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Forage Yield and Quality Performances of Sorghum Genotypes in Mediterranean Ecological Conditions

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Abstract: Sorghum is one of the warm climate species known for its multi-purpose use and water use efficiency. The cultivation of this species, which is known to be more advantageous than maize in terms of water use, is increasing currently. Depending on this increase, it is necessary to develop more varieties that will serve different purposes. In the study, six different genotypes were grown with two standard genotypes in Aydın (Turkey) ecological conditions in 2016-2017 with 3 replications. Plant height (cm), fresh forage yield (t da^{-1}), hay yield (t da^{-1}), number of leaves, crude protein ratio (%), ADF (%), NDF (%) are the measured properties. With these data, crude protein yield (t da^{-1}) and relative feed value characteristics were calculated. In the light of the results obtained from the experiment, it was observed that the fresh forage yield varied between 3.63-10.06 t da^{-1}, the hay yield between 0.79-2.12 t da^{-1}, crude protein yield between 0.075-0.198 t da^{-1}, and the relative feed value between 91.61- 116.40. Among the genotypes, EA27 and EA36 stand out in terms of yield, while Beydarı has high values in terms of some quality characteristics. The results revealed that some genotypes are promising in sorghum breeding according to their intended use.

Keywords: Sorghum, forage yield, correlation, forage quality

Akdeniz ekolojik koşullarında bazı sorgum genotiplerinin verim ve kalite performansları

Öz: *Sorgum çok amaçlı kullanıma sahip olması yanında su kullanım etkinliği ile bilinen sıcak iklim türlerinden biridir. Su kullanımı bakımından mısıra göre daha avantajlı olduğu bilinen bu türün yetiştiriciliği günümüzde artış göstermektedir. Bu artışa bağlı olarak daha fazla ve farklı amaçlara hizmet edecek çeşitlerin geliştirilmesi gerekmektedir. Çalışmada altı farklı genotip iki standart çeşitle 2016-2017 yıllarında Aydın ekolojik koşullarında üç tekrarlamalı olarak yetiştirilmiştir. Bitki boyu (cm), yaş ot verimi (t da^{-1}), kuru ot verimi (t da^{-1}), yaprak sayısı (adet), ham protein oranı (%), ADF (%), NDF (%) ölçülen özellikler arasındadır. Bu veriler ile ham protein verimi (t da^{-1}) ve nispi yem değeri özellikleri hesaplanmıştır. Denemeden elde edilen sonuçlar ışığında yaş ot veriminin 3.63-10.06 t da^{-1} arasında, kuru ot veriminin 0.79-2.12 t da^{-1} arasında, ham protein veriminin 0.075-0.198 t da^{-1} arasında, nispi yem değerinin 91.61-116.40 arasında değiştiği gözlenmiştir. Genotipler arasında EA27 ve EA36 verim bakımından öne çıkarken bazı kalite özellikleri bakımından Beydarı yüksek değerlere sahiptir. Sonuçlar kullanım amacına göre sorgum ıslahında bazı genotiplerin ümitvar olduğunu ortaya koymuştur.*

Anahtar kelimeler: *Sorgum, yem verimi, korelasyon, yem kalitesi*

INTRODUCTION

The amount of water used in agricultural production is gradually increasing and this situation indicates a troubled process in terms of water availability in foreseeable future. Due to the decreasing plant biodiversity in these agricultural production systems, soil fertility is weakened in terms of organic matter and it reveals the use of intensive chemical fertilizers every year. Chemical fertilizers applied every year flow into underground water sources and cause pollution as well as effect soil fertility (Ismaeil et al., 2012).

Maintaining crop production efficiency with limited water availability is a major challenge for producers in arid and semi-arid regions. Sustainable agricultural production is a challenge due to these reasons, decreasing rainfall and limited irrigation water. (Paye et al., 2022 ; Ali et al. 2019; Rostamza et al., 2011). Sorghum (*Sorghum bicolor* L.) can be a valuable alternative to maize with its high biomass yield, low N fertilizer input, and efficient water use (Colombini et al., 2012). In regions where climate and soil characteristics are more limited for silage maize production, this problem is tried to be solved only with an alternative such as sorghum (Marsalis et al., 2009; Öten, 2017). In terms of water use efficiency, sorghum, which can be successfully grown in arid and semi-arid regions in summer, can have a production process that is 40% more efficient than maize (Paye et al., 2022; Erdurmuş et al., 2021). An economic comparison of sorghum with other potential biomass crops, also demonstrated that costs per ton of sorghum biomass produced were the lowest among the crops evaluated (Hallam et al., 2001).

For ruminants, it is very important to develop cultivars with high nutritional content in sorghum. Particularly fiber content and dry matter digestibility are among the selection criterias (Cormi et al., 2006). The desired variety will be revealed as a variety adapted to the ecology that will be produced for certain purposes.

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When production conditions become more suitable, varieties should be tolerant and have high yield performance under different stress conditions (Al-Naggar et al., 2018). In this respect, thanks to the genetic variation of the sorghum, it will be possible to develop the desired characteristics among the existing genotypes with multidimensional programs (Aruna et al., 2015).

Sorghum will gain importance today and soon due to its xerophic properties, wide adaptability, high yield and quality, and easy silage due to its high water-soluble carbohydrate content (Jahanzad et al., 2013; Ahalawat et al., 2018). With this objective, the performance of some sorghum genotypes in terms of yield and quality was carried out under the ecological conditions of the Aegean region, where the summers are dry and hot.

MATERIAL AND METHODS

The research was carried out in Aydın Adnan Menderes University research and experimental fields (37˚ 45' 51'' N, 27˚45' 32'' E, 27 m altitude). The soil properties of the experimental area were sent to Aydın Adnan Menderes University Soil and Plant Nutrition Laboratories for analysis. According to analysis results, the soil of experimental area has a sandy-loamy texture and the reaction is alkaline, and saltless but low about the organic matter. When the amount of nutrients in the soil is examined, it is understood that phosphorus, calcium, and iron are generally at sufficient and moderate levels, while it is understood that they have high values in terms of potassium and magnesium. Sodium content is seen to be at low level. (Table 1.)

Considering the climate data, similar values were observed according to the years of the experiment and long-term temperature data. Only in April 2016, a difference of 3˚C was detected.

According to the precipitation, while irregularity was observed in the precipitation regime in both years, it was determined that the precipitation falling in the summer months decreased according to the climate data for the long-term. This difference has been tried to be covered by surface irrigation organizations (Table 2.; Figure 1.)

Table 1. Soil properties of the experimental area (0-30 cm)

P ppm	K ppm	Ca ppm	Mg ppm	Na ppm	Fe ppm	pH	Total Salt (%)	Organic Matter (%)
19	903	2740	1164	46	8.32	8.16	0.0093	1.20

Table 2. Climatic data of the experimental area

	Temperature (ºC)			Precipitation (mm)		
	2016	2017	Long Term	2016	2017	Long Term
April	19.4	16.4	16.2	8.2	43.2	50.9
May	20.5	21	21	37.5	42	40.3
June	27.8	26.2	26	4	15.6	14.5
July	29.7	29.8	28.6	0	0	6.1
August	29	28.8	28.1	0	16.6	6.7
September	24.3	24.7	23.9	6.7	0	16.9
Mean/Total	25.1	24.5	24	56.4	117.4	135.4

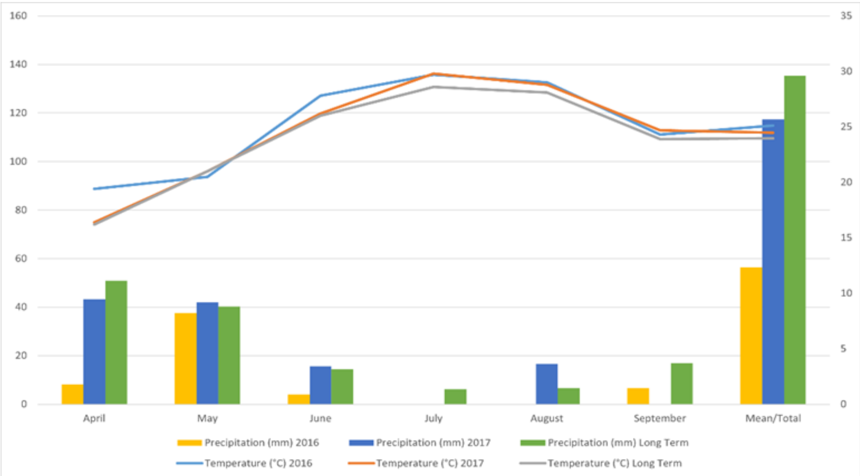


Figure 1. Climatic data of the experimental area for the years the study was carried out and long-term data (Turkish State Meteorogocial Service, 2021)

In the study, genotypes developed by single plant selection breeding in terms of the stem, height, and grass yield were used in the breeding studies initiated in 2005 on the material provided from International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) and the US Department of Agriculture (USDA) by Prof. Dr. Esvet Acikgoz. These provided genotypes include EA27 (Sudan), EA36 (Switzerland), EA29 (USA), EA104 (Unknown origin), EA09 (Taiwan), EA08 (India). In addition to these genotypes, Gulseker and Beydari were evaluated as standard genotypes.

The experiment was carried out in randomized blocks design with three replications. The trial area was plowed at a depth of 20-25 cm with a plow in April, and the soil was prepared by pulling the taping roller to prevent the soil moisture from being lost after the ploughing processes were completed with disc harrows and rotary tillers. Sowing was done with the help of a pneumatic seeder (Gaspardo, Italy). The plots were planned as 4 rows, while the row spacing was determined to be 7 cm over 70 rows. The plot size was 16.8 m^2 (2.8 x 6 m), and the experiment was carried out with 3 replications. Before planting, 5 kg da^{-1} pure phosphorus and 5 kg da^{-1} pure nitrogen were applied as base fertilizer. When the plants reach 40-50 cm, 15 kg da^{-1} pure nitrogen is given as top fertilizer (Girgin, 2012).

The first rotary hoe was made when the plants were between 15-25 cm, while the second tractor hoe was made when the plants were 40 cm. Irrigation program was carried out 4 times at 12-15 day intervals, taking into account the needs of the plant. The harvesting of the plants was carried out in the milky-dough period the grain in the plants, taking into account the maturation time of each genotype (Naoyuki and Yusuke, 2004).

Ten different plants were taken from the plots for the measure of plant height (cm). Edge rows from each side of the plot were cut out and then rest of the plot was harvested and weighed to determine fresh forage yield. Hay yield (t da^{-1}) was measured by fan drying oven (Mikrotest, MST) at 70°C until the weight was fixed (Cook and Stubbendieck, 1986).

Dried materials from the species were prepared for fiber and nitrogen analysis by grinding with a mill to 0.3-0.5 cm fineness. Crude protein ratio (%) of the samples taken from the experiment were measured according to the method of AOAC (2003); NDF and ADF contents (%) were measured according to Van Soest et al. (1991). The crude protein yield (t da^{-1}) and relative feed value were calculated by the obtained data following the procedures of Horrocks and Vallentine (1999).

In the experiment, the analysis of variance was performed with the LSD multiple comparison method using the 'agricolae' package (de Mendiburu and de Mendiburu, 2019) in R Studio (V4.1.2). Correlogram was created in R Studio using the 'corrplot' package (Wei et al., 2017). Heat map was made in R Studio using the heatmap.2 command within the ‘gplots’ package (Warnes et al., 2022).

RESULTS AND DISCUSSION

Plant height varied between 94.50 and 294.16 cm according to the two-year averages. While it was seen that the first year average was higher at 217.16 cm, a significant difference was obtained in the year×genotype interaction. EA36, EA27 and EA29 genotypes stood out with the highest average plant height. Differences between years can also be seen in Appendix A. In the studies, the plant height was determined by Kara et al. (2019) 182.87-195.40 cm; Celik and Turk (2021), 200-229.7 cm; Sharp et al. (2018) 197.1-299.4 cm; Cormi et al. (2006), 74.4-143 cm, Atis et al. (2012) 245.7-266.1 cm; Singh et al. (2016), 274.9-354.9 cm, Salman and Budak (2015), 265-345 cm, Aydinoglu and Cakmakci (2018), stated that it varies between 196.6-223.3 cm. When sorghum genotypes bred for different purposes are evaluated in different ecologies, it can make huge differences in this regard. At the same time, the time of cultivation can provide this difference.

There was no difference in the year×genotype interaction in terms of fresh forage yield. The average values of the two years varied between 3.63 and 10.06 t da^{-1}. The highest fresh forage yield was determined in EA27 genotype. While hay yield averages ranged between 0.79-2.12 t da^{-1}, the highest values were obtained from EA27 and EA36 genotypes (Table 3.). In the studies, Kara et al. (2019) stated that the hay yield varies between 0.81-2.11 t da^{-1}, while Celik and Turk (2021) stated that the fresh forage yield was 4.65-6.26 t da^{-1}; stated that hay yield varies between 1.69-2.24 t da^{-1}. Kir and Sahan (2019) determined the hay yield in the range of 1.35-2.84 t da^{-1}. In other studies, Bilen and Turk (2021) reported hay yield in the range of 1.17-1.31 t da^{-1}, Celik and Turk (2021), fresh forage yield in the range of 5.74-7.77 t da^{-1}, hay yield in the range of 1.89-1.91 t da^{-1}. expressed. In many studies on yield, similar or high or low values were obtained due to differences in genotype, environment and care (Atis et al., 2012; Kir and Sahan, 2019; Moray and Istanbulluoglu, 2022; Singh et al., 2016; Yolcu, 2015). While there was no difference between the years according to the average number of leaves, the values varied between 8.64 and 17.56. While it has been observed that genetic characteristics have effects on yield, it is thought that this situation may also depend on the number of leaves. Singh et al. (2016) stated that the number of leaves has a significant share in yield. They explained that the number of leaves was between 10.7-14.2 in their study. Cormi et al. (2006) observed that the values varied between 8.75-10.5.

Table 3: Average values of plant height (cm), fresh forage yield (t da^{-1}) and hay yield (t da^{-1})

	Plant height (cm)	**Fresh forage yield (t da^{-1})**	**Hay yield (t da^{-1})**
Years			
2016	217.16^{A}	6.79	1.50
2017	209.83^{B}	6.66	1.44
Genotypes			
EA27	285.00^{A}	10.06 ^{A}	2.01 ^{A}
EA36	294.16^{A}	8.75 ^{B}	2.12 ^{A}
EA29	285.50^{A}	7.47 ^{C}	1.69 ^{B}
Gulseker (St.)	241.66^{B}	6.68 ^{D}	1.58 ^{B}
Beydari (St.)	94.50^{E}	5.08 ^{F}	1.14 ^{D}
EA104	167.83^{D}	6.05 ^{E}	1.14 ^{D}
EA09	180.00^{C}	6.07 ^{E}	1.35 ^{C}
EA08	159.33^{D}	3.63 ^{G}	0.79 ^{D}
Mean	213.50	6.73	1.48
Year	**	ns	ns
Genotypes	**	**	**
Y×G	**	*	ns
LSD	10.30	0.30	0.078

*: P≤0,05 **: P≤0,01 ns: non-significant

Depending on the purpose of use and genetic characteristics, the number of leaves may differ in each study. Fiber properties such as acid detergent fiber (ADF) and neural detergent fiber (NDF) enable the analysis of roughage in terms of quality other than yield. It is known that forage with high percentages of fiber has lower digestibility. ADF and NDF are considered to be two important features of forage quality (Caballero et al., 1995). High-quality forages have low concentrations of both NDF and ADF and high dry matter digestbility (DMD) (Paterson et al., 1994). While there was no statistically significant difference between the years according to the ADF values, the two-year averages varied between 34.65 and39.37%. Although it is thought that it is an unexpected situation to have the highest value in terms of EA27 fiber, which has the highest yield characteristics, the observation of this situation in both years suggests that it is due to the genetic characteristics of this genotype. While statistically significant differences were observed between years in terms of NDF, a higher NDF average was observed in the first year. While the averages of the genotypes ranged between 49.38-61.71%, the highest value was obtained from the EA29 genotype. Differences between the years of ADF and NDF can also be seen in Appendix A. The high NDF rate is still an ongoing concern in sorghum and one of the breeding goals is to reduce this rate (Cherney et al., 1991). Carmi et al. (2006), while expressing that the NDF ratio varies between 61.5-67%, Jahanzad et al. (2013) stated that the ADF ranged between 23.8 and27% and the NDF between 55.6 and57.1. In another study, Kir and Sahan (2019) stated that NDF was 51.2% and ADF was 33.7%. Crude protein ratio is also a parameter that affects feed quality in terms of quality characteristics. Crude protein content is one of the most important factors in forage quality (Assefa and Ledin, 2001). High protein has a positive effect on livestock development. In the study, there was no significant difference between the years in terms of crude protein ratio, but the values changed between 9.12-11.25%. Although there is no difference at very high values in terms of protein ratio, there are statistically significant differences. The highest value was obtained from Beydarı (St) (Table 4.). In their studies, the crude protein ratio was determined by Colombini et al. (2012) stated that it was 10.5%, while Carmi et. al. (2006) stated that it varies between 7.09-9.14%. Jahanzad et al., (2013) stated that the values varied between 12.6-14.5%.

In the studies, it has been observed that genotypes grown for the similar ecologies may have the similar protein content. At the same time, fertilization and other maintenance works will reveal that this situation may change. Crude protein yield, in which hay yield and crude protein ratio were examined together, genotype averages for two years varied between 0.075-0.198 t da^{-1}, but there was no significant difference between years. Due to the high yield values, EA27 and EA36 were the genotypes with the highest values.

Table 4. Average values for leaves per plant, ADF(%), NDF(%) and crude protein ratio (%)

	Leaves per plant	ADF (%)	NDF(%)	CPR(%)
Years				
2016	11.49	35.86	57.59 A	10.01
2017	11.38	35.65	56.08 B	9.86
Genotypes				
EA27	17.56 A	39.37 A	59.10 BC	9.56 DE
EA36	14.93 B	34.65 C	52.62 E	9.34 E
EA29	11.03 C	35.56 B	61.71 A	9.12 E
Gulseker (St.)	8.64 E	35.47 B	57.54 CD	10.46 B
Beydari (St.)	9.13 DE	35.38 B	49.38 F	11.25 A
EA104	8.65 E	35.13 BC	60.19 AB	10.30 BC
EA09	11.15 C	35.21 B	56.42 D	9.95 CD
EA08	10.38 CD	35.25 B	57.74 BD	9.52 DE
Mean	11.43	35.75	56.83	9.93
Year	ns	ns	*	ns
Genotypes	**	**	**	**
Y×G	**	**	**	**
LSD	0.64	0.26	2.46	0.47

*: P≤0,05 **: P≤0,01 ns: non-significant

Table 5. Average values for crude protein yield (t da^{-1}) and relative feed value

	CPY (t da^{-1})	RFV
Years		
2016	0.149	98.81 B
2017	0.141	102.38 A
Genotypes		
EA27	0.192 A	91.61 E
EA36	0.198 A	109.40 B
EA29	0.154 B	92.48 E
Gulseker (St.)	0.165 B	99.22 CD
Beydari (St.)	0.128 CD	116.40 A
EA104	0.115 D	95.17 DE
EA09	0.134 C	101.47 C
EA08	0.075 E	98.96 CD
Mean	0.145	100.59
Year	ns	**
Genotypes	**	**
Y×G	ns	**
LSD	0.00787	4.27

*: P≤0,05 **: P≤0,01 ns: non-significant

The genotype with the lowest value was EA08. Relative feed value is an index that is used to predict the intake and energy value of forage which is derived from dry matter digestibility and dry matter intake (Lithourgidis et al., 2006). While significant differences were detected between years in the relative feed value, which is one of the features that allow us to see yield and quality together, the second year general mean stood out with 102.38. Differences in crude protein ratio between years can also be seen in Appendix A. While the averages of the genotypes ranged from 91.61 to 116.40, the highest value was seen in Beydari due to ADF and NDF (Table 5.). The crude protein yield was determined by Kara et al. (2019), while stating that it varies between 0.108 and 0.218, stated that the maintenance practices can create great changes in crude protein yield depending on the yield. When both crude protein yield and relative feed value are examined together, the best genotypes can be seen in terms of yield and quality. In this respect, while EA27 and EA36 genotypes stand out in terms of many features, it has been obtained that digestibility can be high in Beydarı with low fiber content (Figure 2.). When the correlation between the characteristics was examined, it was observed that the grass and hay yield had a positive relationship with crude protein yield, as expected, while plant height and crude protein ratio, relative feed value and NDF (%) had a negative relationship (Figure 3.).

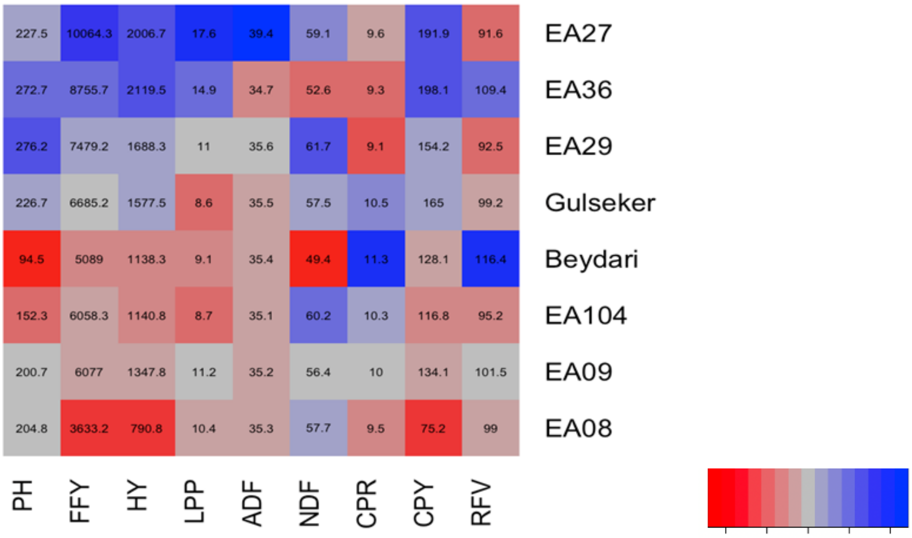


Figure 2. Mean values with heat map for observed characteristics of eight sorghum genotypes (PH: Plant height (cm), FFY: Fresh forage yield (t da^{-1}), HY: Hay yield (t da^{-1}), LPP (Leaves per plant, ADF: Acid detergent fiber (%), NDF: Neutral detergent fiber (%), CPR: Crude protein ratio (%), CPY: Crude protein yield (t da^{-1}), RFV: Relative feed value)

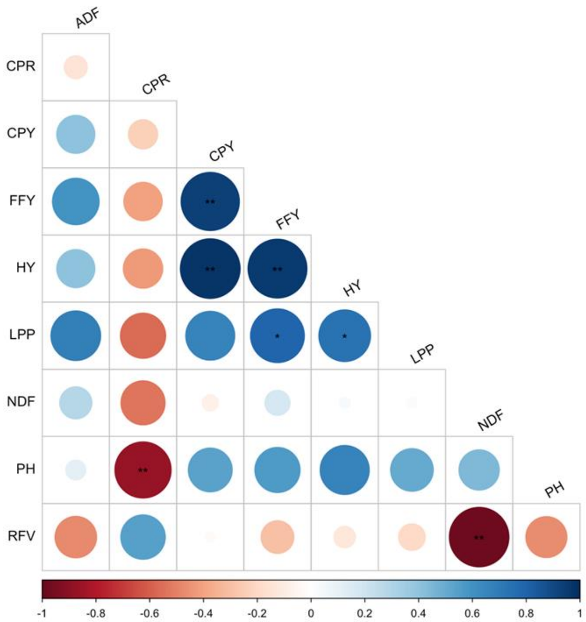
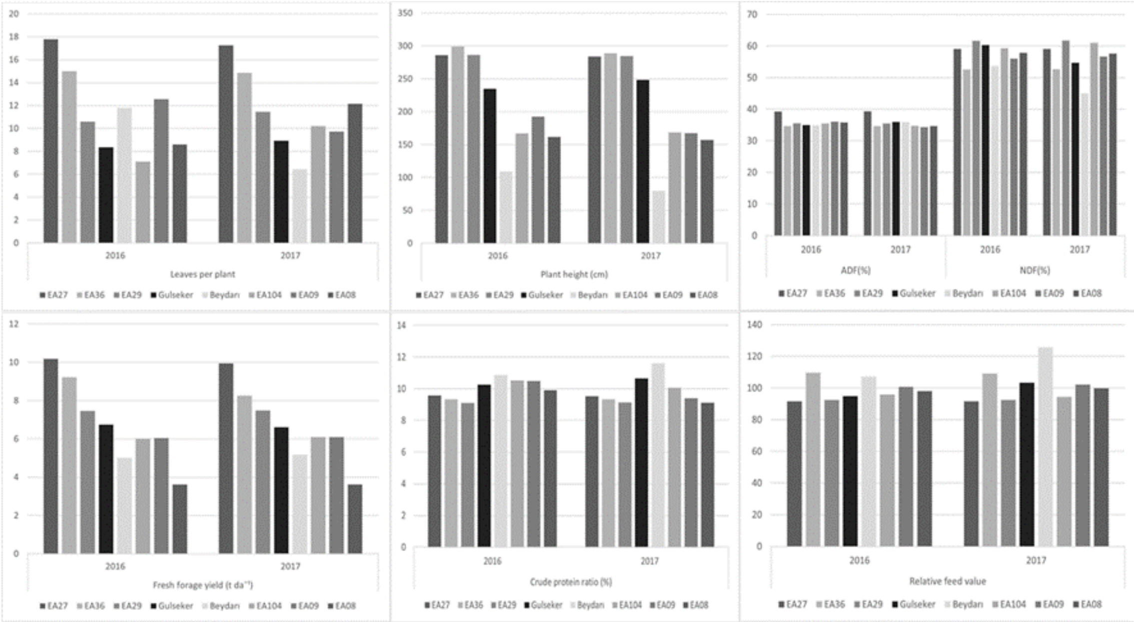


Figure 3. Pearson correlations with correlogram among examined parameters
(PH: Plant height (cm), FFY: Fresh forage yield (t da^{-1}), HY: Hay yield (t da^{-1}), LPP (Leaves per plant, ADF: Acid detergent fiber (%), NDF: Neutral detergent fiber (%), CPR: Crude protein ratio (%), CPY: Crude protein yield (t da^{-1}), RFV: Relative feed value)



Appendix A. Years averages of parameters with statistically significant differences in year × genotype interaction

CONCLUSION

Sorghum, which is known to have high genetic variation, has high importance in terms of water use efficiency. It is grown in many areas of the world because it requires less water compared to maize, and that varieties and genotypes with similar characteristics in terms of yield can be found. The development of new varieties is also very important, especially today when the importance of water use is increasing. In this respect, when the genotypes examined in the experiment and the characteristics of the standard cultivars were compared, it was seen that EA27 and EA36 genotypes had high values in terms of yield. The lowest values were generally found in the EA08 genotype.

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