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# Effects of Different Nitrogen Doses on Dry Matter Yield and Quality in Sweet Sorghum (*Sorghum bicolor* var. *saccharatum* (L.) Mohlenbr.) Varieties

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**ABSTRACT**

This study was conducted to investigate the effects of different nitrogen doses on the dry matter yield and forage quality of sweet sorghum (*Sorghum bicolor* var. *saccharatum* (L.) Mohlenbr.) varieties during the main cropping season. Field experiments were carried out in 2022 and 2023 at the trial fields of the Agricultural Application and Research Center of Bursa Uludag University Faculty of Agriculture, using a split-plot design in randomized complete blocks with 3 replications. Plant height, stem diameter, leaf ratio, stem ratio, dry matter yield, crude protein, acid detergent fiber (ADF) and neutral detergent fiber (NDF) ratios were examined in this research. In the study, the highest dry matter yield was obtained from the Gulseker variety in both years, with average values ranging between 25.92–29.26 t ha$^{-1}$. The effect of nitrogen doses on dry matter yield varied across the years, and the highest yield (23.58 t ha$^{-1}$) in 2023 was obtained from the 160 kg ha$^{-1}$ nitrogen application. While the Uzun variety stood out for its crude protein ratio (6.87% and 7.38% in 2022 and 2023, respectively), the Gulseker and Erdurmus varieties had lower ADF and NDF ratios. The variety × nitrogen dose interaction was significant for dry matter yield and crude protein ratio. Consequently, for sweet sorghum production during the main cropping season in Bursa and similar ecological conditions, the Gulseker variety and a nitrogen dose of 160 kg ha$^{-1}$ are recommended as a suitable combination for productivity and sustainability.

## 1. INTRODUCTION

Sweet sorghum (*Sorghum bicolor* var. *saccharatum* (L.) Mohlenbr) is a typical C4 plant and an annual energy crop with high photosynthetic efficiency (Sadighfard, 2016). Originating in Africa, this plant is now widely cultivated in the USA, Brazil, India, China, Mexico, Sudan, Argentina, and many countries in Asia and Europe. Sweet sorghum shows greater tolerance to abiotic stress conditions than maize. Because of this characteristic, it is considered an alternative forage crop to silage maize in regions where adverse environmental conditions are expected to become widespread. With a broader adaptation capacity than maize, sweet sorghum offers significant potential to close the roughage deficit by producing high biomass with 37% less nitrogen fertilizer and 17% less water consumption (Rutto et al., 2013; Ahmed, 2020). Although the sweet sorghum plant can take up substantial amounts of nitrogen from the soil, its response to nitrogen fertilization varies significantly across different soil and climate conditions (Scordia et al., 2021). Studies conducted on clay-loam soils reported that fertilizer application increased yield by only 23-43%, indicating that the nitrogen requirement of sweet sorghum varies with environmental conditions (Almodares and Hadi, 2009). Therefore, conducting studies involving different nitrogen doses is of great importance. Broad genetic variation and differing responses to similar growing conditions necessitate the determination of suitable varieties and fertilization strategies for specific regions (Kering et al., 2017). Dry matter yield changes significantly depending on the applied nitrogen dose and environmental conditions (Maw et al., 2020), and high dry matter yield is considered an indicator of high nutrient and mineral content in the forage (Oktem et al., 2021). Differences in nutrient uptake and storage among sweet sorghum genotypes lead to marked variations in dry matter accumulation (Ahmed, 2020). Although nitrogen application strongly affects sweet sorghum growth and yield, the plant's response depends primarily on variety and environmental conditions According to previous studies in sweet sorghum grown as a main crop under different ecological conditions, dry matter yield varied between 11.40-55.99 t $ha^{-1}$ depending on variety and nitrogen fertilizer applications (Turgut et al., 2005; Tamang, 2010; Uchino et al., 2013; Ekefre et al., 2017; Oktem et al., 2021; Bhutada et al., 2020). Annual precipitation and temperature differences significantly affect dry matter, juice, and sugar yield, and the nitrogen response of sweet sorghum genotypes varies depending on climatic conditions and irrigation. Additionally, soil structure has a significant effect on dry matter production and nitrogen response (Maw et al., 2016). Since excessive nitrogen use can lead to environmental problems, a balance must be established between yield increase and environmental sustainability in nitrogen applications. In this context, determining the appropriate nitrogen dose for each variety and growing condition is important for sustainable agriculture.

This study was conducted to determine the effects of different nitrogen doses (0, 80, 160, and 240 kg $ha^{-1}$) on the dry matter yield and forage quality of three different sweet sorghum varieties (Gulseker, Erdurmus, and Uzun) grown under main crop conditions.

## 2. MATERIALS and METHODS

### Experimental site

This research was conducted in 2022 and 2023 under Bursa conditions at the trial fields of the Agricultural Application and Research Center of Bursa Uludag University Faculty of Agriculture (40° 11' N, 29° 04' E). Soil samples were taken from different depths (0-20 cm and 20-40 cm) to represent the experimental area in 2022 and 2023, and the results of the soil analysis are given in Table 1. According to soil analysis results, the study area soil was determined to have a clay texture, slightly alkaline reaction, no salinity problem, low lime content, moderate organic matter content, low total nitrogen content, and low to moderate available phosphorus content. Bursa, located in the Southern Marmara region of Turkey, is characterized by a Mediterranean transition climate. During the six-month vegetation period (May-October) when the field trials were conducted, the average temperature in 2022 was 20.98 °C, in 2023 was 22.55 °C, and the long-term average for the region is 21.23 °C. The average temperature value recorded in the first year of the experiment was similar to the long-term average, whereas in the second year, it was 1.32 °C higher. The total amount of precipitation during the six-month vegetation period was recorded as 238.90 mm and 49.80 mm in 2022 and 2023, respectively, and these values were significantly below the long-term average (392.40 mm). Notably, no precipitation occurred in June, July, August, and September of 2023 (Fig. 1).

### Experimental details

In the research, Gulseker, Erdurmus, and Uzun sweet sorghum (*Sorghum bicolor* var. *saccharatum* (L.) Mohlenbr.) varieties were used as plant materials. Four nitrogen doses (0, 80, 160, and 240 kg $ha^{-1}$) were applied in the experiment, and ammonium sulfate (21% N) and urea (46% N) were used as nitrogen sources. The field trials were established in a split-plot design in randomized blocks with 3 replications, and the total experimental area was 874 $m^2$. Varieties were assigned to the main plots, and nitrogen doses were assigned to the subplots. In each subplot, planting was done in 5 rows with a plot length of 5 m, a row spacing of 70 cm, and an intra-row spacing of 10 cm. After parceling according to the

experimental design, phosphorus fertilization was applied before sowing at a rate of 100 kg $P_2O_5$ $ha^{-1}$. Triple superphosphate fertilizer (42% $P_2O_5$) was used as the phosphorus source. Sowing in the experiment was carried out on May 14, 2022, and May 19, 2023. Half of the nitrogen fertilizer (21% ammonium sulfate) was applied at sowing. Thinning was performed after seedling emergence in the experimental area, and subsequently, a drip irrigation system was installed. The second half of the nitrogen fertilizer was applied with 46% urea fertilizer when the plants reached 40-50 cm in height (June 23, 2022, and July 07, 2023). Weed development was monitored in the experimental areas, and manual weed control was performed.

**Table 1.** Physical and chemical properties of the soils in the experimental area

| Properties | Depth (cm) | 2022 | 2023 |
|---|---|---|---|
| Texture | 0-20 | Clay | Clay |
| | 20-40 | Clay | Clay |
| pH | 0-20 | 7.80 | 7.95 |
| | 20-40 | 7.72 | 7.68 |
| EC (µS $cm^{-1}$) | 0-20 | 650 | 655 |
| | 20-40 | 637 | 634 |
| Lime (%) | 0-20 | 2.05 | 2.55 |
| | 20-40 | 2.21 | 2.64 |
| Organic matter (%) | 0-20 | 2.46 | 3.76 |
| | 20-40 | 2.15 | 3.70 |
| Total nitrogen (%) | 0-20 | 0.071 | 0.083 |
| | 20-40 | 0.069 | 0.088 |
| Available phosphorus (mg $kg^{-1}$) | 0-20 | 13.63 | 5.24 |
| | 20-40 | 6.56 | 15.84 |
| Available Potassium (mg $kg^{-1}$) | 0-20 | 63.21 | 51.30 |
| | 20-40 | 53.07 | 46.86 |

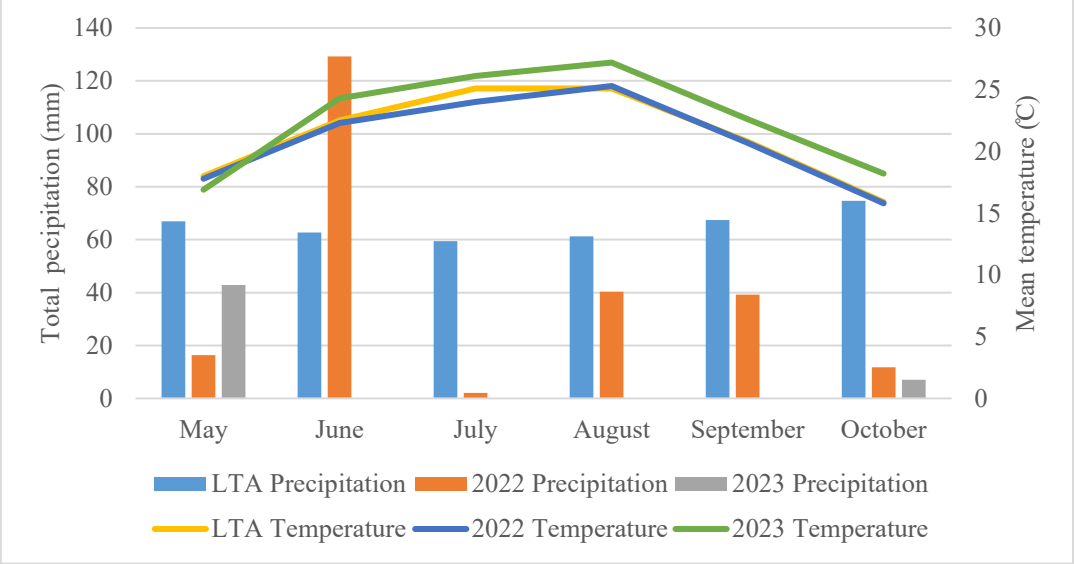



**Figure 1.** Climatic data for 2022, 2023, and the long-term average (LTA-1990-2020) in Bursa.

Measurements, observations, and analysis

Harvesting in the experiment was carried out during the milk-dough stage of the grains in the plant panicles (Yucel et al., 2020). Before harvest, plant height, stem diameter, and stem and leaf ratio were determined in 10 randomly selected plants from each subplot (Yucel et al., 2018). During harvest, after leaving a 0.5 m buffer zone at the row ends in the two central rows of each subplot, the remaining plants were manually cut to a stubble height of 3-5 cm and weighed. Two randomly selected plants from each subplot were weighed separately, then dried in a drying oven at 70 °C until a constant weight was reached, and their dry weights were determined (Yucel et al., 2018). The dry matter ratio was calculated using the obtained values, and the dry matter yield was determined by multiplying this ratio by the green forage yield. The dried

plant samples used to determine the dry matter ratio were ground in a mill with a 1 mm sieve and prepared for chemical analyses. The crude protein ratio was determined using the Kjeldahl method (AOAC, 2000). The ADF and NDF ratios in the plant samples were analyzed using the Ankom 200/220 device according to the method reported by Van Soest et al. (1991).

Statistical Analysis

The data obtained from the characteristics examined in both years of the study (2022 and 2023) were analyzed using analysis of variance (ANOVA) in JUMP Pro 13, an appropriate software package for the split-plot experimental design. 1% and 5% probability levels were used for significance tests, and a 5% probability level was used for group comparisons, with the least significant difference (LSD) test for group separation.

## 3. RESULTS and DISCUSSION

In the study, environmental conditions varied significantly each year (Fig.1), which led to different sweet sorghum yields each year. Although the amount of precipitation recorded between May and October in 2022 was much higher compared to 2023, the average temperature in 2022 was 1.57 °C lower than in 2023. The fact that 2022 was colder yet more rainy compared to 2023 negatively affected plant development, which resulted in lower yields. Indeed, Maw et al. (2016) reported that low temperature and high precipitation reduce the plant's nitrogen utilization potential and decrease yield.

The variance analysis results for the examined characteristics are presented in Table 2. Since the differences between years were determined to be statistically significant with respect to the characteristics examined in the study, each year was evaluated separately. In 2022, the effects of varieties on stem ratio, leaf ratio, dry matter yield, and NDF ratio were significant at the 1% probability level. In contrast, their effects on crude protein and ADF ratio were significant at the 5% probability level. In the same year, nitrogen doses showed a significant effect on stem diameter at the 1% probability level, and on stem ratio and dry matter yield at the 5% probability level. The variety × nitrogen dose interaction was significant only for dry matter yield at the 5% level; no other significant interactions were detected. In 2023, varieties had a significant effect on stem diameter, stem ratio, dry matter yield, and NDF ratio at the 1% probability level, and on crude protein and ADF ratio at the 5% probability level. The effect of nitrogen doses was significant for dry matter yield at the 5% probability level and for crude protein ratio at the 1% probability level. In contrast, no statistically significant differences emerged for the other traits. The variety × nitrogen dose interaction was significant in 2023 for dry matter yield at the 5% probability level and for crude protein ratio at the 1% probability level; no significant interaction was observed for other traits (Table 2).

**Table 2.** Variance analysis results for 2022 and 2023 (Mean Squares)

| Y | SV | DF | PH | SD | SR | LR | DMY | CP | ADF | NDF |
|---|---|---|---|---|---|---|---|---|---|---|
| 2022 | Blocks | 2 | 275.100 | 0.777 | 13.755 | 3.617 | 18588.500 | 0.377 | 10.988 | 10.456 |
| | V | 2 | 737.550 | 5.947 | 341.251** | 70.822** | 2272960** | 9.030* | 30.325* | 227.911** |
| | MPE | 4 | 359.070 | 1.629 | 17.284 | 1.963 | 17460.800 | 1.059 | 2.558 | 11.292 |
| | ND | 3 | 161.410 | 9.161** | 21.166* | 2.469 | 112215* | 2.433 | 1.039 | 7.367 |
| | VxND | 6 | 384.010 | 0.958 | 4.438 | 2.198 | 63044.300* | 0.874 | 2.104 | 6.029 |
| | SPE | 18 | 436.660 | 1.578 | 5.525 | 2.575 | 30054 | 1.031 | 8.993 | 11.650 |
| 2023 | Blocks | 2 | 67.019 | 0.978 | 5.431 | 0.013 | 49818.700 | 0.233 | 2.515 | 0.284 |
| | V | 2 | 125.074 | 38.353** | 95.666** | 1.434 | 2829195** | 17.814** | 71.490* | 310.887** |
| | MPE | 4 | 110.402 | 1.807 | 4.375 | 0.352 | 20191.700 | 0.160 | 5.038 | 15.338 |
| | ND | 3 | 181.454 | 0.644 | 1.945 | 1.009 | 190897* | 6.280** | 6.500 | 3.904 |
| | VxND | 6 | 51.362 | 0.920 | 5.542 | 1.279 | 186536* | 1.667** | 6.040 | 2.586 |
| | SPE | 18 | 239.080 | 0.585 | 2.503 | 0.742 | 51116 | 0.364 | 7.857 | 19.087 |
| 2022-2023 | Y | 1 | 3035.5** | 0.879** | 59.005** | 142.95** | 986832** | 16.743** | 100.111** | 656.488** |
| | Blocks | 4 | 171.060 | 68.973 | 9.593 | 1.815 | 34203.600 | 0.305 | 6.752 | 5.370 |
| | V | 2 | 475.863 | 37.048** | 392.198** | 45.459** | 4894210** | 25.665** | 71.103** | 438.767** |
| | VxY | 2 | 386.757 | 7.254 | 44.719* | 26.796** | 207945* | 1.180 | 30.712* | 100.031* |
| | MPE | 8 | 234.736 | 1.718 | 9.832 | 1.157 | 26487 | 0.610 | 3.798 | 13.315 |
| | ND | 3 | 327.798 | 6.024** | 15.393* | 1.399 | 252070** | 7.653** | 2.019 | 5.332 |
| | VxND | 6 | 143.319 | 1.179* | 4.014 | 2.205 | 120127* | 0.786 | 6.450 | 5.059 |
| | NDxY | 3 | 15.0661 | 3.780 | 7.718 | 2.079 | 51132.200 | 1.060 | 5.520 | 5.939 |
| | VxNDxY | 6 | 292.050 | 0.699 | 5.966 | 1.272 | 129453** | 1.755* | 1.694 | 3.556 |
| | SPE | 36 | 337.872 | 1.082 | 4.340 | 1.659 | 37165 | 0.697 | 8.425 | 15.360 |

PH: plant height, SD: stem diameter, SR: stem ratio, LR: leaf ratio, DMY: dry matter yield, CP: crude protein, ADF: acid detergent fiber, NDF: neutral detergent fiber
SV: source variation, DF: degrees of freedom, Y: year, V: variety, ND: nitrogen dose, MPE: main plot error, SPE: subplot error
*, **: significant difference at probability level of 5% and 1% respectively.

According to the analysis of variance performed for plant height, the effects of variety and nitrogen dose were found to be statistically insignificant in both years (Table 2). Plant height in sweet sorghum varieties ranged between 304.90-320.18 cm in 2022 and 323.07–329.45 cm in 2023 (Table 3). Although no significant difference in plant height was observed among varieties in this study, many studies in the literature have reported significant variation in plant height among sweet sorghum varieties/genotypes (Olugbemi et al., 2018; Bhutada et al., 2020; Ghallab & Helmy, 2023; Khalil et al., 2024). Increasing nitrogen doses did not statistically affect plant height (Table 3). These results are consistent with some studies reporting that nitrogen application has an insignificant effect on plant height (Olugbemi et al., 2018; Khalil et al., 2024), but differ from research reporting that nitrogen doses significantly increased plant height (Almodares et al., 2013; Elnasikh & Ibrahium, 2015; Galal et al., 2019; Bhutada et al., 2020).

In 2022, the stem diameters of sweet sorghum varieties ranged from 18.37 to 19.75 mm, and differences among varieties were not statistically significant. In 2023, the highest stem diameter was observed in the Gulseker variety at 22.84 mm, and the lowest was observed in the Uzun variety at 19.27 mm; differences among varieties were statistically significant (Table 3). However, studies in the literature report no statistically significant difference in stem diameter among sweet sorghum varieties (Besheit & Mekdad, 2016; Bhutada et al., 2020). In 2022, stem diameter increased with increasing nitrogen doses up to 160 kg N ha$^{-1}$, and the highest stem diameter (20.14 mm) was observed at this dose. In 2023, the effect of nitrogen doses on stem diameter was not statistically significant, and stem diameters generally ranged from 20.78 to 21.44 mm (Table 3). The findings obtained are consistent with those reported by Mahmoud et al. (2013), Galal et al. (2019), and Mekdad and Emam (2019), but differ from those reported by Bhutada et al. (2020). These differences are thought to stem from the genetic characteristics of the varieties used and the variability in environmental conditions.

The highest stem ratio was obtained from the Gulseker and Erdurmus varieties in both 2022 and 2023, while the lowest stem ratio was obtained from the Uzun variety (Table 3). In the literature, stem ratios have been reported to range from 74.7% to 91.5% across different ecological conditions, depending on sweet sorghum variety (Ekefre et al., 2017; Oktem et al., 2021). Although these values are absolutely higher, the relative variation trends among varieties are consistent with the current findings. In 2022, increasing nitrogen doses negatively affected the stem ratio; the stem ratio decreased at the highest nitrogen dose, whereas higher values were observed in the control and at 80 kg N ha$^{-1}$. In contrast, in 2023, the effect of nitrogen doses on stem ratio was statistically insignificant, and stem ratios ranged from 79.26% to 80.35% (Table 2 and Table 3).

In the experiment, the highest leaf ratio in 2022 was observed in the Uzun variety at 15.47%, and the lowest was observed in the Gulseker variety at 10.62%. In 2023, differences among varieties in leaf ratio were found to be statistically insignificant, with leaf ratios ranging from 9.79% to 10.44% (Table 2 and Table 4). Oktem et al. (2021) reported that the leaf ratio varied between 6.23% and 20.98% in different sweet sorghum varieties grown under Harran Plain conditions. In both years the experiment was conducted, the effect of increasing nitrogen doses on leaf ratio was statistically insignificant; leaf ratios ranged from 13.10–13.44% to 9.69–10.40% in 2022 and 2023, respectively (Table 2 and Table 4).

**Table 3.** Effects of variety and nitrogen doses on plant height, stem diameter, and stem ratio in 2022 and 2023.

| Nitrogen Dose (kg ha$^{-1}$) | Plant height (cm) | | | | Stem diameter (mm) | | | | Stem ratio (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | G | E | U | Mean | G | E | U | Mean | G | E | U | Mean |
| 2022 | | | | | | | | | | | | |
| 0 | 320.70 | 314.70 | 310.13 | 315.18 | 19.31 | 16.49 | 18.16 | 17.99$^{c}$ | 80.06 | 76.32 | 70.50 | 75.63$^{a}$ |
| 80 | 312.30 | 316.80 | 326.67 | 318.59 | 18.77 | 18.11 | 19.01 | 18.63$^{bc}$ | 80.57 | 74.54 | 70.38 | 75.16$^{a}$ |
| 160 | 296.97 | 317.37 | 312.63 | 308.88 | 20.35 | 19.94 | 20.13 | 20.14$^{a}$ | 78.13 | 75.71 | 68.73 | 74.19$^{ab}$ |
| 240 | 289.97 | 313.43 | 331.30 | 311.57 | 20.56 | 18.95 | 19.96 | 19.82$^{ab}$ | 78.20 | 73.36 | 64.95 | 72.17$^{b}$ |
| Mean | 304.90 | 315.58 | 320.18 | | 18.37 | 19.75 | 19.31 | | 79.24$^{a}$ | 74.98$^{a}$ | 68.64$^{b}$ | |
| 2023 | | | | | | | | | | | | |
| 0 | 324.63 | 323.07 | 330.00 | 325.90 | 22.61 | 18.60 | 22.09 | 21.10 | 81.64 | 82.07 | 75.60 | 79.77 |
| 80 | 331.27 | 326.53 | 341.40 | 333.07 | 22.44 | 19.18 | 20.73 | 20.78 | 82.88 | 81.32 | 75.99 | 80.06 |
| 160 | 324.13 | 320.50 | 325.40 | 323.34 | 22.95 | 19.38 | 20.91 | 21.08 | 81.28 | 82.38 | 77.38 | 80.35 |
| 240 | 328.37 | 322.17 | 321.00 | 323.84 | 23.50 | 19.91 | 21.06 | 21.44 | 81.60 | 78.64 | 77.54 | 79.26 |
| Mean | 327.10 | 323.07 | 329.45 | | 22.84$^{a}$ | 21.20$^{b}$ | 19.27$^{c}$ | | 81.85$^{a}$ | 81.10$^{a}$ | 76.63$^{b}$ | |

Means of the same column and line followed by the same letter were not significantly different at the 0.05 level using the LSD test.
G: Gulseker, E: Erdurmus, U: Uzun

**Table 4.** Effects of variety and nitrogen doses on leaf ratio, dry matter yield, and crude protein in 2022 and 2023.

| Nitrogen Dose (kg ha$^{-1}$) | Leaf ratio (%) | | | | Dry matter yield (t ha$^{-1}$) | | | | Crude protein (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | G | E | U | Mean | G | E | U | Mean | G | E | U | Mean |
| 2022 | | | | | | | | | | | | |
| 0 | 10.90 | 13.38 | 15.76 | 13.44 | 22.86$^{b}$ | 18.72$^{c-e}$ | 17.35$^{e}$ | 19.64$^{b}$ | 5.89 | 5.67 | 6.16 | 5.91 |
| 80 | 10.01 | 13.73 | 15.91 | 13.22 | 25.93$^{a}$ | 22.31$^{b}$ | 17.24$^{e}$ | 21.83$^{a}$ | 5.03 | 6.25 | 6.96 | 6.08 |
| 160 | 10.60 | 12.30 | 16.33 | 13.10 | 26.77$^{a}$ | 20.48$^{b-d}$ | 18.18$^{de}$ | 21.81$^{a}$ | 6.05 | 6.63 | 8.36 | 7.02 |
| 240 | 10.94 | 11.97 | 13.83 | 13.25 | 28.14$^{a}$ | 21.44$^{b-c}$ | 16.34$^{e}$ | 21.97$^{a}$ | 5.81 | 6.19 | 8.05 | 6.68 |
| Mean | 10.62$^{c}$ | 12.92$^{b}$ | 15.47$^{a}$ | | 25.92$^{a}$ | 20.74$^{b}$ | 17.28$^{c}$ | | 5.69$^{b}$ | 6.19$^{b}$ | 7.38$^{a}$ | |
| 2023 | | | | | | | | | | | | |
| 0 | 10.41 | 9.79 | 10.86 | 10.35 | 27.54$^{b}$ | 20.76$^{de}$ | 17.88$^{e}$ | 22.06$^{c}$ | 3.64$^{de}$ | 4.19$^{de}$ | 6.63$^{a-c}$ | 4.82$^{b}$ |
| 80 | 8.98 | 10.96 | 10.94 | 10.30 | 26.83$^{bc}$ | 23.30$^{cd}$ | 22.59$^{d}$ | 24.24$^{ab}$ | 3.28$^{e}$ | 4.22$^{de}$ | 6.61$^{a-c}$ | 4.70$^{b}$ |
| 160 | 9.72 | 9.69 | 9.65 | 9.69 | 34.32$^{a}$ | 21.22$^{de}$ | 20.89$^{de}$ | 23.58$^{a}$ | 5.72$^{c}$ | 4.57$^{d}$ | 7.38$^{a}$ | 5.89$^{a}$ |
| 240 | 10.05 | 10.86 | 10.30 | 10.40 | 28.65$^{b}$ | 18.45$^{e}$ | 21.72$^{de}$ | 22.94$^{bc}$ | 6.25$^{bc}$ | 6.18$^{bc}$ | 6.84$^{ab}$ | 6.42$^{a}$ |
| Mean | 9.79 | 10.32 | 10.44 | | 29.26$^{a}$ | 20.93$^{b}$ | 20.77$^{b}$ | | 4.72$^{b}$ | 4.79$^{b}$ | 6.87$^{a}$ | |

Means of the same column and line followed by the same letter were not significantly different at the 0.05 level using the LSD test.
G: Gulseker, E: Erdurmus, U: Uzun

The highest dry matter yield was obtained from the Gulseker variety in both years, determined as 25.92 t ha$^{-1}$ and 29.26 t ha$^{-1}$ in 2022 and 2023, respectively (Table 4). The present results clearly demonstrate significant differences in dry matter yield among cultivars, which is in strong agreement with previously reported findings (Zhao et al., 2009; Ekefre et al., 2017; Inal et al., 2021; Oktem et al., 2021). The effect of nitrogen doses on dry matter yield varied across the years. In 2022, nitrogen applications increased dry matter yield compared with the control plots, but differences among the 80, 160, and 240 kg N ha$^{-1}$ doses were not statistically significant. In 2023, the increase in nitrogen doses increased the dry matter yield up to the 160 kg N ha$^{-1}$ dose, and the highest dry matter yield (23.58 t ha$^{-1}$) was obtained from this dose (Table 4). The literature reports that the highest dry matter yield is obtained at different nitrogen doses, depending on environmental conditions. Studies conducted in Bursa, Texas, and India reported that the highest yield was obtained with applications of 100–150 kg N ha$^{-1}$ (Turgut et al., 2005; Tamang, 2010; Uchino et al., 2013; Bhutada et al., 2020). In both years, the interaction effect of variety x nitrogen dose was found to be statistically significant in terms of dry matter yield. In 2022, particularly in the Uzun variety, increasing nitrogen doses enhanced dry matter yield up to the 160 kg ha$^{-1}$ application, but with nitrogen increases beyond this dose, yield showed a declining trend. In contrast, in other varieties, there were no significant yield increases between the 160 kg ha$^{-1}$ and 240 kg ha$^{-1}$ nitrogen applications. In 2023, the highest yield in the Gulseker variety was obtained from the 160 kg ha$^{-1}$ nitrogen application, and subsequent additional nitrogen applications caused a decrease in yield, while in the other two varieties, yields obtained from the 160 kg ha$^{-1}$ and 240 kg ha-1 nitrogen applications were similar. The differential responses of varieties to nitrogen doses resulted in the variety × nitrogen dose interaction being statistically significant in terms of dry matter yield. While the highest dry matter yields (28.14 t ha$^{-1}$, 26.77 t ha$^{-1}$ and 25.93 t ha$^{-1}$) in 2022 was obtained from the 240, 160 and 80 kg N ha$^{-1}$ applications of the Gulseker variety, the highest value (34.32 t ha$^{-1}$) in 2023 was determined in the 160 kg N ha$^{-1}$ application of the same variety (Table 4).

**Table 5.** Effects of variety and nitrogen doses on ADF and NDF in 2022 and 2023.

| Nitrogen Dose (kg ha$^{-1}$) | ADF (%) | | | | NDF (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | G | E | U | Mean | G | E | U | Mean |
| 2022 | | | | | | | | |
| 0 | 35.02 | 36.12 | 36.76 | 35.97 | 53.48 | 54.74 | 61.89 | 56.71 |
| 80 | 33.31 | 33.92 | 38.21 | 35.15 | 51.60 | 58.03 | 60.12 | 56.58 |
| 160 | 34.32 | 35.21 | 36.87 | 35.69 | 52.45 | 55.63 | 59.97 | 56.01 |
| 240 | 34.26 | 35.17 | 37.42 | 35.62 | 53.78 | 56.70 | 63.95 | 58.14 |
| Mean | 34.23$^{b}$ | 35.11$^{b}$ | 37.31$^{a}$ | | 52.83$^{b}$ | 56.28$^{b}$ | 61.48$^{a}$ | |
| 2023 | | | | | | | | |
| 0 | 34.10 | 30.40 | 31.44 | 31.98 | 50.83 | 44.16 | 55.66 | 50.22 |
| 80 | 31.08 | 29.85 | 35.96 | 33.30 | 49.28 | 45.31 | 56.47 | 50.36 |
| 160 | 31.08 | 31.14 | 36.59 | 33.93 | 51.05 | 47.59 | 56.23 | 51.62 |
| 240 | 34.05 | 30.34 | 36.28 | 33.56 | 50.97 | 45.31 | 55.47 | 51.10 |
| Mean | 34.08$^{a}$ | 30.43$^{b}$ | 35.07$^{a}$ | | 50.53$^{b}$ | 45.88$^{c}$ | 56.05$^{a}$ | |

Means of the same column and line followed by the same letter were not significantly different at the 0.05 level using the LSD test.
G: Gulseker, E: Erdurmus, U: Uzun

In the experiment, the highest crude protein ratio was obtained from the Uzun variety in both years, determined as 7.38% and 6.87% in 2022 and 2023, respectively (Table 4). Findings regarding the crude protein ratio in sweet sorghum are generally consistent with the values reported in the literature. Studies conducted under different ecological conditions have reported that crude protein ratios range from 5.6–10.00% (Madibela et al., 2002; Mahmood et al., 2013; Naeini et al., 2014; Behling Neto et al., 2017; Inal et al., 2021). In 2022, the effect of increasing nitrogen doses on the crude protein ratio was found to be statistically insignificant, with values ranging from 5.91% to 7.02%. In contrast, in 2023, increasing

nitrogen doses increased the crude protein ratio up to the 160 kg N ha$^{-1}$ dose; the increase remained limited beyond this dose, and the highest crude protein ratios were obtained with the 160 and 240 kg N ha$^{-1}$ applications, which were in the same statistical group (Table 4). Almodares et al. (2009) reported that under Isfahan/Iran conditions, increasing the nitrogen dose from 50 kg N ha$^{-1}$ to 200 kg N ha$^{-1}$ increased the crude protein ratio from 4.30% to 8.00%, and the values determined in our study are consistent with this range. In 2023, the variation in crude protein ratio of sorghum varieties in response to increasing nitrogen doses differed, which resulted in the variety x nitrogen dose interaction being statistically significant. In terms of the variety × nitrogen dose interaction in 2023, the highest crude protein ratio (7.38%) was obtained from the plots of the Uzun variety treated with 160 kg N ha$^{-1}$ (Table 4).

In 2022, the lowest ADF rate was obtained from the Gulseker variety, followed by the Erdurmus variety, which was in the same statistical group. In the second year of the experiment, the lowest NDF rate was obtained from the Erdurmus variety (Table 5). The literature reports that the ADF ratios of sweet sorghum range from 24.4–40.8%, and these results are consistent with the current findings (Madibela et al., 2002; Mahmood et al., 2013; Inal et al., 2021; Oktem et al., 2021). The effect of nitrogen doses on the ADF ratio was not statistically significant in both years, with ADF ratios ranging from 35.15–35.97% in 2022 and 31.98–33.93% in 2023 (Table 2 and Table 5).

In 2022, the lowest NDF ratio was obtained from the Gulseker and Erdurmus varieties, which were in the same statistical group with 52.83% and 56.28%, respectively, and in 2023, it was obtained from the Erdurmus variety with 45.88% (Table 5). Studies conducted under different ecological conditions have reported NDF ratios ranging from 40.3% to 64.5%, values consistent with those obtained in the current study (Madibela et al., 2002; Mahmood et al., 2013; Behling Neto et al., 2017; Inal et al., 2021; Oktem et al., 2021). The effect of increasing nitrogen doses on NDF ratio was not statistically significant in either year, with NDF ratio ranging from 56.01% to 58.14% in 2022 and from 50.22% to 51.62% in 2023 (Table 2 and Table 5). The results obtained are consistent with Tamang's (2010) findings.

## 4. CONCLUSION

This study revealed that the effects of nitrogen doses on the yield and quality of sweet sorghum varieties grown as a main crop under the ecological conditions of Bursa largely depend on the variety and the year. No significant differences were observed between varieties and nitrogen doses for plant height; however, significant differences were observed for dry matter yield and feed quality characteristics. The highest dry matter yield in both years was obtained from the Gulseker variety. The effect of nitrogen doses on dry matter yield was significant in 2023, and the highest yield was obtained with the application of 160 kg ha$^{-1}$ nitrogen. While the Uzun variety stood out for crude protein ratio (6.87%-7.38%), the Gulseker and Erdurmus varieties were found to be more advantageous for fiber quality, with lower ADF and NDF ratios. Consequently, given its high dry matter yield and feed quality, the Gulseker variety can be recommended for main-crop sweet sorghum cultivation in Bursa and similar ecological conditions. Furthermore, a nitrogen dose of 160 kg ha$^{-1}$ may be preferred for sweet sorghum cultivation to achieve higher yield and quality.

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