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DETERMINATION OF BIOMASS YIELD, FORAGE QUALITY AND MINERAL CONTENT OF PEARL MILLET VARIETIES (*Pennisetum glaucum* (L.) Br.) UNDER SEMI-ARID CONDITIONS

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Abstract: With the continuous growth of the world population and Türkiye, researchers are investigating quality forage alternatives to satisfy the expanding demands of livestock. The promotion of pearl millet (*Pennisetum glaucum* (L.) R. Br.) as a summer crop and a potential green forage source during the summer season is significant. This study was conducted to determine the biomass yield and forage quality values of some pearl millet varieties under the second crop conditions in Akcakale/Sanlıurfa. Plants were harvested plants were harvested in the soft dough stage of the seeds in the panicle. In addition to biomass yield and components, quality traits in dry biomass were also determined this study. Significant statistical differences were found among all examined varieties in the yield components of biomass. Plant height (PH, cm), number of leaves per main stem (MSL, number), number of tillers per plant (PTN Number), biomass yield (BY, kg da^{-1}) and dry biomass yield (DBY, kg da^{-1}) varied between 198-341 cm, 11.1-15.7 number, 7.45- 12.30 number, 5938-12571 kg da^{-1} and 1847-3666 kg da^{-1} respectively. Moreover, significant and positive correlations were identified between DBY and BY, PH, MSL. As a result of the study, while, the White variety showed better performance in components of yield, the Ashana variety performed better in terms of forage quality. Moreover, Yellow and Tifleaf III varieties have CP values above 10%. Based on high biomass yield and moderate forage quality of the pearl millet varieties in the study, pearly millet could play an important role in closing the forage deficit of ruminant animals, especially in arid and semi-arid ecologies around the world and Türkiye.

Keywords: Pearl millet (*Pennisetum glaucum* (L.) R. Br.), Variety, Forage yield, Quality, Semi-arid

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1. Introduction

In Türkiye, it was reported that the approximate roughage requirement for a year for 17 million cattle units is 76 million tons. About half of this feed has been obtained from field agriculture and pasture meadow areas. Additionally, if garden pastures, alternative roughages, and straw stubble residues are not considered, there is still a significant need for roughage (BUGEM, 2024). It is important to explore different roughage sources to close Türkiye's roughage deficit. According to the latest report published by the IPCC, the global average temperature has increased by approximately 1.45 °C in the last century. It was reported that this increase causes to climate change, warming the land and the seas. Furthermore, it has been stated that these temperature increases will continue to rise day by day, especially on land, with occasional droughts and high temperatures being experienced. The production and development of new plant species that can tolerate abiotic stress conditions such as drought and high temperatures will become increasingly important in future projections (IPCC, 2023)

Pearl millet is more tolerant to abiotic stress factors such as temperature, drought, and salinity compared to corn and sorghum species, and is more adaptable to marginal areas. Therefore, this plant is becoming prominent for arid and semi-arid regions (Yucel and Yucel, 2022). Moreover, compared to similar species like corn and sorghum, it was reported that the production of this plant will increase in the coming years due to its lower agricultural inputs and higher tolerance to diseases and pests (Devi et al., 2011; Yucel and Yucel, 2022). Pearl millet is utilized in very different forms such as grazing, silage, dry and green biomass (Newman et al., 2010). It has been reported that pearl millet can be harvested several times in a growing season, and about a week after harvest, the stems start to regrow from the root (Banks and Stewart, 1998). The dry biomass of pearl millet is emphasized to be rich in phosphorus (P) and calcium (Ca), have a high protein content, be of better quality than the forage of species like sorghum and Sudan grass,

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and not contain toxic secondary metabolites such as hydrocyanic and prussic acid for animals (Arya et al., 2009; Hassan et al., 2014; Malakar et al., 2024). C4 plants with summer characteristics, which have high biomass yield per unit area and silage quality that can be an alternative to silage corn, need to increase their agricultural production. If the production of alternative species with low inputs is not popularized, it is estimated that the roughage deficit in developing countries and Türkiye cannot be closed with the current production systems.

This study was conducted to determine the biomass yields of some pearl millet varieties, some important quality traits of dry biomass, and mineral element contents in the GAP region of southeastern Türkiye, which has arid or semi-arid conditions

2. Materials and Methods

Pearl millet varieties such as Tifleaf III from the United States and Yellow, Ashana, White, and Heveahri from Sudan were used in the study.

The study was carried out in 2020 pearl millet growing periods, at the GAP Agricultural Research Institute, Talat Demirören Research Station, Sanlıurfa/Türkiye (36 54′ 13″ N, 38 55′03″E, altitude 378 m). The field experiment used randomized block trial design with four replications. The inter row and intra row spacings were 70 and 25 cm, respectively. Each plot had four rows, 5 m in length, and the area of each plot was 14 m. Fertilizer was applied in the seedbeds at a rate of 8 kg^{-1} da in the form of compose (20%N - 20%P_2O_5 – 0 %K_2O) during sowing. Nitrogen (40 kg ha^{-1}) was applied as urea (46% N) at the fourth week of sowing (Mesquita and Pinto, 2000). Weed control was performed mechanically by hand. The plants were harvested for biomass yield when the soft dough period of the seed (Newman et al., 2006).

The traits such as plant height (PH, cm), number of leaves per main stem (MSL, number), number of tillers per plant (PTN, number), biomass yield (BY, kg da^{-1}), and dry biomass yield (DBY, kg da^{-1}) were determined using established methods (Rao and Bramel, 2000; Upadhyaya et al., 2008; Upadhyaya and Gowda, 2009). 500 g of fresh biomass was taken from each experimental plot. These plant samples were dried in incubator at 70°C until their weight stabilised, then, DBY (kg da^{-1}) was calculated from fresh and dry samples.

After drying process in incubator, the plant samples were ground in a specially designed mill with a sieve with a diameter of 1-2 mm and prepared for forage quality analysis. Forage quality traits were analyzed on NIRS (Near Reflectance Spectroscopy) and Foss XDS Rapid Content Analyser devices.

The forage quality traits which are crude protein (CP, %), neutral detergent fiber (NDF, %) and acid detergent fiber (ADF, %) analyzed by these devices. Moreover, dry matter digestibility Rate (DMD, %), dry matter intake (DMI, %), relative feed value (RFV) and net energy lactation (NEL, Mcal/kg) were also calculated from the equations (1-4) below (Schroeder, 1994; Anonymous, 2018). Furthermore, the mineral element content including P, K, Mg, and Ca of the same plant samples were also analyzed.

$$DMD\ (\%)\ =\ 88.9 - (0.779\ x\ \%ADF) \quad (1)$$

$$DMI = 120/\ \%\ NDF \quad (2)$$

$$RFV\ =\ (\%DMD\ x\ \%\ DMI)/1.29 \quad (3)$$

$$(NEL)\ (Mcal/kg, dry\ matter) = 1.892 - (0.0141 * ADF) \quad (4)$$

2.1. The Climate and Soil Characteristic of the Study Area

The study area was located in a semi-arid climate with high temperatures and low relative humidity during the summer season. The average temperature ranged from 23.9 °C to 33.0 °C during the growing period from June to October in 2020. The average temperatures for July and August were 32.4 °C and 33.0 °C respectively, while the average temperature for the growing period was recorded at 30.2 °C. Additionally, the average relative humidity ranged from 27.5% to 41.0% during the growing period. While, the highest relative humidity value recorded in October, lowest values recorded in June and July. The climate data of the study area recorded during the pearly millet growing seasons of 2020 are provided in Table 1 (MGD, 2020).

In addition, among the physical properties of the soil, it was determined that the silt, clay and sand contents were between 26-27%, 44-45% and 28-30%, respectively, and the soil texture was clayey. PH varies from 7.96 to 8.00 and electrical conductivity is between 1.05 and 1.40 dS m^{-1} which indicates no salinity problem.

Table 1. Some climate parameters of the study area (https://www.mgm.gov.tr/)

Months	June	July	August	September	October	Average
Mean temperatures(°C)	31.5	32.4	33.0	30.1	23.9	30.2
The lowest temperatures (°C)	23.0	25.4	23.7	22.2	18.8	22.6
The highest temperatures (°C)	39.2	39.0	41.7	36.9	30.7	37.5
Total precipitation (mm m^{-2})	0.0	0.0	0.0	0.0	0.0	0.0
Mean humidity (%)	29.3	27.5	31.2	32.6	41.0	32.3
Precipitation (day)	0.0	0.0	0.0	0.0	0.0	0.0

2.2. Statistical Analysis

Statistical analysis was performed using JMP (Version13.2.0) statistical software. The mean values for the varieties were compared using the LSD test at P≤0.05 probability level. A correlation test was performed between all traits determined in the study (Yurtsever, 2011).

3. Results and Discussion

3.1. Agronomic Traits

The difference between varieties was statistically significant (P≤0.05) for all parameters such as plant height (PH, cm), number of leaves on per main stem (MSL, number), and number of tillers per plants (PTN, number), biomass yield (BY, kg da^{-1}) and dry biomass yield (DBY, kg da^{-1})

3.1.1. Plant height (cm)

The average plant height of pearl millet varieties ranged from 198 to 341 cm. The lowest plant height was observed in the Tifleaf III variety, while the other varieties were statistically same grouped together (Table 2). PH varied between 137.4-377.0 cm (Izge et al., 2007; Angarawai et al., 2016), 150-219 cm (Medici et al., 2018), 143-262.4 cm (Shah et al., 2012; Hassan et al., 2014) and 30-490 cm (Upadhyaya et al., 2007; Govindaraj et al., 2011; Upadhyaya et al., 2013) in studies conducted with different pearl millet genotypes in countries such as Nigeria, Brazil, Pakistan and India. Moreover, pH of pearl millet varied between 174-449 cm in Cukurova (Dagtekin, 2019; Cakır et al., 2023; Donmez and Hatipoglu, 2024) and 146.5-352.0 cm in GAP conditions in Türkiye (Ozer, 2023; Yucel et al., 2023a). Although the region where the experiment was conducted is a semi-arid region with high temperatures, plant heights are taller than plants grown in other parts of the world, and the reason for this is that pearl millet may be tolerant to abiotic stress conditions. Additionally, it can be said that quantitative traits such as plant height are affected by genetic and environmental factors (climate and soil).

3.1.2. Number of leaves on per main stem (number)

The average MSL of varieties was ranged from 11.1 to 15.7 number. It was observed that the leaf numbers of Heveahri, White and Yellow varieties were close to each other, statistically in the same group, and had higher values than the remaining other varieties. Additionally, it was determined that varieties with high PH also had high MSL (Table 2). This could be explained by the fact that there are significant and positive correlations between PH and MSL (Table 5). The results of previous studies were similar to our findings (Dagtekin, 2019; Cakır et al., 2023; Yucel et al., 2023a). MSL ranged from 8.0 to 19.0 (Izge et al., 2007; Abdulhakeem et al., 2019), 6.9 to 9.7 (Abd-El-Lattief, 2011), and 11 to 15 number (Shah et al., 2012) in studies conducted with various pearl millet genotypes across countries such as Nigeria, Benin Republic, and Pakistan. In addition, the number of leaves varies between 8.4 and 22.2 (Dagtekin, 2019; Cakır et al., 2023) and 7.67 and 17.0 (Yucel et al., 2023a) in Cukurova/Türkiye and Sanlıurfa/Türkiye conditions respectively. It was thought that the most important reason for the difference between the MSL determined in the study in question and the number of leaves obtained in previous studies was due to environmental factors such as climate and soil and variety characteristics.

3.1.3. Number of tillers per plants (number)

PTN varied between 7.45 and 12.30 number and the White variety formed more tillers than the other varieties (Table 2). PTN is one of the important agronomic traits affecting unit area yield. Therefore, positive and significant relationships were found between PTN and BY, DBY (Table 5). Consistent with our study, significant and positive relationships between PTN and BY, DBY were reported by many researchers (Kumari and Nagarajan, 2008; Dagtekin, 2019; Aswini et al., 2022; Cakır et al., 2023; Yucel et al., 2023a). PTN values in different environments ranged from 1.7 to 2.3 number in Nigeria (Izge et al., 2007) and 0.55 to 6.4 number in India (Govindaraj et al., 2011; Athoni et al., 2016; Thomas et al., 2018). And also, 6 to 8 number in Ghana (Asungre, 2014) and 5.3 to 12.5 number in Algeria (Rahal-Bouziane and Semiani, 2016). In addition to international studies, PTN varied between 3.67 and 18.0 number under Cukurova conditions (Dagtekin, 2019; Cakır et al., 2023; Donmez and Hatipoglu, 2024) and 2.33 and 7.50 number under GAP conditions (Yucel et al., 2023a) in Türkiye. It was determined that the PTN of pearl millet varieties in the study were higher than PTN obtained from other national and international studies. In short, it was decided that the varieties used in the study were compatible with the regional conditions.

Table 2. Averages of forage yield and yield-related traits of pearl millet varieties

Varieties	PH (cm)	MSL(Number)	PTN(Number)	BY(kg da^{-1})	DBY (kg da^{-1})
Ashana	320 a	13.4 b	7.45 c	6384 cd	2108.3 bc
Heveahri	328 a	14.2 ab	9.94 b	8348 bc	2605.2 b
White	341 a	15.7 a	12.30 a	12571 a	3666.0 a
Yellow	325 a	15.4 a	9.57 b	9952.3 b	2576.2 b
Tifleaf III	198 b	11.1 c	8.17 c	5938 d	1847.0 c
Mean	303	14.0	9.48	8638	2560.5
CV (%)	4.61	7.44	9.27	16.72	15.89
Sig.	0.001**	0.0003**	0.001**	0.0002**	0.0004**

*,**= significant at 0.05 and 0.01 levels of probability respectively, NS= not significant, According to the LSD test, There is statistically significant difference at P≤0.05 level among the averages shown with different letters in the same column, PH= plant height (cm), MSL= number of leaves per main stem (number), PTN= number of tillers per plant (number), BY= biomass yield (kg da^{-1}), DBY= dry biomass yield (kg da^{-1}).

3.1.4. Biomass yield (kg da^{-1})

It was determined that the BY values of the varieties varied between 5938 and 12571 kg da^{-1}, and White variety had higher yields than other varieties in study (Table 2). It was observed that varieties with high PH, MSL and PTN also have high BY yields. Significant positive correlations were recorded between PH and PTN, MSL, and BY and DBY (Table 5). The findings obtained from the study are compatible with other studies (Dagtekin, 2019, Subbulakshmi et al., 2022; Yucel et al., 2023a; Cakır et al., 2023; Donmez and Hatipoglu, 2024). BY varied between 7744 and 8615 kg da^{-1} (Abd-El-Lattief, 2011) and 3300 and 10000 kg da^{-1} (Shah et al., 2012) in Benin Republic and Pakistan conditions respectively. Moreover, in studies conducted at national level, BY ranged from 4110 to 8400 kg da^{-1} in Cukurova/Türkiye (Donmez and Hatipoglu, 2024) and 5400 to 8076 kg da^{-1} in Sanlıurfa/Türkiye conditions. Although some findings obtained in previous studies were similar to the data in the study, it was observed that some varieties had higher yields.

3.1.5. Dry biomass yield (kg da^{-1})

DBY varied between 1847 and 3666 kg da^{-1} for all varieties. The highest DBY was obtained from the White variety, while the lowest DBY was obtained from the Tifleaf III variety (Table 2). Varieties with high BY are also high in DBY. Significant positive correlations were recorded between DBY and BY. In addition, significant and positive relationships were determined between DBY and BY, PH, MSL and PTN (Table 5). The data found in the study are in parallel with some previous studies (Dagtekin, 2019, Subbulakshmi et al., 2022; Cakır et al., 2023; Yucel et al., 2023a). DBY ranged from 750 to1250 kg da^{-1} in India (Sheahan, 2014), 390 to 520 kg da^{-1} in Brazil (Medici et al., 2018), 169 to 347 kg da^{-1} in Pakistan. (Hassan et al., 2014) and 216 to 276 kg da^{-1} under Mexican conditions (Morales et al., 2015). When the studies conducted in Türkiye were looked into, it was reported that DBY varied between 690 and 1800 kg da^{-1} in Cukurova conditions (Donmez and Hatipoglu, 2024) and 2322.0 and 3472.8 kg da^{-1} in Sanliurfa ecological conditions (Ozer, 2023). Although the results obtained in studies conducted in different ecology and different regions of Türkiye are similar to the results obtained from the study, the DBY results obtained from the study are slightly higher than other DBY results, the reason for this is that the temperature and soil characteristics of the region where the study was conducted were thought to be effective in creating this difference.

3.2. Quality Traits of Fodder

Except for crude protein (CP, %), the difference between varieties was not statistically significant (P≤0.05) for other quality parameters such as neutral detergent fiber (NDF, %), acid detergent fiber (ADF, %), dry matter digestibility (DMD, %), dry matter intake (DMI, %), relative feed value (RFV) and net energy lactation (NEL, Mcal/kg^{-1}).

3.2.1. Neutral detergent fiber (%)

NDF varied between 63.98% and 74.24% for all varieties. The highest NDF was obtained from the Tifleaf III variety, while the lowest NDF was obtained from the Ashana variety (Table 3). Different findings were obtained for NDF in studies conducted in different environments. NDF content ranged from 63.2% to 67.3% in Kentucky/ABD (Rasnake et al., 2005), 56.3% to 60.1% in Brazil (Buso et al., 2014) and 46.1% to 64.8% in Pakistan conditions (Heuzé et al., 2015). When the studies conducted in Türkiye were examined, it was reported that NDF varied between 78.3% and 87.5% in Cukurova conditions (Dagtekin, 2019), 47.19% and 66.85% in GAP (Yucel et al., 2023b), 44.49% and 52.09% in the region where the study was conducted (Ozer, 2023). It is seen that the NDF contents obtained in the study are higher than the NDF values obtained in previous studies. It is estimated that the reason for this difference is the genetic structure of the varieties and the harvest period. As biomass harvests are delayed or the plants get older, the cellulose ratio of biomass increases, thus, increasing the NDF content.

3.2.2. Acid detergent fiber (%)

ADF varied between 35.78% and 39.71% for all varieties. The highest ADF was obtained from the Tifleaf III variety, while the lowest ADF was obtained from the Ashana variety. Varieties with high NDF are also high in ADF (Table 3). Significant positive correlations were recorded between NDF and ADF (Table 5). Dagtekin (2019) and Yucel et al. (2023a) were declarated similar findings. In addition, ADF contents was reported 37.8%, 31.1% and 37.9% respectively by Rasnake et al., (2005) and Buso et al., (2014) and Heuzé et al., (2015). ADF values obtained in pearl millet in different regions of Türkiye varied between 42.6% and 51.5% (Dagtekin, 2019), 34.33% and 46.89% (Yucel et al., 2023b), 31.11% and 36.69% (Ozer, 2023). ADF values were obtained in the study are within more acceptable limits in terms of animal nutrition, cellulose and lignin contents compared to NDF values. As ADF values exceed 30%, feed digestibility and quality decrease.

3.2.3. Crude protein (%)

CP contents varied between 8.54% and 11.72% in the study. Tifleaf III variety has the highest CP rate, while Heveahri variety has the lowest CP rate. CP rates were varied in studies conducted with different environments and genotypes.

CP ranged from 7.4% to 9.6% in Benin Republic (Abd-El-Lattief, 2011), 6.73% and 10.35% in Pakistan (Hassan et al., 2014), 8.8% and 16.2% in Sudan (Babiker et al., 2015) and 6.24% and 11.63% in India conditions (Thomas et al., 2018). CP varied between 4.3% and 14.4% in Cukurova/Türkiye conditions (Dagtekin, 2019) and 6.45% and 14.75% in GAP/Türkiye ecological conditions (Ozer, 2023; Yucel et al., 2023b). Additionally, Pearl millet CP rates varied between 12% and 14%. This value was stated to be higher than the CP rate of corn silage by Sheahan (2014).

Table 3. Averages of some forage quality traits of pearl millet varieties

Varieties	NDF (%)	ADF (%)	CP (%)	DMD (%)	DMI (%)	RFV	NEL (Mcal kg^{-1})
Ashana	63.98	35.28	9.19 bc	61.42	1.890	90.29	1.395
Heveahri	69.61	37.89	8.54 c	59.39	1.729	79.74	1.358
White	68.68	37.89	8.87 c	59.78	1.749	81.12	1.365
Yellow	67.84	36.95	10.44 ab	60.12	1.776	82.51	1.371
Tifleaf III	74.24	39.71	11.72 a	57.97	1.624	73.13	1.332
Mean	68.87	37.44	9.75	59.73	1.754	81.43	1.36
CV (%)	6.96	7.89	9.23	3.85	7.13	10.86	3.06
Sig.	NS	NS	0.001**	NS	NS	NS	NS

*,**= significant at 0.05 and 0.01 levels of probability respectively, NS= not significant, According to the LSD test, There is statistically significant difference at P≤0.05 level among the averages shown with different letters in the same column, NDF= neutral detergent fiber (%), ADF= acid detergent fiber (%), CP= crude protein (%), DMD= dry matter digestibility rate (%), DMI= dry matter intake (%), RFV= relative feed value, NEL= net energy lactation (Mcal kg^{-1}).

Table 4. Some mineral element contents of pearl millet varieties

Varieties	Ca (%)	K (%)	Mg (%)	P (%)
Ashana	0.223 b	3.043	0.270 bc	0.290
Heveahri	0.333 a	3.443	0.240 c	0.270
White	0.250 b	3.518	0.363 a	0.300
Yellow	0.333 a	3.530	0.278 b	0.295
Tifleaf III	0.173 c	3.490	0.240 c	0.300
Mean	0.262	3.405	0.278	0.291
CV (%)	9.49	13.49	7.55	5.57
Sig.	0.001**	NS	0.001**	NS

*,**= significant at 0.05 and 0.01 levels of probability respectively, NS= not significant, According to the LSD test, There is statistically significant difference at P≤0.05 level among the averages shown with different letters in the same column, Ca= calcium (%), K= potassium (%), Mg= magnesium (%), P= phosphorus (%).

3.2.4. Dry matter digestibility (%)

DMD rate was varied between 57.97% and 61.42% in the study. Ashana variety had higher rates of DMD than the remaining varieties (Table 3). According to Hassanat et al. (2007), the digestibility rate of silage pearl millet ranged from 640 to 690 g kg^{-1} DM. DMD results of Kichel et al. (1999) are parallel to our study results. DMD rate was varied between 52.37% and 62.16% (Yucel et al., 2023b). In addition, Yucel (2020) was reported that digestibility rate of silage sorghum material is higher than dry material.

3.2.5. Dry matter intake (%)

DMI contents was varied between 1.624% and 1.890% in the study. Ashana variety had the highest DMI rate, while Tifleaf III variety had the lowest DMI rate (Table 3). DMI values varied was reported between 1.80% and 2.54% under GAP region conditions in Türkiye (Yucel et al., 2023b). Additionally, the results of this study are compatible with our study.

3.2.6. Relative feed value (RFV)

RFV values varied between 73.13 and 90.29 in the study. Ashana variety had the highest RFV values in study (Table 3). Ashana variety had medium-class feed quality reported by Rohweder et al. (1978). RFV values of dry biomass varied between 74.66 and 122.52 stated Yucel et al. (2023b).

3.2.7. Net energy lactation (Mcal kg^{-1})

NEL contents were varied between 1.332 and 1.395 Mcal kg^{-1} in the study. Ashana and Tifleaf III varieties had the highest and lowest values, respectively (Table 3). While, significant negative correlations were recorded between NEL and NDF, ADF, significant positive correlations were recorded between NEL and DMD, DMI and RFV (Table 5). In order to obtain feeds with high energy content, ADF and NDF contents must be low. In this aspect, Ashana variety had better energy value than the remaining varieties in study. NEL contents were varied between 1.23 and 1.41 Mcal kg^{-1} DM reported by Yucel et al. (2023b).

3.3. Mineral Element Contents

The difference between varieties were statistically significant (P<0.05) for Calcium (Ca) and Magnesium (Mg) (Table 4).

Ca contents was varied between 0.173% and 0.333% in the study. While the highest Ca value was obtained in the Heveahri and Yellow varieties, the lowest value was obtained in the Tifleaf III variety (Table 4). Ca contents was ranged from 0.42% to 0.51% (Weichenthal et al., 2003), 0.29% to 0.85% (Heuzé et al., 2015), 0.28 % to 0.56% (Dagtekin, 2019) and 0.01% to 0.40% (Yucel et al., 2023b).

K contents was varied between 3.043% and 3.530% in the study. While the highest K content was obtained in the Yellow variety, the lowest value was obtained in the Ashana variety (Table 4). Many different results were obtained in previous studies on the K content of pearl millet. K contents ranged from 3.2% to 4.3% (Weichenthal et al., 2003), 0.160% to 0.419% (Heuzé et

al., 2015), 1.901% to 4.233% (Dagtekin, 2019) and 2.48% to 4.33% (Yucel et al., 2023b).

Mg contents was varied between 0.240% and 0.363% in the study. While the highest Mg content was obtained in the White variety, the lowest value was obtained in the Heveahri and Tifleaf III varieties (Table 4). Many different results were obtained in previous studies on the Mg content of pearl millet. Mg contents ranged from 0.320% to 0.330% (Weichenthal et al., 2003) and 0.24% to 0.45% (Heuzé et al., 2015). Moreover, Mg contents ranged from 0.201% to 0.343% in Cukurova/Türkiye (Dagtekin, 2019) and 0.04% to 0.255% in GAP/Türkiye (Yucel et al., 2023b). Mg data were obtained from the study are in line with past studies.

P contents was varied between 0.270% and 0.300% in the study. While the highest P content was obtained in the White and Tifleaf III varieties, the lowest value was obtained in the Heveahri variety (Table 4). Different regions, treatments and genotypes affected the P contents of pearl millet. P contents ranged from 0.191% to 0.240% (Weichenthal et al., 2003) and 0.04% to 0.45% (Heuzé et al., 2015). In addition, P contents was ranged from 0.270% to 0.434% in Cukurova/Türkiye (Dagtekin, 2019) and 0.290% to 0.540% in GAP/Türkiye (Yucel et al., 2023b). P data obtained from the study are in agreement with past studies.

3.4. Analysis of Relationships between Traits

All parameters of pearly millet varieties were determined via correlation test. The results of correlation test including correlation coefficients and level of significance was given in Table 5. Significant and positive correlational relationships were obtained in the study. Significant positive correlations were recorded between NDF and ADF (r=0.9652**, P<0.01), BY and DBY (r=0.9512**, P<0.01), DBY and PTN (r=0.4248**, P<0.01), K and CP (r=0.5228*, P<0.05). Significant positive correlations were recorded between DMD and DMI (r=0.9508**, P<0.01), RFV (r=0.9721**, P<0.01), NEV (r=1.0000**, P<0.01). Significant positive correlations were recorded between PH and MSL (r=0.6535**, P<0.01), BY (r=0.5316**, P<0.05), DBY (r=0.5790**, P<0.01).

There were significant and positive relationships between PH and BY and DBY of pearl millet was reported by Dagtekin, 2020, Yucel et al., 2023a, Cakır et al., 2023 and Donmez and Hatipoglu, 2024. Additionally, studies conducted in different environments were reported significant and positive correlations between biomass yield and plant height, number of leaves, number of nodes and number of fertile tillers (Berwal et al., 1996; Yadav et al., 2012; Singh et al. al., 2014; Kanwar and Shekhawat, 2015; Aswini et al., 2022).

Table 5. Correlation coefficients and significance levels of all traits in study

Traits	Ca	K	Mg	NDF	P	CP	DMD	DMI	RFV	NEL	PH	MSL	BY	DBY	PTN
ADF	-0.35	0.17	-0.23	0.97	-0.29	-0.32	-1.00	-0.95	-0.97	-1.00	-0.36	-0.09	-0.08	-0.13	0.09
Ca		0.02	0.73	-0.29	-0.34	-0.06	0.35	0.26	0.28	0.35	0.61	0.65	0.36	0.35	0.06
K			-0.16	0.24	0.36	0.52	-0.17	-0.30	-0.28	-0.18	-0.08	0.16	0.07	0.04	0.32
Mg				-0.12	-0.33	-0.01	0.23	0.11	0.15	0.23	0.32	0.31	0.20	0.28	-0.02
NDF					-0.26	-0.17	-0.97	-0.99	-0.99	-0.96	-0.46	-0.16	-0.11	-0.18	0.13
P						0.69	0.29	0.24	0.25	0.29	-0.18	-0.16	0.09	-0.01	0.02
CP							0.32	0.15	0.20	0.32	-0.35	-0.01	0.05	-0.02	0.16
DMD								0.95	0.97	1.00	0.36	0.09	0.08	0.13	-0.09
DMI									0.99	0.95	0.43	0.14	0.07	0.13	-0.15
RFV										0.97	0.41	0.12	0.06	0.12	-0.14
NEL											0.36	0.09	0.08	0.13	-0.09
PH												0.65	0.53	0.58	0.23
MSL													0.66	0.62	0.33
BY														0.95	0.34
DBY															0.42

PH= plant height (cm), MSL= number of leaves per main stem (number), PTN= number of tillers per plant (number), BY= niomass yield (kg da^{-1}), DBY= nry biomass yield (kg da^{-1}), NDF= neutral detergent fiber (%), ADF= acid detergent fiber (%), CP= crude protein (%), DMD= dry matter digestibility rate (%), DMI= dry matter intake (%), RFV= relative feed value, NEL= net energy lactation (Mcal kg^{-1}), Ca= calcium (%), K= potassium (%), Mg= magnesium (%), P= phosphorus (%).

4. Conclusion

As a result of the study, White variety was showed better performance than remaining varieties for forage yield and other yield components under second crop conditions in the GAP region. Ashana is the variety with the best relative feed quality in the trial and has middle class feed quality. It has also been determined that Yellow and Tifleaf III varieties are better than other varieties in terms of crude protein ratio. The biomass yield and feed quality traits of pearl millet varieties in the study conducted in the semi-arid climate zone was within acceptable limits for livestock farming. For this reason, pearl millet cultivation could be recommended in regions of the world with similar climate zones, especially in order to close the roughage gap. Pearly millet has the potential to be an alternative to silage corn, especially in arid regions.

Author Contributions

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

	M.N.S.	C.Y.	T.T.
C	40	30	30
D	50	30	20
S		50	50
DCP	20	30	50
DAI	15	70	15
L	80	10	10
W	50	30	20
CR	30	40	30
SR	10	10	80
PM	20	50	30

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.

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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