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Research Article

Agro-Morphological and Forage Quality Traits of Some Pearl Millet (*Pennisetum glaucum* (L.) R. Br.) Populations Grown Under Şanlıurfa Conditions

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Abstract

The research was conducted to determine the dry matter yield and some quality characteristics of pearl millet [*Pennisetum glaucum* (L.) R. Br.], a warm-season annual forage grass grown as a summer crop in 2022. In addition to the Yellow witness variety, seven pearl millet populations (9198, 8022, 4903, 9645, 9449, 5455, and Yellow) obtained from ICRISAT were used as the study material. The harvests were carried out during the dough stage of the grains. Although dry matter yield varied among the populations, it was found to range between 2.32 and 3.47 t ha^{-1}. Moreover, forage quality characteristics showed that crude protein content ranged from 6.87% to 9.25%, ADF from 31.11% to 36.69%, NDF from 44.49% to 52.09%, and RFV (Relative Forage Value) from 108.83 to 136.04. Among the populations studied, populations 5455, 9198, and Yellow were superior in terms of dry matter yield, while population 9198 outperformed the Yellow witness variety in terms of forage quality. Based on the results of the study, it was concluded that the 9198 population could be considered in future breeding programs when yield and quality characteristics are evaluated together for Şanlıurfa province and similar ecological conditions.

Keywords: *Pennisetum glaucum* L. yield, quality, population

1. Introduction

Pennisetum glaucum (L.) R. Br., commonly referred to as pearl millet, is a cereal species within the Poaceae family, indigenous to Africa. Its domestication occurred approximately 3.000 to 5.000 years ago (de Morais Cardoso et al., 2017). This crop exhibits exceptional resilience to a wide array of environmental challenges, such as low soil fertility, elevated temperatures, and limited water availability. Pearl millet is predominantly cultivated in the semi-arid regions of Africa and Asia, where it constitutes a critical staple food source for local populations (Mawouma et al., 2022). In contrast, in Western countries, millets are primarily grown for birdseed and livestock forage. Additionally, they serve as a strategic crop in agricultural systems, providing a safeguard against crop failure and fulfilling emergency fodder requirements. Their rapid growth and adaptability make them particularly suited for these roles (Baltensperger, 2002). In recent years, with the effects of global warming, pearl millet has gained prominence as an annual warm-season cereal that is resistant to hot and dry conditions. Millets are among the most important drought-tolerant crops, ranking 6th in global agricultural production (Cicek and Yucel, 2022). This plant's ability to withstand drought and high temperatures plays a crucial role in maintaining sustainable agricultural practices, especially in regions with limited water resources. Furthermore, its ability to adapt to saline and acidic soils enhances its potential for production in marginal areas where agriculture is challenging (Bhattacharya et al., 2021). The increasing greenhouse gases and resulting climate changes have made the development of new, abiotic stress-tolerant plant varieties increasingly important (Cicek and Yucel, 2022). Pearl millet (*Pennisetum glaucum* (L.) R. Br.) was originally cultivated in the United States for feed production and grazing purposes. It also serves as a primary cereal source for approximately 90 million people in Africa and the Indian subcontinent, and is widely used as feed and fuel (FAO, 2011). According to Ullah et al. (2017), pearl millet uses only 70% of the water required by maize to produce the same amount of dry matter, making it a promising crop for semi-arid regions and water-scarce conditions. Pearl millet is a short-day plant, completing its flowering process in short days. It is reported that a day length of 12 hours and an average daily temperature of 28-30 °C are ideal for its growth (House, 1985; Andrews et al., 1993). Pearl millet thrives in sandy, light-textured, low-fertility soils with pH ranging from 6.2 to 7.7 and responds well to low inputs (Anonymous, 1996). As a C4 plant adapted to hot climates, pearl millet is among the leading drought-resistant cereals, though it cannot be grown without water (Rai et al., 2008). Moreover, according to BUGEM (Republic of Türkiye Ministry of Agriculture and Forestry) data, Turkey faced a shortage of approximately 27 million tons of quality roughage in 2022, with Şanlıurfa province accounting for 8.3 million tons of this deficit. This gap is expected to widen in the coming years due to climate change and increases in livestock populations (Anonymous, 2021; Anonymous, 2022a).

This study aims to assess the forage yield potential and feed quality of pearl millet populations selected and obtained from ICRISAT in the drought-prone and hot climate conditions of Şanlıurfa, Turkey. By determining the yield and quality potential of these pearl millet populations, selected varieties will provide fundamental materials for ongoing and future breeding efforts. The cultivation of these high-quality materials is expected to significantly contribute to meeting the quality roughage needs of livestock in Turkey.

2. Material and Methods

In this study, seven pearl millet (*Pennisetum glaucum* (L.) R. Br.) populations, sourced from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), were utilized as experimental materials. The pearl millet populations analyzed in this research are designated as follows: 9198, 8022, 4903, 9645, 9449, 5455, and Yellow (control).

2.1. Soil and climate characteristics of the study area

Soil was sampled from the 0-15 cm and 15-30 cm in the experimental area were analyzed, revealing the following characteristics: pH values ranged from 7.65 to 7.80, total salt content ranged from 0.30% to 0.40%, nitrogen content ranged from 0.05% to 0.08%, organic carbon content ranged from 0.34% to 0.55%, phosphorus content ranged from 0.39 to 0.50 mg kg^{-1}, and lime content ranged from 44.5% to 47.2%. The sand, silt, and clay proportions were 28-30%, 26-27%, and 44-45%, respectively. Based on these values, the soil structure has been determined to be clayey (C) (Anonymous, 2022b).

Table 1. Some climate data for the trial year and long-term averages*

Yıl	Months	Temperature values (°C)			Relative humidity (%)	Total precipitation (kg m^{-2})
		Average	Maximum	Minimum		
2022	June	26.7	41.0	19.9	42.70	1.20
	Long years average**	28.1	34.7	20.5	33.20	1.37
	July	28.9	40.7	26.8	42.95	0.00
	Long years average**	32.0	38.8	24.3	30.50	0.30
	August	26.9	40.4	23.3	62.45	0.00
	Long years average**	31.6	38.4	24.0	33.30	0.23
	September	22.7	37.0	21.7	60.44	0.00
	Long years average**	27.2	34.0	20.0	66.44	0.79
	October	17.3	28.1	8.8	57.68	0.90
	Long years average**	20.6	27.1	14.6	34.30	25.90

*: GAPTAEM, (2022). Talat Demiroren Research Station (TARBIL). **: MGM, (1929-2022).

As shown in Table 1, during the growing season of the experiment, the lowest average temperature was recorded at 17.3 ºC in October, while the highest average temperature was 28.9 ºC in July (Anonymous, 2022a). In long-term average temperature values, the lowest average temperature was 20.6 ºC in October, and the highest average temperature was 32.0 ºC in July (Anonymous, 2022c). Considering the average relative humidity values, the highest relative humidity was observed at 62.45% in August, and the lowest was 42.7% in June. The amount of precipitation recorded during the experimental period was negligible. This experiment was conducted in the second week of June 2022 at the Talat Demirören experimental field of the GAP Agricultural Research Institute and Training Center in Şanlıurfa. The geographical coordinates of the experimental area are 36° 54′ 10″ N latitude and 38° 55′ 23″ E longitude, with an elevation of 410 meters above sea level (Anonymous, 2016). The field experiment were carried out from June to October following the wheat harvest. The research was designed as a randomized block experiment with three replications. In the study, the populations were planted in four rows with 70 cm row spacing and 25 cm plant spacing, with the sowing carried out by hand on June 15, 2022. Each plot was separated by 50 cm, and there was a 1.5-meter distance between replications. Based on soil analyses, 5 kg of pure nitrogen and 8 kg of P_2O_5 were applied per decare in the form of a 20:20:0 compound fertilizer. During the first week of August (when the plants reached tillering stage), 5 kg da^{-1} of pure N in urea form was applied by hand between rows (Mesquita and Pinto, 1998; Cicek and Yucel, 2022). Sowing was done in tilled soil, and irrigation was provided as needed throughout the growing period after plant emergence. Weed control was carried out manually during the initial growth stages and by hand hoeing when the plants reached 40-50 cm in height. The total experimental area was planned to be 22.6 m x 17 m = 384.2 m². Harvesting (for forage) was performed on October 12, 2022, by hand when the seeds in the spike were in the dough stage. In addition to sprinkler irrigation for germination, four flood irrigations were carried out. Weed control was done mechanically until the application of top-dressing, and manually thereafter. For harvesting, five plants were sampled from each population and replication to determine the forage yield, and the average yield per replication was calculated. In the study, the dry matter yield (kg da^{-1}) of the plants in each population was determined following the methods outlined by Upadhyaya et al. (2008) and Upadhyaya and Gowda (2009). In addition to dry matter yield, forage quality characteristics were also assessed. Approximately 500 g of fresh samples from each replication were dried first in the air and then in a drying oven at 65 °C, ground, and sieved through a 1 mm mesh. Crue protein (CP) ratios were calculated, and neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using the ANKOM fiber analyzer (Van Soest et al., 1991; Ankom, 1997). Additionally, digestible dry matter (DDM), dry matter intake (DMI), and relative feed value (RFV) were calculated using the following equations: Digestible Dry Matter (DDM) = 88.9-(0.779 × %ADF), Dry Matter Intake (DMI) = 120 / %NDF, and Relative Feed Value (RFV) = (%DDM × %DMI) / 1.29 (Schroeder, 1994; Anonymous, 2018).

The data obtained from the research were analyzed using variance analysis in JMP 10 software, and statistically significant means were grouped according to the LSD (5%) multiple comparison test (Yurtsever, 2011).

3. Results and Discussion

3.1. Dry matter yield

As presented in Table 2, the average dry matter yield among the examined genotypes ranged from 2.32 to 3.47 t ha^{-1}, with this variation being statistically significant. In the study, the populations 5455, 9198, and the control variety Yellow produced the highest dry matter yields, while populations 9645 and 9449 yielded lower compared to the others. In studies conducted in different ecological settings with various applications and genotypes, Kollet et al. (2006) reported 3.25 to 4.36 t ha^{-1} in Brazil, El-Lattief (2011) reported forage yields ranging from 3.675 to 5.915 t ha^{-1} in Benin, Al-Suhaibani (2011) reported 49.97 to 58.32 t ha^{-1} in Saudi Arabia, Dagtekin (2019) observed 498.8 to 2869.9 g $plant^{-1}$ under Çukurova conditions, Dagtekin et al., (2020) reported 84.6 to 164.4 g $plant^{-1}$ also under Çukurova conditions, Saygidar (2021) found yields of 1.84 to 3.66 t ha^{-1} under GAP conditions, Nwajei (2023) reported yields ranging from 2.49 to 5.80 t ha^{-1} under conditions in Edo State, Nigeria and Donmez and Hatipoglu (2024) obtained 7.9 to 20.3 t ha^{-1} of dry matter yield in Kahramanmaraş. However, since some of these reported yields are per plant (g per plant), a direct comparison with our results is not feasible. The significant variation in dry matter yield can be attributed to differences in the materials used, as well as variations in growing conditions and sowing norms.

3.2. Crude protein content

Although the average crude protein content values in the examined pearl millet populations were statistically insignificant, the highest numerical value was measured at 9.25% for the 9198-coded population, while the population average was determined to be 7.62% (Table 2). The importance of roughages is vital for both agriculture and livestock farming. While high yield per unit area of forage crops is certainly crucial, forage quality is equally important. The most prominent indicator of the nutritional value of roughages is the crude protein content. According to Senel (1986), the crude protein content of forage crops must be at least 6% for them to be used in animal rations. In various studies conducted in different ecologies, applications, and genotypes, the crude protein content has been reported as follows: Rasnake et al. (2005) found 9.3% in Kentucky, Chacón-Hernández and Vargas-Rodríguez (2009) reported that in the Cartago province of Costa Rica, the prevalence ranged from 8.42% to 9.56%, El-Lattief (2011) reported 6.38% to

10.65% in Benin, showing some similarity to our findings. Hassan et al. (2014) observed 6.73% to 10.35% in Pakistan, Heuzé et al. (2015) reported a prevalence range of 6.6% to 17.0% in India, Babiker et al. (2015) found 8.8% to 16.2% in Sudan, Dagtekin (2019) reported 4.3% to 14.4% in Çukurova, Cicek and Yucel (2022) observed 8.49% to 12.93% in Akçakale/Şanlıurfa, Bahsis (2023) reported 7.81-12.68% in Akçakale/Şanlıurfa, Cerempei et al. (2023) found 8.08–16.20% in Moldova, Guanuquiza et al. (2023) reported 9.07% to 14.20% in Ecuador, Inal et al. (2023) reported 5.59-11.94% in Adana, and Yucel et al. (2023) found 6.45% to 14.75% in Şanlıurfa. These varying results can be attributed to differences in ecological conditions and cultural practices applied.

Table 2. Assessment of different pearl millet populations for dry matter yield and key forage quality traits

Population code	Dry grass yield (t ha^{-1})	Crude protein (%)	ADF (%)	NDF (%)	Relative feed value (RFV)
Yellow (control)	3.16 a[1]	7.99	33.89	47.47	124.07
9198	3.28 a	9.25	31.11	44.49	136.04
8022	2.74 ab	7.41	34.85	49.49	116.70
4903	2.85 ab	7.56	35.63	51.31	110.92
9645	2.32 b	6.87	35.06	49.52	116.00
9449	2.36 b	6.88	34.39	49.89	115.87
5455	3.47 a	7.41	36.69	52.09	108.83
Means	**2.88**	**7.62**	**34.52**	49.18	**118.35**
C.V. (%)	14.94	16.95	6.89	8.31	11.68
LSD (%5)	767.07	n.s.	n.s.	n.s.	n.s.

[*)] Means denoted by the same letter within the same column are not statistically different at the 5% significance level according to the LSD test. n.s.; Not significant.

3.3 ADF content

Although the values for ADF (Acid Detergent Fiber) in different pearl millet populations though statistically insignificant, the highest numerical value was achieved of 36.69% was observed in the 5455 coded population, with an average value of 34.52% for this trait (Table 2). Acid detergent fiber (ADF) is a parameter used to measure fibrous substances such as cellulose and lignin in forages. These fibrous substances can hinder digestion and reduce nutrient absorption in animals. The ADF content in rations should not exceed 16-20%, as higher ADF levels can complicate digestion and lead to inadequate energy intake by the animal (Gursoy and Macit, 2014). It is preferable for forages to have low levels of such fibrous substances (Yucel et al., 2012). Populations with high crude protein (CP) content typically have lower ADF values, indicating that forages with high protein content also tend to have lower acid detergent fiber levels. Moreover, significant positive relationships between CP content and ADF values have been reported by Yucel et al. (2023). Similar findings have been observed in studies conducted in various geographic conditions: Buso et al. (2014) reported 31.03% ADF in Brazil, Saygidar (2021) found 35.28% to 39.71% ADF under GAP conditions, and Guanuquiza et al. (2023) reported 34.67% to 39.15% ADF in Ecuador. In contrast, Rasnake et al. (2005) observed 37.8% in Kentucky, Heuzé et al. (2015) reported 30.7% to 45.1% in India, Dagtekin (2019) found 42.6% to 51.5% under Çukurova conditions, Cicek and Yucel (2022) reported 37.84% to 45.75% in Akçakale/Şanlıurfa, Bahsis (2023) observed 37.86% to 44.98% in Akçakale/Şanlıurfa, and Inal et al. (2023) found 33.43% to 45.73% in Adana. These differences can be attributed to variations in ecological conditions, population differences, and especially differences in harvest periods affecting ADF content.

3.4. NDF content (%)

Neutral Detergent Fiber (NDF) characterizes the presence of components such as hemicellulose, cellulose, lignin, cutin, and silica in forages, which can negatively affect digestion processes. High levels of these indigestible substances can reduce the nutritional efficiency of animal feed. Although the average NDF values among different pearl millet populations were not statistically significant, the highest numerical value of 52.09% was observed in the 5455 coded population, with an average value of 49.18% for this trait (Table 2). As noted in the study, populations with low ADF values also tend to have low NDF values. Research has shown that populations with high crude protein (CP) content have low NDF values, and significant positive relationships between CP and NDF content have been reported by Yucel et al., (2023). Additionally, while delayed harvesting may lead to increased yields, it may also result in decreased quality. The rapid growth and physiological maturation of warm-climate cereals like pearl millet lead to a rapid decline in CP content and digestibility. In studies conducted in different ecologies and genotypes, NDF values have been found to be somewhat consistent with Heuzé et al. (2015) reporting 46.1% to 64.8% in India and Guanuquiza et al., (2023) finding 56.29% to 61.68% in Ecuador. However, values reported by Barreto et al. (2001) in Brazil were 56.53% to 61.94%, Rasnake et al. (2005) in Kentucky reported 67.3%, Buso et al. (2014) in Brazil reported 56.33% to 60.11%, Dagtekin (2019) in Çukurova conditions reported 78.3% to 87.5%, Saygidar (2021) in Southeastern Anatolia reported 63.98% to 74.24%, Cicek and Yucel (2022) in Akçakale/Şanlıurfa reported 52.04% to 65.65%, Bahsis (2023) in Akçakale/Şanlıurfa reported 52.42% to 62.29%, Inal et al. (2023) in Adana reported 46.85% to 65.96%, and Yucel et al. (2023) in Şanlıurfa reported 47.19% to 66.85% are lower. The differences in findings may be attributed to differences in ecological conditions and cultivation methods, harvest timing, and methods used for determining NDF content.

3.5. Relative feed value (RFV)

Various quality indices are used to determine the quality of forages, with Relative Feed Value (RFV), Acid Detergent Fiber (ADF), and Neutral Detergent Fiber (NDF) contents being prominent among these indices. RFV is used to estimate the potential intake of the forage by animals and the energy value it provides. RFV plays a significant role in determining the quality of the forage and assessing its commercial value. Therefore, RFV calculations are considered an important criterion in the marketing of forages (Gursoy and Macit, 2017). Although the average RFV values were not significantly different among populations, the numerically highest value was recorded for the 9198 population at 136.04, with an overall average of 118.35 (Table 2). RFV, calculated based on the 100% flowering stage of alfalfa, is one of the important characteristics that determine forage quality. A high RFV is desirable. RFV is a forage quality indicator calculated from the digestible dry matter percentage and dry matter intake, and it is primarily based on NDF and ADF values. Lower NDF and ADF values result in higher RFV values. The findings of this study show higher RFV values compared to those reported by Saygidar (2021) under GAP conditions (73.13-90.29) and by Cicek and Yucel (2022) under GAP conditions (70.71-104.90).

4. Conclusion

As per the study's findings, taking into consideration both dry matter yield and quality traits for Şanlıurfa province and similar ecological environments, the 9198 population seems to be a favorable genetic resource for future breeding programs aimed at developing new lines and varieties. It is also suggested that this population could serve as an alternative to maize and other crops. Moreover, it is recommended as a promising option to quickly address the roughage deficit observed in the region.

Declaration of Author Contributions

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

Declaration of Conflicts of Interest

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

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