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Effects of Different Nitrogen Doses on Forage Yield of Some Sweet Sorghum [*Sorghum bicolor* var. *saccharatum* (L.) Mohlenb.] Varieties[A]

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Abstract: This study was carried out to determine the forage production potentials of different sweet sorghum genotypes under Mediterranean-type climate conditions as the second crop in 2020. Three different sweet sorghum genotypes (Erdurmuş, Uzun varieties, and M81-E line) and four nitrogen doses (0.0, 7.5 12.5, 17.5 kg da^{-1}) were used in this research. The experimental design was a randomized complete block with three replications. Some parameters such as plant height, stem diameter, plant number per m^2, leaf number, leaf and stem ratio, forage yield, and dry matter yield of sweet sorghum genotiyps were investigated in the experiment. According to the results, M81-E gave the highest values in terms of stem diameter, leaf number, forage yield, and dry matter yield parameter compared to other genotypes. Forage yield values of the genotypes were between 2969.9 and 5815.0 kg da^{-1} and dry matter yield values were 1105.7 and 2837.8 kg da^{-1}. Forage yield values vary between 2920.1 and 4674.6 kg da^{-1} for the nitrogen doses. The highest forage yield was obtained at 12.5 and 17.5 kg da^{-1} nitrogen doses, which were in the same statistical group. Fertilization can be made with a 12.5 kg da^{-1} nitrogen dose in sweet sorghum due to the negative environmental effects of chemical fertilizers.

Keywords: Forage yield, nitrogen, sweet sorghum.

[A] No ethics commission permission is required in this manuscript. The article has been prepared in accordance with research and publication ethics.

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Farklı Azot Dozlarının Bazı Şeker Darısı [*Sorghum bicolor* var. *saccharatum* (L.) Mohlenb.] Genotiplerinin Yem Bitkisi Verimi Üzerine Etkileri

Öz: Bu çalışma farklı şeker darısı genotiplerinin, Akdeniz iklim koşullarında ikinci ürün olarak yem bitkisi potansiyellerinin belirlenmesi amacıyla 2020 yılında yürütülmüştür. Bitki materyali olarak üç farklı şeker darısı genotipi (Erdurmuş, Uzun ve M81-E hattı) ve dört farklı azot dozu (0, 7.5 12.5, 17.5 kg da^{-1}) kullanılmıştır. Tesadüf bloklarında 3 tekerrürlü olarak kurulan ararştırmada; bitki boyu, sap çapı, m^2 deki bitki sayısı, yaprak sayısı, yaprak ve sap oranı, yeşil ot verimi ve kuru madde verimi gibi bazı parametreler incelenmiştir. Araştırma sonuçlarına göre; sap çapı, yaprak sayısı, yeşil ot verimi ve kuru madde verimi parametleri açısından en yüksek değerler M81-E çeşidinden alınmıştır. Çeşitlerin yeşil ot verim değerleri 2969.9 ve 5815.0 kg da^{-1} arasında; kuru madde verim değerleri ise 1105.7 ve 2837.8 kg da^{-1} arasında değişmektedir. Azot dozları açısından ise yeşil ot verim değerleri 2920.1 ve 4674.6 kg da^{-1} arasındadır. En yüksek yeşil ot verimleri aynı istatistiki gruba giren 12.5 ve 17.5 kg da^{-1} azot dozlarından elde edilmiştir. Aşırı kimyasal gübre kullanımının olumsuz çevresel etkileri olduğundan dolayı, şeker darısında 12.5 kg da^{-1} azot dozu ile gübreleme önerilebilir.

Anahtar Kelimeler: Yeşil ot verimi, azot, şeker darısı.

Introduction

The roughage requirement to feed Turkey's livestock potential is inadequate and getting also increased over the years. Therefore, to compensate for roughage needs, expanding the cultivation area and increasing yields per unit area of various forage crops is essential. Sweet sorghum (*Sorghum bicolor* var. saccharatum (L.) Mohlenb.) is an important plant as an alternative forage crop and energy crop grown around the world. (Dolciotti et al., 1998; Legwaila et al., 2003; Berenji and Dahlberg, 2004; Gnansounoua et al., 2005; Almodares and Mostafafi, 2006). Sweet sorghums are tall-height, thick-stemmed, have a high dry matter yield, and are generally produced for abundant fresh forage yield (Berenji and Dahlberg, 2004). In recent years, sweet sorghum has gained importance due to biomass yield and high bioethanol content. The use of bioethanol reduces both the usage of gasoline fuel and air pollution. Also, sweet sorghum is a biomass plant used in human food and animal feed and adapted to extreme soil and climatic conditions (Guiying et al., 2003; Köppen et al., 2009). In regions with irrigation facilities, it can be easily produced as a summer second crop forage plant.

Nitrogen is the most common fertilizer to increase crop yields, but excessive nitrogen use harms the environment and reduces the extra cost and income of farmers (Rashid and Voroney, 2005). When nitrogen is applied to crops, a significant proportion is lost in the atmosphere in the form of nitrogen oxides, which unfortunately damage the ozone layer, leading to global warming (Crutzen and Ehhalt, 1977; Ruser et al., 1998; Crutzen et al., 2007). It is estimated that the amount of nitrogen used as fertilizer in agriculture will triple by

2050, and its negative impact on the environment is expected to increase as a result (Subbarao et al., 2009). Therefore, the high cost of nitrogen to attain maximum yields, its negative environmental impact, and the amount of biofuel needed to meet future energy demands make it very important to study ways to properly manage N fertilization. Efficient and optimal use of nitrogen is important for the proper production of crops for biofuel production also important to explore ways of applying nitrogen fertilization appropriately to meet future energy demands (Bock, 1984; Schepers et al., 1991; Vitousek et al., 1997). Bring about not to cause environmental pollution, and for the production to be economical, optimum plant density and nitrogen rates should be determined for various ecologies in the agriculture of sweet sorghum, as in all cultivated crops. Many researchers have stated that various nitrogen doses and plant density significantly affect yield and yield traits in sweet sorghum. Besides using less water and N than corn (*Zea mays* L.) for similar ethanol yields so excessive nitrogen application is not recommended in sweet Sorghum (Geng, 1989; Keeney, 1992).

Sweet sorghum can give a moderate yield with a small amount of nitrogen fertilization. However, it can be grown in various conditions without applying nitrogen fertilizers, and relatively high ethanol yields can be achieved even in poor soil conditions. It can also be used to prevent erosion in soils with various erosion risks. Due to the features mentioned above, it has an extensive cultivation area (Akdoğan, 2004).

Researchers conducted to date on the impact of N fertilization on the biomass production of sweet sorghum has still not adequate in Turkey. It is a necessity to determine the effects of nitrogen in all suitable ecological regions where sweet sorghum can be grown in Turkey. This research aimed to evaluate the optimum nitrogen doses and effects of nitrogen fertilization on yield in sweet sorghum as a second summer crop.

Materials and Methods

The research was conducted in Bursa Uludag University, Faculty of Agriculture, Agricultural Application and Research Center in 2020. The research field has a Mediterranean-type climate. This climatic zone's long-term (1928- 2020) annual total rainfall was 719.1 mm year $^{-1}$, and the annual mean temperature was 14.9 °C. Climate data for the vegetation period in 2020, when the study was conducted, are given in Table 1. When the climate data are examined, it is seen that the average temperature data and total precipitations were compatible with the long-term data. The experimental design was a randomized complete block with three replications. Three different sweet sorghum genotypes (Erdurmuş, Uzun varieties, and M81-E line) and four nitrogen doses (0, 7.5 12.5, 17.5 kg da^{-1}) were used in this research. Each plot consisted of 5 rows with 5 m long and 0.7 m apart, 20 cm intervals from the row. The total research area was 1288 m^2 (40 m x 32.2 m). The sowing date was 7 June 2020.

Table 1. Meteorological data of the research area

Months	Temperature (°C)		Precipitation (mm)		Relative Humidity (%)	
	2020	**LT***	**2020**	**LT**	**2020**	**LT**
June	21.7	22.6	40.5	42.8	67.9	57.8
July	24.8	25.1	1.5	14.3	64.1	56.2
August	24.7	25.2	1.8	17.5	62.0	57.3
September	23.0	20.8	6.5	50.1	67.3	63.8
October	18.4	15.9	59.6	84.4	71.8	68.7
November	10.4	10.7	14.3	67.3	75.7	69.3
December	9.9	22.6	13.0	42.8	77.6	68.7
Total	-	-	**137.2**	**276.4**	-	-
Average	**18.9**	**20.1**	-	-	**69.4**	**63.1**

* LT: Long term (1991-2020)

The soils of the Agricultural Application and Research Center, where the experiment was carried out, are clay and marl layered, 50-200 cm thick and heavy textured depending on the slope; the primary materials are light gray or close to white and are rich in clay and lime (Katkat et al., 1983). The soil analysis results are given in Table 2.

Table 2. The soil analysis results of the experiment area.

Texture	Clay	**pH**	7.76
Depth (cm)	0-20	**CaCO3 (%)**	4.30
Sand (%)	25.95	**Phosphorus**	9.16
Clay (%)	58.60	**Potassium (kg da^{-1})**	100.67
Silt (%)	15.45	**Organic matter**	2.04

The plots were seeded by hand at a triple rate and then thinned by hand after emergence to the required intra-row spacings. After seeding, good germination was performed due to sufficient rainfall in 2020. However, it was observed that starting with the period after seeding and in August and September, the daily temperatures generally exceeded the monthly average temperatures. In this process, sprinkler irrigation was applied as needed. 2,4-D was used in the research area for weed control. Half of the nitrogen doses used in this study were applied before seeding, and the rest as urea (46%) when the plants reached 40-50 cm height.

Ten plants were randomly selected from each plot for measurements and observations just before cutting for forage production. At the soft dough-hard dough stage, two rows from center plots were harvested. Forage yields and growth parameters were measured individually in the experiment, such as plant height, stem diameter, plant number per m², leaf number, leaf and stem ratio, forage yield, and dry matter yield. Half of the interior three rows in each plot were harvested for forage yield at the soft dough-hard dough stage. One plant was selected from each plot and the selected plant dried at 70°C for 48 h to calculate dry matter yield. ANOVA results statistically were assessed all data for split split-plots of a randomized complete block design. The differences between treatment means were evaluated by the least significant difference (LSD) at P= 0.05 probability level.

Results and Discussions

The variance analysis results of the year 2020 traits are given in Table 3. The average values of the morphological measurements of genotypes and nitrogen doses are given in Table 4 and Table 5, respectively.

Generally, genotypes were statistically significant, but genotype x nitrogen dose interactions were not significant in most measurements and observations. While nitrogen doses were statistically significant in some traits, they were not significant in others.

Table 3. Plant height, Stem Diameter, Plant Number per m^2, Leaf Number, Leaf and Stem Ratio, Forage Yield, and Dry Matter Yield of Variance Analysis Results for Genotypes, Nitrogen Doses, and Genotypes x Nitrogen Doses Interaction in 2020 Period.

Sources of Variation	Plant Height (cm)	Stem Diameter (mm)	Plant Number per m^2	Leaf Number	Leaf Ratio (%)	Stem Ratio (%)	Forage Yield (kg da^{-1})	Dry Matter Yield (kg da^{-1})
Genotypes (G)	ns	**	ns	**	**	**	**	**
Nitrogen Doses (ND)	ns	**	ns	*	ns	ns	**	**
G x ND	ns	ns	ns	ns	ns	ns	ns	**

*, **: F-test significant at p≤ 0.05 and p≤ 0.01, respectively. ns: not significant.

Plant height, stem diameter, leaf number are essential traits that affect the yield of forage crops grown for forage and silage. According to the average measurements and observation ratings of genotypes, M81-E has the highest values for stem diameter, leaf number, leaf ratio, forage yield, and dry matter yield. Erdurmuş genotype has only a high value for the stem ratio parameter. M81-E and Uzun genotypes gave together with the highest value for the leaf ratio parameter (Table 4).

Table 4. Plant Height, Stem Diameter, Plant Number per m^2, Leaf Number, Leaf Ratio, Stem Ratio, Forage Yield and Dry Matter Yield Average Values of the Genotypes in 2020 Period.

Genotypes	Plant Height (cm)	Stem Diameter (mm)	Plant Number per m^2	Leaf Number	Leaf Ratio (%)	Stem Ratio (%)	Forage Yield (kg da^{-1})	Dry Matter Yield (kg da^{-1})
Erdurmuş	282	18.6 c	13.9	9.9 c	13.5 b	86.5 a	2969.9 b	1105.7 c
Uzun	269	21.0 b	14.1	11.0 b	16.4 a	83.5 b	3206.7 b	1326.9 b
M81-E	283	22.9 a	12.8	12.8 a	16.5 a	83.5 b	5815.0 a	2837.8 a
LSD (0.05)	ns	1.72	ns	1.02	0.02	0.02	574.0	215.4

The same column measurements followed by the same letter were not significantly different at the 0.05 level using the LSD test.

According to our trial results forage yield values of the genotypes were between 2969.9 kg da^{-1} and 5815.0 kg da^{-1} and dry matter yield values were 1105.7 kg da^{-1} and 2837.8 kg da^{-1}. Chavan et al. (2009) reported that biomass yields in 14 sweet sorghum genotypes ranged from 3646 - 7488 kg da^{-1}. Almodares et al. (2008) were found that the forage yield ranged from 7400-7800 kg da^{-1}. Since our research was carried out under second crop conditions, the results of forage and dry matter yield were found to be lower than the results of other researchers (Turgut et al., 2005; Akgün and Acar, 2008). Geren et al. (2011) reported that sweet sorghum was well adapted to local conditions in the second crop conditions. According to the researcher; the average plant height is 204 cm, the number of siblings is 3.2 plants, the total fresh forage yield is 5600 kg da^{-1}, the dry matter rate of the whole plant is 28.4%, the stem yield is 1300 l da^{-1}, the sugar rate is 11.9%, the sugar yield is 156 kg da^{-1} and theoretical ethanol yield are in 83.1 l da^{-1}.

In research conducted in the USA using Dale, Theis, and M81-E genotypes, it was stated that the plant heights ranged between 230-281 cm, stem diameters were 17-22 mm, and sugar ratios were recorded as 9.4-14.9% (Ekefre et al., 2017). In the present study, we obtained 283 cm and 282 cm plant height which is higher than 281 cm with M81-E and Erdurmuş genotypes. No difference was found between plant numbers and plant heights among sweet sorghum genotypes.

The present study results clearly showed that sweet sorghum genotypes treated with high nitrogen resulted in higher stem diameter, leaf number, forage yield and dry matter yield. Martin et al. (1976) stated that the leaf number of sweet sorghum can vary between 6 and 17 under optimum conditions. In a study conducted in Bursa conditions, it was reported that the leaf number in sugar sorghum was not affected by cultural practices (Turgut et al., 2005). Contrary to the researcher, the number of leaves was found to be statistically significant and it was determined that the highest leaf number was given by 17.5 kg da^{-1} nitrogen doses in our research (Table 5).

Akdoğan (2004) stated that the average stem diameter ranged between 17.52 - 21.10 mm, and the largest stem diameter was obtained from the application of 18 kg N da^{-1}. In our study, stem diameter averages showed values ranging from 15 to 21 and the highest nitrogen dose of 17.5 kg da^{-1} gave the highest stem diameter values (Table 5).

In our study, sweet sorghum genotypes respond positively to nitrogen fertilization for forage yield and dry matter yield. Turgut et al. (2005) reported that 5 or 10 cm intra-row spacings and 100 or 150 kg ha^{-1} nitrogen rates are provided maximum forage, dry matter, and seed yield in sweet sorghum in Bursa. In a study conducted in Konya-Turkey conditions to determine the effects of four different doses of nitrogen (7.5, 12, 15, and 18 kg da^{-1}) on a sweet sorghum genotype obtained from the Deliorman Region of Bulgaria; nitrogen doses significantlyaffected grain yield and yield characteristics at other doses except for 18 kg N da^{-1} (Akgün and Acar, 2008). Similarly, the fact that the 12.5 kg da^{-1} and 17.5 kg da^{-1} nitrogen doses were in the same statistical group in our study shows that the increased nitrogen dose does not increase the forage yield and dry matter yield value and confirms the other researchers.

Table 5. Plant Height, Stem Diameter, Plant Number per m^2, Leaf Number, Leaf Ratio, Stem Ratio, Forage Yield and Dry Matter Yield Average Values of the Nitrogen Doses in 2020 Period.

Nitrogen Doses (kg da^{-1})	Plant Height (cm)	Stem Diameter (mm)	Plant Number per m^2	Leaf Number	Leaf Ratio (%)	Stem Ratio (%)	Forage Yield (kg da^{-1})	Dry Matter Yield (kg da^{-1})
0.0	262	15.1 c	14.2	10.3 c	15.5	84.4	2920.1 c	1050.6 c
7.5	280	22.4 b	14.1	11.6 ab	14.8	85.1	3996.7 b	1403.2 b
12.5	279	21.0 b	13.4	10.8 bc	15.2	84.7	4397.3 ab	1786.1 a
17.5	290	24.8 a	12.7	12.1 a	16.2	83.7	4674.6 a	1929.2 a
LSD (0.05)	ns	1.98	ns	1.18	ns	ns	662.8	248.7

Table 6. Plant Height, Stem Diameter, Plant Number per m^2, Leaf Number, Leaf Ratio, Stem Ratio, Forage Yield, and Dry Matter Yield Average Values the Genotypes x Nitrogen Doses Interaction in 2020 Period.

	Nitrogen Doses							
Genotypes	**Plant Height**				**Stem Diameter**			
	1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1*	270	271	280	309	13,6	20,0	19,0	22,0
2	252	286	278	259	15,3	22,3	21,0	25,3
3	266	283	280	303	16,3	25,0	23,0	27,3
Genotypes	**Plant Number per m^2**				**Leaf Number**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1	13,3	15,2	14,7	12,4	9,3	10,3	9,6	10,3
2	15,7	13,8	13,3	13,5	10,3	11,0	11,0	11,6
3	13,6	13,3	12,1	12,1	11,3	13,6	12,0	14,3
Genotypes	**Leaf Ratio**				**Stem Ratio**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1	14,0	12,0	11,6	16,3	86,0	88,0	88,3	83,6
2	16,0	16,3	16,6	16,6	84,0	83,6	83,3	83,3
3	16,6	16,3	17,3	15,6	83,3	83,6	82,6	84,3
Genotypes	**Forage Yield**				**Dry Matter Yield**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1	1746,5	3023,6	3514,1	3595,3	620,5 g	842,3 fg	1125,0 ef	1835,0 d
2	2561,2	3107,1	3295,4	3863,4	979,0 efg	1854,0 d	1182,0 ef	1292,6 e
3	4452,8	5859,5	6382,6	6565,0	2476,5 c	3163,5 a	3051,5ab	2660,0bc

*1.Erdurmuş, 2.Uzun, 3. M82-E; **1. 0.0 kg da^{-1}, 2. 7.5 kg da^{-1}, 3. 12.5 kg da^{-1}, 4. 17.5 kg da^{-1}

Nitrogen doses did not affect plant number, plant height, leaf ratio, and stem ratio values. Only genotypes and dry matter yield values were found to be statistically significant. 7.5 and 12.5 nitrogen dose interactions of the M81-E genotype were in the same statistical group and gave the highest values (Table 6).

Conclusion

As a result of the yearly experiment carried out to investigate the effects of nitrogen dose in sweet sorghum genotypes with high biomass nitrogen fertilization significantly affected stem diameter, leaf number, forage yield, and dry matter yield. According to the results, M81-E gave the highest values in terms of stem diameter, leaf number, forage yield, and dry matter yield parameter. The highest forage yield was obtained at 12.5 and 17.5 kg da^{-1} nitrogen doses. In this respect, considering the negative environmental effects caused by chemical fertilizers, fertilization can be made with a 12.5 kg da^{-1} nitrogen dose in sweet sorghum.

Sweet sorghum, which has very few cultivation areas in Turkey, has an essential potential both as an energy and forage crop. Sweet Sorghum was found to be able to grow as a second crop in crop design in Bursa (Mediterranean-type climate). With these possibilities, the sweet sorghum offers a wide use potential both in closing the roughage deficit and as biomass. These data indicated that the study needs to be repeated for one more year to give healthier results.

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