2007) reported a value of 10% under the conditions of Ankara, while Çiğdem and Uzun (2006) found values ranging from 6% to 10.16% in Samsun. Büyükburç et al. (1997) reported a range of 8.5% to 10% in Tokat, and İptaş (1993) found a value of 6% in Tokat. Hosaflıoğlu (1998) reported values ranging from 7% to 8% under irrigated conditions in Van, while Cacares and Santana (1987) found a value of 10% in Cuba. Açıkgöz (1995) observed a range of 6% to 9%, and Yılmaz and Hoşafoğlu (2000) reported a range of 7% to 8% in their study in Van. Uygur (2012) found values between 8% and 12% in Tokat, while Torrecillas et al. (2011) observed values between 4% and 4.2%

in Argentina. The differences in these results may be attributed to the use of different varieties in the trials, as well as variations in temperature, total rainfall, ecological conditions, and irrigation practices

CONCLUSION

In conclusion, the average plant height of the sorghum varieties planted in this study was found to be 175.38 cm, with plant heights ranging from 96.33 cm to 243.66 cm. The average dry matter yield of the sorghum varieties was 755.37 kg per decare, with dry matter yield ranging from 345.95 kg/da to 1057.18 kg/da. The average single plant weight of the sorghum varieties was 1550.96 g, with single plant weights ranging from 868.33 g to 2418.33 g. The average total plant crude protein content of the sorghum varieties was found to be 7.38%, with crude protein content ranging from 6.08% to 10.02%. According to the results of this study, in terms of quality, the genotypes Leoti, Uzun, and Beydarı stood out, while in terms of yield, the genotypes Gözde 80, Uzun, and Mataco were more prominent. For obtaining good yields under the ecological conditions of Muş and similar regions, it is recommended to grow one of the Gözde 80, Uzun, or Mataco genotypes

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Ethics Approval

This project is not required ethical statement.

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Conflict of Interest

The authors have no relevant interests

Author Contributions

Research Design (CRediT 1) Author 1 (%20) – Author 2 (%80)
Data Collection (CRediT 2) Author 1 (%20) – Author 2 (%80)
Research - Data analysis - Validation (CRediT 3-4-6-11) Author 1 (%20) – Author 2 (%80)
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Sustainable Development Goals (SDG)

12 Responsible Consumption and Production

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