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EFFECTS OF DIFFERENT SOWING FREQUENCIES AND NITROGEN DOSES ON THE YIELD COMPONENTS OF SILAGE SORGHUM X SUDAN GRASS HYBRID (*Sorghum bicolor* X *Sorghum sudanense* Mtapf.) IN THE IĞDIR BASIN

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Abstract: The study was conducted in 2021 to evaluate the yield and yield parameters of sorghum for silage (Sorghum bicolor x Sorghum sudanense Mtapf., Hayday hybrid) under different nitrogen application rates (0, 6, 12 and 18 kg/da nitrogen application, respectively) and different row distances (5 cm, 10 cm, 15 cm and 20 cm). The experiment was established at Igdir University Agricultural Application and Research Centre in Igdir ecological conditions according to split-plot experimental design with three replications. The data obtained from the experiment were as follows: plant height 190.9 cm and 257.3 cm; herbage yield 1756.1 kg/da and dry herbage yield 3228.5 kg/da; dry herbage yield 522.2 kg/da and 925.2 kg/da; stem ratio 69.1% to 74.8%; leaf ratio 15.3% to 74.8%; 15.3% to 20.2%; crude protein content ranged from 6.4% to 8.1%; NDF content ranged from 58.5% to 63.1%; ADF content ranged from 31.7% to 34.5%. The results showed that N application rates increased plant height, fresh herbage yield and dry matter, while decreasing the NDF ratio of the plants. In the study, row spacing did not affect dry matter, stem and leaf ratio, NDF and ADF of sorghum plants. It was concluded that 28.570 plants/da sowing and 6 kg N/da application could be applied in terms of fresh and dry matter yield under Igdir ecological conditions.

Keywords: Silage sorghum, Nitrogen doses, Green herbage yield, Yield, Quality

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1. Introduction

Climate change, which poses a threat to agricultural production and access to clean food in many parts of the world, and food problems caused by intensive population growth have emerged as one of the most important challenges faced by mankind in the modern age. Agricultural areas are the most affected areas due to environmental problems (Arici and Avci, 2022). It is one of the main problems of agricultural production even in countries that have advanced in agriculture. Forage crops play an important role in the agricultural economy of developing countries by providing the cheapest feed source for livestock. Although our country has a significant potential in terms of livestock, the return obtained from each animal is quite negligible (Keskin et al., 2018). Insufficiency of quality roughage resources is one of the most important factors contributing to the inability to achieve the required amount of animal production. Our meadows and pastures, which are the most important food source for animals, are experiencing a decrease in production as a result of both intensive and irregular grazing (Özkan and Şahin Demirbağ, 2016).

Considering the current need for roughage in Turkey, sorghum is a suitable substitute for maize in animal feed. It shows stability in dry periods, high temperature tolerance and drought resistance. It also regrows rapidly after harvest. Especially sorghum for silage surpasses maize as an alternative due to its improved resistance to pests and diseases (Keskin et al., 2005). Sorghum (*Sorghum bicolor* L.) is an important plant with a wide range of ecological adaptations due to its xerophytic properties. It is widely cultivated as fodder and forage by subsistence farmers in both wetland and non-wetland regions of Turkey. Its feed is fed to almost all classes of animals and can be used as hay or silage. However, the quality of sorghum forage is poor due to low protein content and the presence of hydrocyanic acid (Salman and Budak, 2015). The performance of dairy animals depends on the availability of quality feed in sufficient quantity and continuously. Therefore, the critical limitation on profitable animal production in developing countries is the shortage of quality feed (Sarwar et al., 2002). Among the many options to overcome the shortage of roughage, the best one is the introduction of high-yielding crop varieties (Akbay et al., 2023).

Sorghum is one of the most important multifunctional crops grown all over the world for both grain and feed purposes. The genus Sorghum, which belongs to the grass family known as Poaceae, is home to over 25 different flowering plant species (Salman and Budak, 2015). There are several different names for sorghum such as orshallu, milo, durra and Asian millet. Vitamin B1, niacin, 10% protein, 3.4% fat, carbohydrate and trace amounts of iron are some of the nutrients that can be found in sorghum. It is one of the five most widely cultivated crops in the world and has a number of potential economically important applications. These applications include food (grain), feed (grain and biomass), fuel (ethanol production), fibre (paper), fermentation (ethanol production) and fertiliser (using organic by-products). Most species are nitrogen-efficient, heat- and drought-tolerant, and are particularly important in arid regions where grain is a staple food for the poor and rural people (Kimutai et al., 2023). These characteristics make cereals particularly important in agricultural environments. It is considered one of the most important cereal crops in the world, in addition to wheat (*Triticum aestivum*), rice (*Oryza sativa*), maize (*Zea mays*) and barley (Hordeum vulgare). In addition to maize and pearl millet (*Pennisetum glaucum* L.), it accounts for a large proportion of the dryland cereal crop grown in semi-arid tropical regions.

Sorghum (Sorghum bicolor (L.) Moench = S. vulgare Pers) is categorised under four main groups as grain sorghums, sugar sorghums, forage sorghums and broom sorghums according to their cultivation purposes (Açıkgöz, 2001). Sorghum varieties with thin stalks, tall stems, tillering, high grass yield and herbage yield are grown for fodder production (Balabanlı and Türk, 2005; Parlak and Özaslan Parlak, 2006). Sorghum species have a great potential in the utilisation of dry areas with sufficient rainfall and as an alternative to maize and other cultivated crops in irrigated agricultural areas in seasons when water is limited (Tiryaki, 2005; Temel et al., 2017). Sorghum is a warm season plant of tropical and subtropical origin and is used in African countries for bread making, as raw material for alcoholic beverages, in syrup and starch production due to its rich sugar content, as grain and green, biofuel, broom and animal feed (Kazungu et al., 2023). Sorghum, a C_4 crop, is characterised by its high and high quality grass yield as well as its ability to thrive in a variety of agro-ecosystems. Feed, food and industrial use are the main reasons for its cultivation. According to House (1985), sorghum gives twice as many roots as maize. Sorghum is more efficient than maize and other crops in utilizing water and plant nutrients (N, P, and K) (Kimbrough, 2002; Bean et al., 2002). As a result, it was able to produce a greater amount of biomass.

This study aimed to evaluate the potential of sorghum for high quality biomass production in the Igdir Aras basin and similar regions. There is a dire need to develop such varieties with higher yield potential to meet the increasing demand for feed for livestock (Chohan et al., 2006). Therefore, this study was designed to find the most suitable sorghum variety capable of producing large quantities of biomass in terms of feed yield and quality.

2. Materials and Methods

The investigation was conducted to determine the effects of different green herbage yield and nitrogen doses on the Sorghum x Sudan grass hybrid variety Hayday under the conditions of Iğdır Ecology in n 2021 at the Agricultural Application and Research Center of Iğdır University. The experiment Split Plot Desing was established in three replications according to four different nitrogen doses (0, 6, 12, 18 kg/da) and four sowing frequencies (5 cm, 10 cm, 15 cm, and 20 cm = 28.570, 14.285, 8.570 and 7,142 plants/da) were applied. The average lime ratio of the research area trial soil was 6.53, pH 7.98, electrical conductivity 1.8 dS m^{-1}, potassium 0.3 t ha^{-1}, phosphorus 0.008 t ha^{-1}, and organic matter was very low 1.6%, soil structure was clay loam. On July 5, 2021, when the total parcel area reached 17.5 m2 and the planting soil temperature reached 18-20 °C, with a distance of 70 cm between rows and five rows in each parcel, sowing was applied to the rows at a depth of approximately 4-5 cm in each row using hand markers. Irrigations were irrigated by sprinkler method on July 14, 2021, and July 20, 2021, when the soil moisture meter consumed 50% of the field capacity. Furrows were irrigated the rows with a fertilizer machine, and the first dose of nitrogen was given by sowing. Irrigation was carried out on August 16, 2021, and the last irrigation was on August 26, 2021. All of the triple super phosphate and half of the nitrogen were given equally to all plots, 6 kg/da at the sowing time. Half of the nitrogen and all of the phosphorus were applied; the rest of the nitrogen was given when the plant reached 50 cm height. After leaving 50 cm of edge rows at the beginning of each plot, it was cut with a sickle based on 4 m x 3 rows = 8.4 m^2 area, 3 rows in the middle. In the research, the plant height of 10 plants randomly selected from each plot, the part from the soil surface to the tip of the plant from 5-6 cm was measured, and then the leaf ratio, stem ratio, and panicle ratios were found by cutting. The green herbage yield was cut in the middle 3 rows and immediately weighed; the dry matter ratio (%) and the yield of 2 or 3 plants taken from each plot were immediately weighed as a fresh weight and then dried in the laboratory at 70 ^{o}C for 48 hours, and the dry matter ratio was found. Dry matter was calculated on the green grass yield using the ratio of hay. The crude protein ratio was determined using Kacar (1984), NDF (Neutral Detergent Fiber), ADF (Acid Detergent Fiber), and Van Soest et al. (1991).

3. Results and Discussion

Under the conditions of Iğdır Ecology, together with the agricultural characteristics of different row distances and nitrogen doses on Sorghum x Sudan grass-Hayday variety, crude protein ratio, NDF, and ADF ratios are presented in Table 1.

3.1. Traits of Plants Examined in the Study

3.1.1. Plant height (cm)

Green grass yield, nitrogen doses and the interaction of these two factors were found to be significant in Sorghum x Sudan grass-Hayday cultivar (Figure 1). Plant height varied between 190.9 cm and 257.3 cm (Table 1). Among the different sowing frequency and nitrogen doses, the highest plant height was 257.3 cm obtained from the plants with 20 cm sowing frequency and 12 nitrogen doses, while the lowest plant height was 190.9 cm obtained from the plants with 5 cm sowing frequency and 0 (zero) nitrogen dose. In terms of nitrogen applications, plant height increased with increasing nitrogen applications (Table 1).

Table 1. Some plant and chemical properties of the sorghum sudan grass hybrid

Row distances	Nitrogen doses	Plant height, cm	Green herbage, kg/da	Dry matter ratio, %	Dry matter yield, kg/da	Stem ratio, %	Leaf ratio, %	Panicle ratio, %	Crude protein ratio, %	NDF, %	ADF, %
	0	190.9	1837.7	28.4	522.2	69.7	16.8	13.3	6.4	60.7	32.1
5	6	251.6	3228.5	28.7	925.2	72.3	18.6	9.1	7.5	61.8	33.2
	12	236.1	2439.1	28.9	706.3	72.9	17.4	9.7	7.5	60.9	33.6
	18	220.7	3071.9	27.7	851.7	74.3	16.8	8.9	8.1	59.2	31.7
	0	234.4	2363.2	28.9	680.9	72.4	16.3	11.4	7.1	60.5	32.3
10	6	228.2	2449.4	30.0	735.5	70.1	18.3	11.6	6.9	63.1	34.5
	12	253.5	2804.5	28.9	804.3	73.9	15.3	10.8	6.9	61.0	33.4
	18	249.6	2684.6	28.0	750.1	71.4	16.7	11.9	7.3	60.7	33.7
	0	250.1	2404.7	29.8	715.8	74.8	15.3	9.8	8.0	62.4	33.1
15	6	247.5	2765.6	28.1	776.6	72.6	16.5	10.8	6.9	60.6	32.5
	12	242.0	2765.5	29.6	818.6	72.6	17.0	10.4	7.2	60.9	33.5
	18	245.2	2198.4	27.7	608.7	71.3	16.9	11.7	8.1	60.6	33.7
	0	223.5	1756.1	30.0	526.7	73.4	17.3	9.4	6.8	60.2	32.1
20	6	224.5	2386.1	28.0	669.3	69.1	20.2	10.7	7.6	63.6	33.9
	12	257.3	2623.9	27.2	714.6	73.2	16.3	10.4	7.8	60.6	33.5
	18	247.5	2976.2	27.9	832.7	74.2	15.7	10.7	7.4	58.5	33.2

Frequency means

Row distances	Plant height	Green herbage, kg/da	Dry matter ratio	Dry matter yield	Stem ratio	Leaf ratio	Panicle ratio	Crude protein ratio	NDF	ADF
5 cm	218.5 ^{c}	2644.3 ^{a}	28.4	751.3 ^{a}	72.3	17.4	10.2	7.4 ^{a}	60.6	32.7
10 cm	234.7 ^{b}	2575.4 ^{ab}	28.8	742.7 ^{a}	71.9	16.6	11.4	7.0 ^{b}	61.3	33.4
15 cm	239.9 ^{a}	2533.5 ^{b}	28.7	729.9 ^{a}	72.8	16.4	10.7	7.5 ^{a}	61.1	33.2
20 cm	231.2 ^{b}	2435.6 ^{c}	28.2	685.8 ^{b}	72.4	17.3	10.3	7.4 ^{a}	60.7	33.2
Nitrogen										
0	224.7 ^{c}	2090.5 ^{b}	29.2 ^{a}	611.4 ^{b}	72.6 ^{a}	16.4 ^{b}	10.9	7.0 ^{c}	60.9 ^{b}	32.3 ^{b}
6 kg	237.9 ^{b}	2707.3 ^{a}	28.7 ^{a}	776.6 ^{a}	71.0 ^{b}	18.3 ^{a}	10.5	7.2 ^{bc}	62.3 ^{a}	33.5 ^{a}
12 kg	247.2 ^{a}	2658.2 ^{a}	28.6 ^{a}	760.9 ^{a}	73.1 ^{a}	16.5 ^{b}	10.3	7.3 ^{b}	60.8 ^{b}	33.6 ^{a}
18 kg	240.7 ^{a}	2732.7 ^{a}	27.8 ^{b}	760.8 ^{a}	72.8 ^{a}	16.5 ^{b}	10.8	7.8 ^{a}	59.7 ^{c}	33.1 ^{a}

a,b= different letter within column shows the statistical diference (P<0.05).

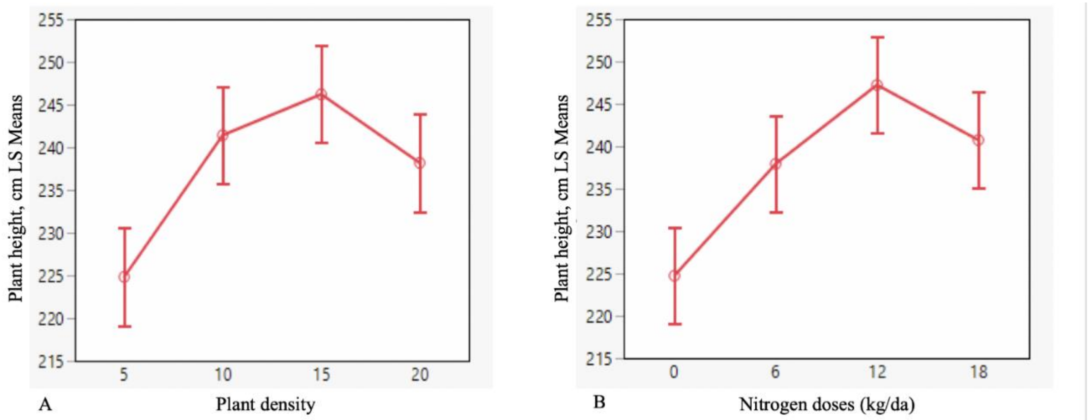

Figure 1. A- Plant height and density, B- Plant height and Nitrogen dose.

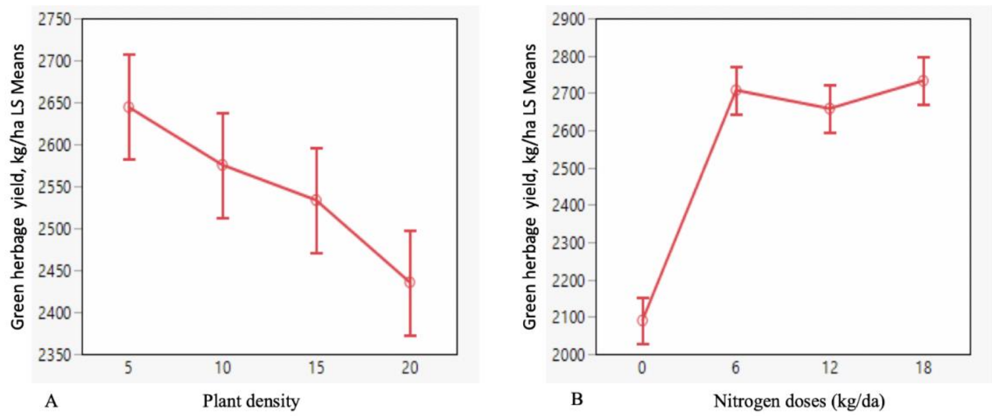

Figure 2. A- Green herbage yield and density, B- Green herbage yield and Nitrogen dosage.

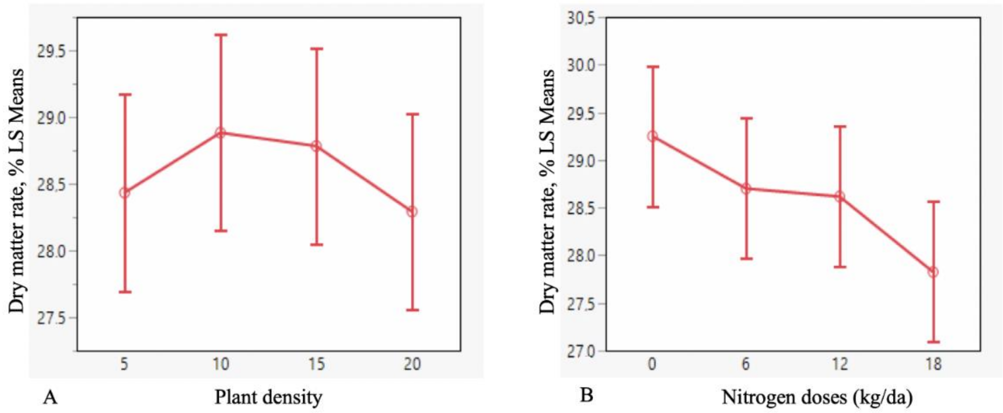

Figure 3. A-Dry grass ratio and density, B-Dry grass ratio and Nitrogen dosage.

When the plant height data of sorghum plants were evaluated in terms of sowing frequency, the plant height increased as the row spacing increased, but showed a decrease at 20 cm row spacing (Figure 1). However, due to the increase in N doses, plant height increased up to 12 N doses per hectare and showed a decreasing trend after the next N dose of 18 kg/ha (Figure 2). In the study, plant height varied between 190.9 cm and 257.3 cm, and Karadağ et al. (2014) found plant height as 183.9-224.2 cm, which is very close to the results of the study. At the same time, Gonulal, (2020) reported the average plant height as 269.0 cm in a study using hayday variety. Some researchers reported that different row spacings (30-40-50 cm) in different regions did not affect plant height of sorghum silage varieties (Yılmaz et al., 2003; Güler et al. 2003). It is similar to the results obtained in the study conducted by Ghazal and Al-Juheishy (2024) with plant height values (158.58-187.60 cm). Additionally, Ozkan et al. (2023) reported that the average plant height was 210.37 cm.

As the distance between rows increases, it may cause an increase in dry matter rather than plant height due to the plant's tendency to tiller more. As can be understood in Figure 1, both the green herbage yield rate and the increase in nitrogen doses up to a certain amount and the decrease after that show the importance of determining the most suitable planting density and nitrogen applications in cultivated plants.

3.1.2. Green herbage yield (kg/da)

According to the variance analysis of green herbage yield, both green Herbage yield and nitrogen doses and the interactions of these two factors were found to be statistically significant (P<0.05). In this study, green herbage yield of sorghum, which is an important feed source in arid and semi-arid regions, varied between 1756.1 kg/ha and 3228.5 kg/ha (Table 1).

When Table 1 is analysed, the highest green herbage yield with 3228.5 kg/ha was obtained from 5 cm row spacing and 6 nitrogen doses. The lowest green herbage yield was obtained from 20 cm row height and 0 (zero) nitrogen dose application with 1756.1 kg/ha. Table 1 shows that the increase in row height showed a decrease in green herbage yield. However, nitrogen increase caused an increase in green herb yield in the above-row applications (Figure 2-A). According to the fertiliser doses, less green herbage yieldwas obtained from the control plots without nitrogen. There was no statistically significant difference between 6, 12 and 18 kg N fertiliser doses (Table 1 and Figure 2-B). Green herbage yield of sorghum plants, in which nitrogen doses and different sowing frequencies were examined, varied between 1756.1 kg/ha and 3228.5 kg/ha. Some researchers found these values lower than the values of Karadağ et al. (2014), green herbage yield 2128.2-4764.3 kg/da, Keskin et al. (2018), green herbage yield 3482.0-8337.6 kg/da.

3.1.3. Dry matter ratio (%)

In this study, green grass yield and nitrogen doses were discussed; Nitrogen doses have a partial effect on dry matter (Figure 3-A) and their interactions are insignificant (P>0.05). The dry matter ratio varied between the lowest 27.2% and the highest 30%. Despite the increase in nitrogen doses, a decreasing trend in the hay ratio of Sorghum was determined (Table 1 and Figure 3-B). The results of the study by Keskin et al. (2018) showed similar results with hay ratio values of 32.0-38.0%. Ozkan et al. (2023) reported the average dry matter ratio as 32.53% in their study.

3.1.4. Dry matter yield (kg/da)

In terms of variance analysis on dry matter yield, as in green grass yield, both in-row and nitrogen doses and their interactions were found to be statistically significant on dry matter yield (P<0.05). According to the data obtained, dry matter yield varies between 522.2 kg/da and 925.2 kg/da. Keskin et al. (2018) reported the hay yield between 1141.2 -2658.1 kg/da in their study. The data obtained from Keskin et al. (2018) was observed to be lower than the results.

In parallel with the increasing green herbage yield, Dry matter yield has also increased, and the lowest Dry matter yield was obtained from the plant plots planted at least frequently, 20 cm over rows (Table 1 and Figure 4-A). The green herbage yield alone shows that Sorghum can be planted in rows of 5 to 15 cm. Dry matter yield is not statistically significant between applications given 6, 12 and 18 kg / N per hectare (Table 1), Dry matter yield from 6 kg N / da to 18 kg N / da is almost constant with a very decrease if the plant is dry If it will be considered as grass, it shows that 6 N application per decare will be sufficient (Figure 4-B).

While the Dry matter yield values of this experiment are between 522.2-925.2 kg/da, dry matter yield 1433.7-3422.3 kg da; Karadağ et al. (2014), dry matter yields 935.0-1924.0 kg/da; Yazıcı (2005) found that Dry matter yield is lower than the yields of 977-2055 kg/da. Güler et al. (2003), in their studies conducted under Diyarbakır conditions, emphasized that in order to increase the Dry matter yield per unit area in silage sorghum cultivation, the gaps between rows should be narrowed in relation to green grass yield per unit area. On the other hand, Kaplan et al. (2019), in sweet Sorghum, the greater the distance between the rows, the lower the feed yield.

Increasing green herbage yield in sorghum cultivation affects feed yield and quality (Zhao et al., 2022). Beyaert and Roy (2005) reported that the maximum feed yield was obtained at 125 kg N/ha. Some studies have reported that increasing the amount of nitrogen above the threshold does not benefit the dry matter yield of forage sorghum (Marsalis et al., 2010).Some researchers reported that with increasing row spacing, the total biomass yield decreased, and the highest yield was obtained in the first year (May et al. 2015).

3.1.5. Stem ratio (%)

The stem ratio of Sorghum varied between 69.1% and 74.8% (Table 1). From nitrogen applications, the sap ratio value of 6 kg/da N dose was lower than control and other applications with a very small difference. However, neither the densities nor the effects of nitrogen on the stem ratio were seen clearly and obviously in these applications (Figures 5-A, 5-B). The stem ratios of the sorghum plant were similar to the stem values (69.7% and 73.2%) of a study conducted by Yilmaz (2000) under Van conditions. Additionally, Keskin et al. (2018) reported the stem ratio as 71.7-78.0% in their study. The data obtained are consistent with other literature data. Some researchers have shown that the effect of green herbage yield and nitrogen applications on grain and Dry matter yield is important in grain sorghum (Musemwa and Musara, 2020).

3.1.6. Leaf ratio (%)

The effect of nitrogen dose on leaf ratio was found to be significant (P<0.05). The leaf ratio in forage plants is one of the important factors affecting the quality and efficiency of the produced feed, and in this experiment, the leaf ratio varied between 15.3% and 20.2% (Table 2).

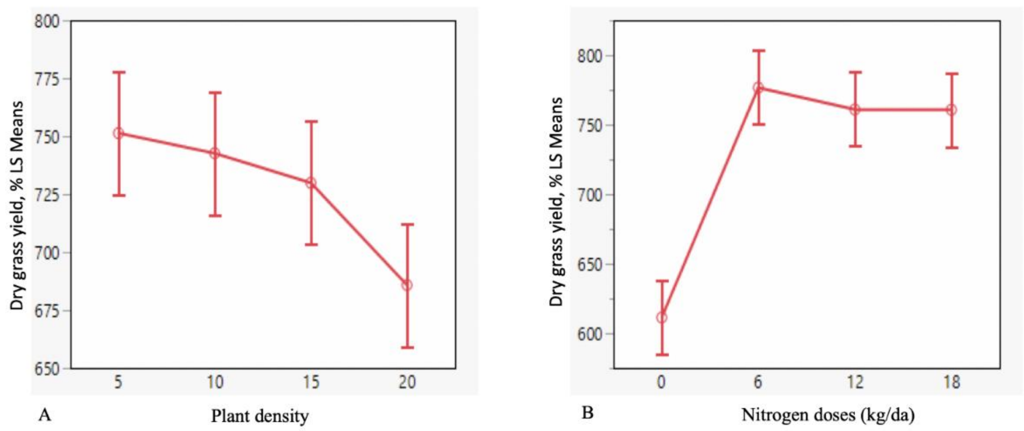

Figure 4. A-Dry grass yield and density, B- Dry grass yield and Nitrogen dose.

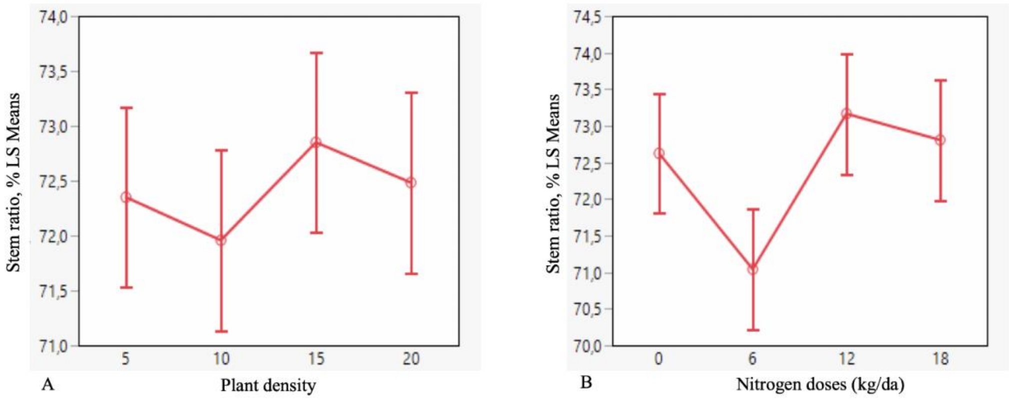

Figure 5. A-Stalk ratio and Frequency, B-Stalk ratio and Nitrogen dosage.

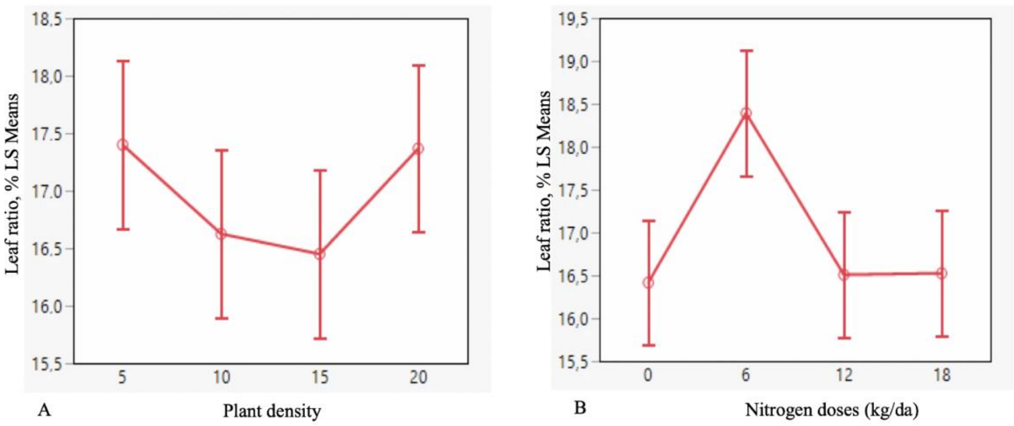

Figure 6. A-Leaf ratio and Frequency, B-Leaf ratio and Nitrogen dose.

The green herbage yield decreased after 5 cm in the study and showed a fluctuating trend (Figure 6-A), but there was no significant difference between applications. Similarly, the leaf ratio of the plots applied at 6 kg N / da was found to be higher and significant compared to other applications (Figure 6-B) but not statistically significant (P>0.05).

A slight difference was observed between leaf ratios depending on nitrogen doses. In a similar study, it was observed that different nitrogen doses (0, 5, 10, 15 and 20 kg/da) did not affect the number of leaves of the plant in Bursa sugar sorghum. Keskin et al. (2018) reported that the leaf ratio varied between 15.7% and 20.0%. Also Kaplan et al. (2019) reported in their study that the leaf ratio was between 16.81 - 20.97%. Nitrogen fertilization positively affected yield and yield components, leaf area index, growth rate, and characteristics such as leaves, stems and clusters (Szabó et al., 2022).

3.1.7. Panicle ratio (%)

The factors and their interaction on the panicle ratio of the plant were not statistically significant (P>0.05). However, as the green grass yield increased from 5 cm to 10 cm, the bunch ratio increased slightly and followed an unstable trend (Figure 7). It is estimated that at 12 k/da N dose, the statistically insignificant decrease in panicle ratio is large. Kaplan et al. (2019) reported that the average cluster rate in their study with different nitrogen applications was between 68.88 - 71.37%. Some researchers have reported that N rates significantly affect the total weight of the panicle, with the optimum occurring at 9 kg/ha N (Xorse Kugbe, 2019). Others found that green grass yield and nitrogen levels were not important on the number of seeds per cluster, but they achieved green grass and hay yield with the application of 240 kg N/ha (Shahrajabian et al., 2011).

3.1.8. Crude protein ratio (%)

It was observed that different row distances and nitrogen doses applied to the sorghum plant were very important on the crude protein yield rate of the plant (P<0.05). The nitrogen content of sorghum varies between 6.4% and 8.1%. Although there was not a large variation between the nitrogen rate of the plant and the nitrogen application in terms of density, the nitrogen rate in the 10 cm density application was slightly lower than in other applications; In terms of nitrogen, the crude protein rate of the plant to which 18 doses of nitrogen was applied per decare was higher at 7.8% compared to other applications, and the rate of the plant without nitrogen was the lowest at 7.0%. The density effect on crude protein differed little (Figure 8-A); However, no significant differences were found between nitrogen treatments; the crude protein ratio increased in parallel with the dose increase (Figure 8-B).

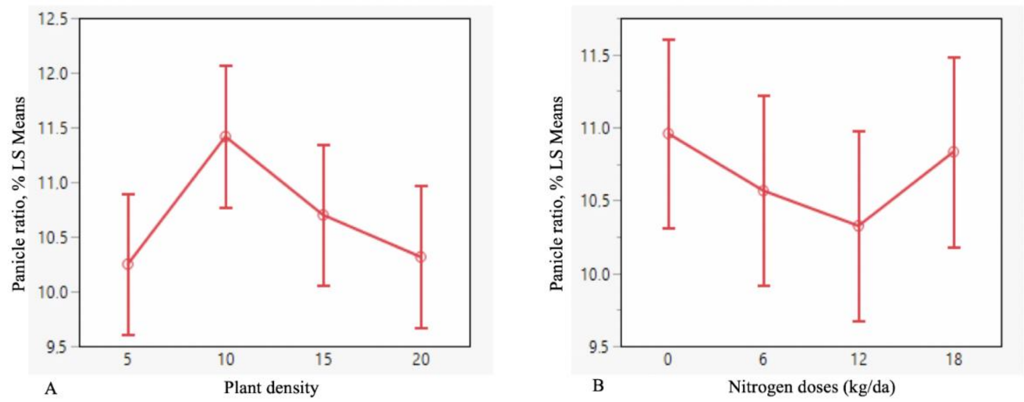

Figure 7. A-Bunch ratio and Frequency, B-Bunch and Nitrogen dosage.

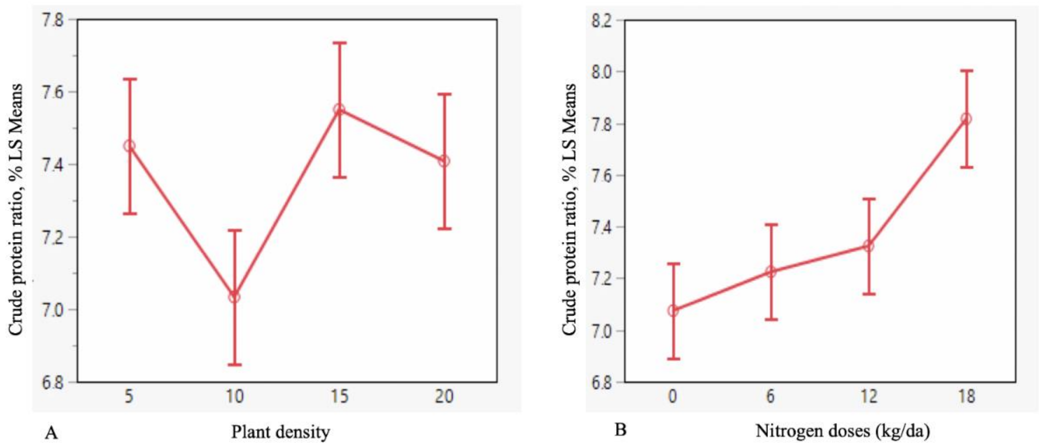

Figure 8. A-Crude protein ratio and Frequency, B-Crude protein content and Nitrogen dosage.

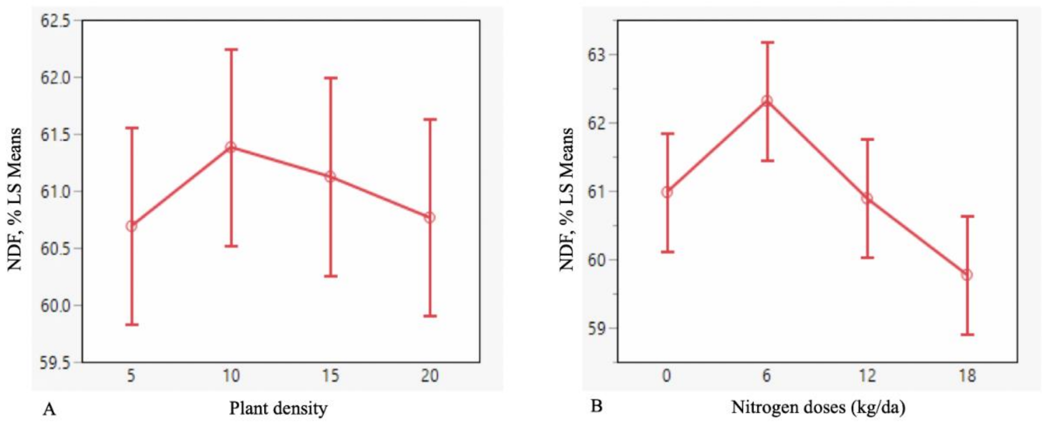

Figure 9. A-NDF ratio and Frequency, B-NDF ratio and Nitrogen dose.

In this research, the crude protein content of sorghum varied between 6.4% and 8.1%. Kaplan et al. (2019) reported in their study with different nitrogen applications that crude protein ratios varied between 4.88 - 6.70%. Similar results are seen when compared to the literature. In our study, it was determined that there was an increase in the crude protein ratio with increasing nitrogen content.

3.1.9. NDF ratio (%)

The NDF ratio of the plant varies between 58.5% and 63.6% depending on density and nitrogen averages. Only the applied nitrogen doses had an effect on the NDF ratio of the plant; the NDF ratio of the plants in the plot where 6 kg nitrogen was given per decare was highest with 62.3%; The lowest one was taken from the parcel with the highest nitrogen (Table 1 and Figure 9-A). Although the density was insignificant, NDF started to decrease in the plant after 10 cm; similarly, if the control plot is not taken into account, the NDF content of the plant decreased after 6 kg N/da. Similar results were reported by Kaplan et al. (2019) in their study, the NDF ratio is similar to the values of 57.20 - 61.33%.

3.1.10. ADF ratio (%)

The interaction of density and nitrogen dose was not statistically significant, except for nitrogen doses in sorghum (P>0.05). The ADF rate of sorghum varies between 31.7% and 34.5%. However, nitrogen doses, although significant, may have appeared more pronounced between treatments. It was observed that the ADF rate in the control plot where only fertilizer was not applied was lower than in nitrogen applications (Table 1). Nitrogen increased the ADF rate from 32.7% at 5 cm row spacing to 33.4% at 10 cm density (Figure 10), the ADF rate of nitrogen applications is shown in Figure 10. The ADF rate obtained in the study was compared to that of Kaplan et al. (2019) found that the ADF rate was lower than 34.80 - 38.83%.

Structural carbohydrates found in roughage are divided into two groups: NDF (cellulose, hemicellulose and lignin) and ADF (cellulose, hemicellulose) (Tekce and Gül, 2014). The NDF rate of the sorghum plant used in the experiment varies between 58.5-63.1% and the ADF rate varies between 31.7-34.5%. Karadağ et al. (2014), NDF rates are 61.23-63.00% and ADF rates are 39.14-40.92%. Additionally, Kaplan et al. (2019), NDF rate, 57.20 - 61.33%, ADF rate, 34.80 - 38.83%. This study, Karadağ et al. (2014), Kaplan et al. (2019) is supported by the results.

Atalay (2019) examined the effects of different nitrogen applications on yield and some quality characteristics of sorghum x sudangrass (*Sorghum bicolor* (L.) Moench x *Sorghum sudanense* (Piper) Stapf) hybrid varieties, and the increased nitrogen content, excluding the leaf ratio in the plant. The total green and hay yield and crude protein ratios are investigated; on the other hand, the crude fiber, ADF, and NDF ratios have decreased with the increase in the amount of pure nitrogen applied per decade. It is seen that it is very in line with the results of this study (Atalay, 2019). In a similar study, Olak and Tan (2016) reported that different nitrogen doses significantly affected other parameters, except for nitrogen doses in Gin Millet (*Panicum italicum* L.) ADF and NDF ratios in millet.

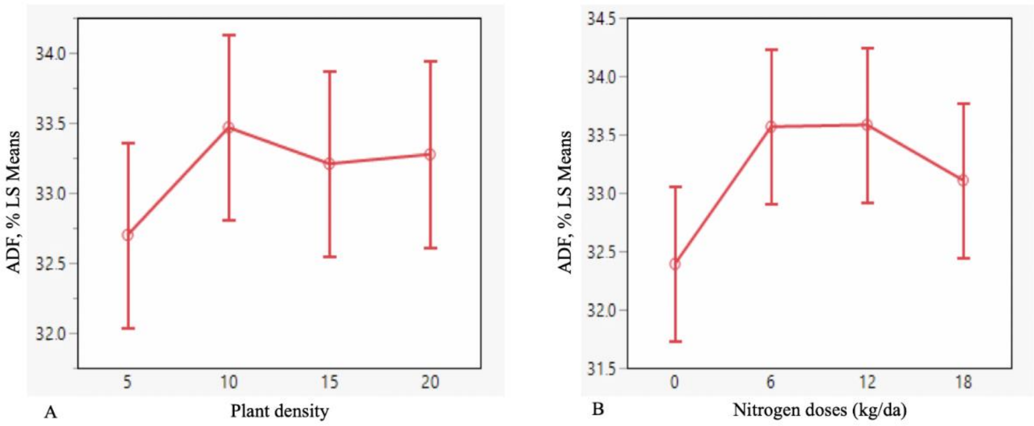

Figure 10. A- ADF ratio and Frequency, B- ADF ratio and Nitrogen dose.

Table 2. Correlations between some agronomic and quality traits of sorghum plant

	Plant height, (cm)	Green herbage yield, (kg/da)	Hay ratio, (%)	Hay yield, (kg/da)	Leaf ratio, (%)	Stem ratio, (%)	Panicle ratio, (%)	Crude protein ratio, (%)	PDF ratio, (%)	ADF ratio, (%)
Plant height, cm	1	0.510**	-0.064	0.482**	-0.332*	0.483**	-0.308*	0.209	0.142	0.418**
Green herbage yield, kg/da		1	-0.179	0.957**	-0.129	0.341*	-0.299*	0.356*	-0.120	0.088
Hay ratio,%			1	0.102	0.105	-0.045	-0.039	-0.186	0.050	-0.069
Hay yield, kg/da				1	-0.099	0.324*	-0.303*	0.306*	-0.112	0.057
Leaf ratio,%					1	-0.726**	-0.152	-0.064	0.178	0.125
Sap ratio,%						1	-0.518**	0.300*	-0.133	-0.086
Panicle ratio,%							1	-0.261	-0.083	-0.103
Crude protein ratio,%								1	-0.057	0.051
PDF ratio,%									1	0.581**
ADF ratio,%										1

Türk and Alagöz (2019) support the results of this study, with the results that nitrogen applications on a different plant, bee grass, increase the hay yield and crude protein ratio while decreasing the ADF and NDF ratios.

3.1.11. Correlation between investigated properties of the Sorghum

The correlation between plant height, green herbage yield, hay rate, hay yield, leaf rate, stem ratios, and crude protein, NDF, and ADF ratios are shown in Table 2. Plant height and green herbage yield, hay yield, and ADF ratio are very significantly and positively related, and the leaf ratio has been found to be significantly but negatively related to the panicle ratio (P<0.05). The positive and strongest relationship between green herbage and hay yield was r=0.957. However, a strong negative relationship between leaf ratio and stem ratio r=0.726 was observed. In a study conducted with grain sorghum, they stated that the plant given 45 and 90 kg N per decare caused an increase of 13% and 48% in yield, respectively, compared to the control. There was a strong relationship between the number of seeds and the total biomass and grain yield (Mahama et al., 2014). The fact that this study is a single year was insufficient to reveal the relationships between the investigated features.

4. Conclusion

Climate change and rapid population growth have exacerbated global food production problems, particularly affecting agricultural areas. Despite Turkey's significant potential in livestock production, returns per animal remain low, mainly due to inadequate quality forage resources and declining meadow and pasture production. Sorghum as an alternative to maize considering Turkey's roughage needs, sorghum is an excellent maize substitute for animal feed. Sorghum is tolerant to high temperatures and drought and regrows rapidly after harvest. Due to its xerophytic properties, adaptable sorghum (*Sorghum bicolor* L.) is widely grown as forage and roughage. The availability of quality feed is critical for dairy animal performance and shortages of quality feed limit profitable livestock production in developing countries. Introduction of high yielding crop varieties is vital to overcome this shortage.

This study aimed to assess the potential of sorghum for high quality biomass production in the Igdir Aras basin. Development of high yielding varieties is necessary to meet the increasing demand for animal feed (Chohan et al., 2006). This study focussed on the agronomic characteristics of different row spacing and nitrogen doses in Sorghum x Sudan grass-Hayday cultivar, including crude protein, NDF and ADF ratios. According to the data obtained as a result of the study, plant height varied between 190.9 cm and 257.3 cm with the highest at 20 cm sowing frequency and 12 nitrogen doses and the lowest at 5 cm sowing frequency without nitrogen dose. Increasing nitrogen applications are associated with increasing plant height (Karadağ et al., 2014; Gonulal, 2020; Özkan et al., 2023; Ghazal and Al-Juheishy, 2024). Green grass yield varied between 1756.1 kg/ha and 3228.5 kg/ha. The highest yield was obtained at 5 cm row spacing and 6 nitrogen dose and the lowest yield was obtained at 20 cm row height without nitrogen. Increasing nitrogen doses were associated with higher yield (Karadağ et al., 2014; Keskin et al., 2018). Dry matter ratio varied between 27.2 and 30%. Increasing nitrogen doses showed a decreasing trend in dry matter ratio (Keskin et al., 2018; Özkan et al., 2023). Increasing green grass yield is associated with increasing dry matter yield. Dry matter yield varied between 522.2 kg/ha and 925.2 kg/ha. Optimum sowing frequency and nitrogen applications are very important for yield (Keskin et al., 2018).

Stem ratio varied between 69.1% and 74.8%. Nitrogen applications did not significantly affect the stem ratio. Leaf ratio varied between 15.3% and 20.2% and nitrogen doses positively affected leaf ratio and quality (Yılmaz, 2000; Keskin et al., 2018; Kaplan et al., 2019). Crude protein ratio varied between 6.4 and 8.1%. It can be said that increasing nitrogen doses positively affect the crude protein content (Kaplan et al., 2019). NDF ratio varied between 58.5% and 63.6% and ADF ratio varied between 31.7% and 34.5%. Nitrogen doses significantly affected these rates, and increasing nitrogen was associated with higher NDF and ADF rates (Tekce and Gül, 2014; Kaplan et al., 2019).

Sorghum, a resilient and versatile crop, has significant potential to improve animal feed quality and yield in arid and semi-arid regions. To maximise the agronomic benefits of sorghum, it is very important to optimise sowing frequency and nitrogen applications. In this study, it was concluded that sorghum for silage (Sorghum bicolor x Sorghum sudanense Mtapf.) Hayday can be sown at a sowing rate of 28.570/piece per decare and 6 kg nitrogen fertiliser per decare may be sufficient.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	H.A.	B.K.	B.E.
C	25	25	50
D	50	25	25
S	40	30	30
DCP	40	30	30
DAI	50	25	25
L	40	30	30
W	40	30	30
CR	50	25	25
SR	40	30	30
PM	40	30	30
FA	50	25	25

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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