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Research Article

# Evaluation of Some Sorghum (*Sorghum bicolor* L.) Genotypes by Principles Component Analysis

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**Abstract:** To improve sorghum productivity, farmers need high-yielding sorghum cultivars. A field experiment was conducted in the 2020 cropping season to determine the interaction effect of genotypes in Adana and Antalya locations in Turkey. Two lines plus three checks cultivars were evaluated at both locations in Turkey. The analysis of variance showed highly significant (P≤0.01) differences among the genotypes for all traits. The analyzed result indicates that the genotypes gave a higher yield in the Antalya location in terms of forage yield. The lowest forage yield was obtained from Line 2 and Line 1 with 4735.7 and 6212.9 kg da$^{-1}$ in Adana, while the highest forage yield was recorded from all genotypes in Antalya. Moreover, forage yield and plant stalk ratio were positively and significantly associated with hay yield. The first two principal components (PC) accounted for 86.42% of the total genotypic variation.

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## 1. Introduction

The population of Turkey is increasing rapidly, as in the whole world. Increasing urbanization in parallel with population growth is another factor that causes the decrease in pasture areas. Global climate change and the change in precipitation regimes have caused approximately 70-75% of Turkey's rangeland to be located in semi-arid and arid regions. In these regions, yield potential has decreased considerably due to insufficient or no summer precipitation and limited irrigation facilities. In order to meet the need for roughage, it is necessary to open new rangelands or to increase the forage crop ratio and production in field crops. It has been demonstrated by many scientific studies that it is a necessity to choose the plants that will be included in the product pattern from the plants that can provide the highest yield per unit area and that have the least water consumption due to global climate change. Sorghum is the most produced plant after corn among the hot climate cereals, which is used both for human and animal nutrition, for alcohol production, and as a renewable energy source. Sorghum cultivation is carried out in an area of approximately 40 074 667 ha in the world (FAO, 2021). Sorghum can be easily grown in areas that are not ideal for corn cultivation. The most common types of sorghum, which have many types suitable for their intended use, are grain and silage. The stem and leaf surfaces

of sorghum, which is a typical C4 plant, are covered with a waxy layer, which helps the plant to benefit more from daylight in hot periods and to increase the rate of photosynthesis. Besides, sorghum has a high tolerance to drought and soil salinity (Avcioglu et al., 2009). For this reason, its cultivation as a second product is increasing in our regions where irrigation opportunities are relatively low in Turkey. In this regard, some studies have been carried out with different genotypes in different locations. In the experiment conducted by Acar et al. In 2002 in the fields of Konya Livestock Research Institute, with five sorghum-sudangrass hybrids (Elrey, Gmss, Grazer, Jumbo, and Sweet), the average plant heights in two harvests were 215.53 cm (Sweet) and 231.02 cm (Jumbo), dry matter yield was found between 4 486.8 kg $da^{-1}$ (Grass) and 5 745.2 kg $da^{-1}$ (Jumbo) and total green herbage yield was between 14641.3 kg $da^{-1}$ (Grass) and 19038.7 kg $da^{-1}$ (Jumbo). In the study by Cakmakci et al. (1999), which was carried out in the West Mediterranean Agricultural Research Institute (Antalya) trial area for 2 years to investigate the effects of different cutting cycles on yield and quality; Rox variety was harvested at five different developmental stages and it was concluded that it is appropriate to harvest silage sorghum in the yellow maturity stage in Antalya region. In another study conducted by Guneş and Acar in 2005, four sorghum cultivars (Grazer, El Rey, Grass II, Jumbo) were used as material in order to determine the cultivation possibilities of silage sorghum varieties as a second product under irrigated conditions in the Nursery Field of Karaman Province Directorate of Agriculture and their green yields were 6483.73 kg $da^{-1}$ (Grazer) and 7 671.23 kg $da^{-1}$ (Jumbo), dry matter yields were between 2 093.50 kg $da^{-1}$ (Grazer) and 2 321.40 kg $da^{-1}$ (Jumbo), crude protein ratios were between 4.41% (Grazer) and 5.15% (El Rey). All sorghum cultivars included in the experiment were determined as cultivars that could be grown as a second crop.

The correlation, determine the correlation between variables and measures the power of the linear relationship between two variables (Kumar et al. 2022).. Also Correlation is of great importance in evaluating the most effective characters in the selection of superior yielding genotypes. When the main characters to be used in selection are positive, selection will be very effective in terms of breeding, if it is negative, it will be difficult to make simultaneous selection (Nemati, et al. 2009).

Statistical analysis of multivariate methods has wide use in summarizing the genotypes. The principal component analysis is an important multivariate analysis method (Oyelola, 2004). PCA is a technique for increasing interpretability with this minimizing information loss. The principal component analysis reduces to solving an eigenvalue and new variables are defined by the dataset, consequently, PCA is an adaptive data analysis technique (Jolliffe and Cadima, 2016).

The current study aimed to determine by correlation and principal component analysis, some sorghum genotypes that are suitable for both regions, with high yield and quality in Antalya and Adana locations.

## 2. Material and Methods

Two experiments were carried out at the West Mediterranean Agricultural Research Institute's (Altitude 30 m above sea level, average annual rainfall 963.4 mm and the average temperature is 19.03°C) field area in Antalya and Eastern Mediterranean Agricultural Research Institute (Altitude 12 m above sea level, average annual rainfall 757.4 mm and the average temperature is 19.1°C) in Adana in 2020. The soil of the research area was clay-loam-silt in texture, non-saline and rich in calcium carbonate, and slightly alkaline in pH, in Adana. The land of the research area of Antalya had silty-clay loam soil and contained adequate organic matter.

Two candidate varieties of sorghum genotypes (Line 1 and Line 2) along with the tree registered varieties (Erdurmus, Uzun, and Leoti) were arranged in randomized block design with four replications. Experimental materials were sown on May 06, 2020, in Antalya and on May 20, 2020, in Adana. The plot size was 14 $m^2$ (4 rows, 5 meters length, and 0.7m inter-row). Data were collected for the parameters of days to 50% flowering day, plant stalk ratio, plant leaf ratio, forage yield, and hay yield. For determining green forage yield, harvested plants were weighed quickly, then for determining green forage yield, 0.5 kg fresh samples were oven-dried at 70 ºC for 48 hours until reached constant weight for estimating the dry matter content. Data on days to 50% flowering were recorded from the whole plot, but plant stalk ratio and plant leaf ratio components were recorded from randomly selected 10 plants in each plot. Statistical analysis of obtained data was done using the SPSS software version 16.0 and means were compared using Duncan's test at the $p \leq 0.05$ probability level.

## 3. Results and Discussion

### 3.1. Days to 50% flowering

Analysis of variance results showed that days to 50% flowering was significantly affected due to the main effect of variety, location ($P \leq 0.01$), and variety*location interaction ($P \leq 0.05$). The highest days to 50% flowering was recorded in Line 2 with both in Antalya (98.3 days) and Adana (95.8 days) locations (Table 1). In both locations, the lowest days to 50% flowering was obtained from the Erdurmus variety. The candidate variety Line 1 also showed a value (87.8 days) close to the Erdurmus variety (87 days). With this result, it showed an earlier performance than Uzun and Leoti varieties. Days to flowering was affected due to variety and location, moreover, it depends both on the genotypes/varieties and the environment. This could change for the same genotypes/varieties at the different locations if the planting date were changed, as we did. This is in agreement with the finding of different results of researchers (55.0-82.0 days in Saglamtimur et al., (1988) and 55.0-99.1 daysinYucel et al., (2020)).

Table 1. Performance of the varieties and lines in the two locations

| Location | Variety | Days to 50% flowering (Day) | Plant leaf ratio (%) | Plant stalk ratio (%) | Forage yield (kg da$^{-1}$) | Hay yield (kg da$^{-1}$) |
|---|---|---|---|---|---|---|
| Adana | **Line 1** | 87.8 de* | 14.3 ab | 84.7 c | 6 212.9 cd | 2 631.3 c |
| | **Line 2** | 95.8 ab | 15.3 a | 84.7 c | 4 735.7 d | 1 361.2 d |
| | **Erdurmus** | 87.5 de | 11.2 c | 88.9 a | 11 144.5 a | 4 029.7 a |
| | **Uzun** | 90.5 c | 15.3 a | 84.7 bc | 6 800.0 bc | 2 740.2 c |
| | **Leoti** | 90.0 cd | 13.4 b | 86.6 b | 8 095.4 b | 2 851.4 bc |
| Antalya | **Line 1** | 87.0 e | 14.4 ab | 85.6 bc | 10 862.6 a | 3 193.4 bc |
| | **Line 2** | 98.3 a | 15.7 a | 84.4 c | 10 670.6 a | 2 851.9 bc |
| | **Erdurmus** | 87.0 e | 14.8 ab | 85.2 bc | 11 162.6 a | 3 501.3 b |
| | **Uzun** | 93.8 b | 14.5 ab | 85.6 bc | 10 532.3 a | 3 200.6 bc |
| | **Leoti** | 94.0 b | 15.4 a | 84.6 c | 11 152.0 a | 2 888.2 bc |
| F Probability | **Variety** | ** | ** | ** | ** | ** |
| | **Location** | ** | ** | * | ** | ns |
| | **Variety*Location** | * | ** | ** | ** | ** |
| **CV (%)** | | 2.0 | 6.8 | 1.5 | 12.0 | 15.0 |
| **LSD** | | 1.28 | 0.58 | 0.77 | 719.89 | 324.47 |

LSD= Least Significant Difference; CV= Coefficient Variance; ns= Non Significant;*= $P \leq 0.05$; **= $P \leq 0.01$ *The means in the same column with same letters are in the same group.

### 3.2. Plant leaf ratio

The data obtained from the plant leaf ratio in the research are shown in Table 1. According to the statistical analysis results; variety, location, and variety*location interaction were found significant. Plant leaf ratio values ranged from 11.2% to 15.7%. Line 2 had the highest plant leaf ratio in both Adana and Antalya locations, the Erdurmus variety in the Adana location, and Line 1 at the Antalya location had the lowest value. Our results for plant leaf ratio value have broadly similar to the findings reported by İptas, (1993) with 17.7%, Hosaflioglu (1998) with 17.8%, Yılmaz, (2000) with %18.6, Acar et al., (2002) with 15.5%, and Geren and Kavut, (2009) with 16.1%. According to Kır (2014), the high plant leaf ratio is an indicator of the quality of the plant. Furthermore, the leaf/stem ratio is an important quality criterion for forage crops.

### 3.3. Plant stalk ratio

Among the traits studied plant stalk ratio had the highest coefficient of variation. The mean value for plant stalk ratio ranged from 84.4%-88.9%. The Line 1, Line 2 and Leoti variety had the least plant stalk ratio and the Erdurmus variety showed the highest rate. Our results are in agreement with the results by Acar et al. (2002) (74.7%), Gul and Basbag (2005) (70.7%), and Salman and Budak (2015) (77.4%).

### 3.4. Forage yield

There were strong genotypic differences (P<0.001) for forage yield (Table 1) in the study. Forage yield ranged from 4 735.7 kg da$^{-1}$ to 11 162.6 kg da$^{-1}$ averaged across locations and genotypes. Erdurmus variety had the highest forage yield with 11162.6 kg da$^{-1}$, whereas Line 2 had the lowest with 4 735.7 kg da$^{-1}$. While all the materials used in the experiment in the Antalya location were obtained from more than 10 tons of yield, it was yielded more than 10 tons only from the Erdurmuş cultivar in the Adana location. We can explain the high performance of the Erdurmuş cultivar in both locations as "the high performance of a cultivar in different ecologies shows that it is stable" (Keser et al., 1999). Especially among the cultivar candidates, Line 2 had the lowest yield with 4 735.7 kg da$^{-1}$. It can be said that the two weeks difference between planting dates and the annual precipitation difference between locations are effects on forage yield between locations.

Some researchers have obtained different yield values in different ecological conditions, such as; Acar et al. (2002) 14 641.3-19 038.7 kg da$^{-1}$, Karadas, (2008), 6 296.3-7 613.2 kg da$^{-1}$ and Ozkose et al. (2014), 5 356.5-13 446.4 kg da$^{-1}$ in Konya ecological condition, Yolcu (2015), 7 499.5-15 213.8 kg da$^{-1}$ in Çanakkale ecological condition. Balabanlı and Turk (2005), 4 371.2-6 831.5 kg da$^{-1}$ in Isparta ecological condition.

Forage yield was affected due to variety and location. This might be due to the genetic difference of the genotype in response to genotype and location also shows a significant difference in forage yields.

### 3.5. Hay yield

In the current research, the highly significant effect of genotypes on hay yield was determined. The varieties also differentiated on the basis of locations in terms of the hay yield, similar to the forage yield. However, the difference between varieties in terms of hay yield was found to be insignificant between locations (Table 1). While all the varieties were in the same group in the Antalya location, the lowest hay yield was obtained from Line 2 with 1 361.2 kg da$^{-1}$ in the Adana location. Erdurmus variety had the highest hay yield with 4 029.7 kg da$^{-1}$ in the Adana location, whereas Line 2 had the lowest hay yield with 1 361.2 kg da$^{-1}$ in the Adana location. The reason for the difference between the two locations in terms of hay yield of the Erdurmus cultivar may be that it was planted late in the Adana location and therefore the harvest date was delayed. This result is consistent with Avcıoğlu et al., (2000), who reported that dry matter yield increased with the advancement of harvest time in forage crops.

Similar results were obtained by Acar et al. (2002) 4 486-5 745 kg da$^{-1}$, Gunes and Acar (2005) 2 093.5-2 321.4 kg da$^{-1}$, Karadas (2008) 1 908.9-2 343.4 kg da$^{-1}$ and Salman and Budak (2015), 5 210.3 kg da$^{-1}$.

### 3.6. Correlation analysis

The correlations among parameters are presented in Table 2. In the present investigation, correlation coefficients were worked out among five characters. Results of correlation analysis indicated that the hay yield was found to be significantly correlated with all characters. However, days to flowering was negatively and significantly correlated with stalk ratio forage yield and hay yield. Furthermore, plant leaf ratio was also negatively and significantly correlated with stalk ratio forage yield and hay yield. Hay yield showed a strong correlation with these traits, as well as with flowering days and plant leaf ratio negatively, and positively with plant stem ratio and forage yield.In many previous studies conducted on sorghum, positive and negative correlations were found among the investigated traits (Moyer et al., 2003; Khandelwal et al., 2015; Abate, 2016; Mesfin, 2016; Temesgen, 2018).

Table 2. The correlation coefficient of the characters

| Parameter | Days to 50% flowering (Day) | Plant leaf ratio (%) | Plant stalk ratio (%) | Forage yield (kg da$^{-1}$) | Hay yield (kg da$^{-1}$) |
|---|---|---|---|---|---|
| Days to 50% flowering | 1.0000 | 0.4590** | -0.3909* | -0.1393ns | -0.4582** |
| Plant leaf ratio | | 1.0000 | -0.9400** | -0.1290ns | -0.5535** |
| Plant stalk ratio | | | 1.0000 | 0.1717ns | 0.5193** |
| Forage yield | | | | 1.0000 | 0.6962** |
| Hay yield | | | | | 1.0000 |

### 3.7. Principal component analysis

In the present study, the first two eigenvectors have eigenvalues greater than one and cumulatively explained about 86.42% percent of the total variation among genotypes of sorghum (Table 3 and Figure 1). Therefore, PC 1 had an eigenvalue of 3.26 and accounted for 65.21 % of the variations. This represented an equivalent of five variables (Days to 50% flowering and plant leaf ratio negative correlation, plant stalk ratio, forage, and hay yield positive correlation) and indicated that were important contributing variables for the variation among the genotypes. This study shows that the PCA analysis is able to identify a few key traits that accounted for the largest variability in genotypes of sorghum. The aim of the PCA is to get more important information from the available data, simplify the characterization of the data, and analyze the structure of the observations on the variables. Ozdamar (2010) reported that to determine the appropriate number of principal components in PCA, components with an eigenvalue greater than one, or principal components that could explain at least 67% of the total variance should be considered. Additionally, Gozen, (2008) emphasized that eigenvalues greater than one are considered significant and component loading greater than 0.3 are considered to be meaningful. PCA is used as an effective size reduction method in multivariate data sets.

Table 3. Principal component analysis

| **Principal Components** | **PC1** | **PC2** |
|---|---|---|
| Eigenvalue | 3.26 | 1.06 |
| Total Variance (%) | 65.21 | 21.21 |
| Cumulative Variance (%) | 65.21 | 86.42 |
| **Factor loading by parameters** | | |
| Days to 50% flowering | -0.663 | 0.389 |
| Plant leaf ratio | -0.906 | 0.329 |
| Plant stalk ratio | 0.912 | -0.199 |
| Forage yield | 0.554 | 0.817 |
| Hay yield | 0.928 | 0.306 |

The maximum number of principal components that can be obtained in PCA is equal to the original number of variables. However, analysis of results is usually interpreted taking into account the first two or three basic components, not all components. Thus, most of the variation in the original variables can be explained by the first two principal components. In this way, the original variables can be provided that are largely summarized and easier to interpret (Demir et al., 2016). The present study is supported by earlier results by Ali et al. (2011) and Abraha et al. (2015).

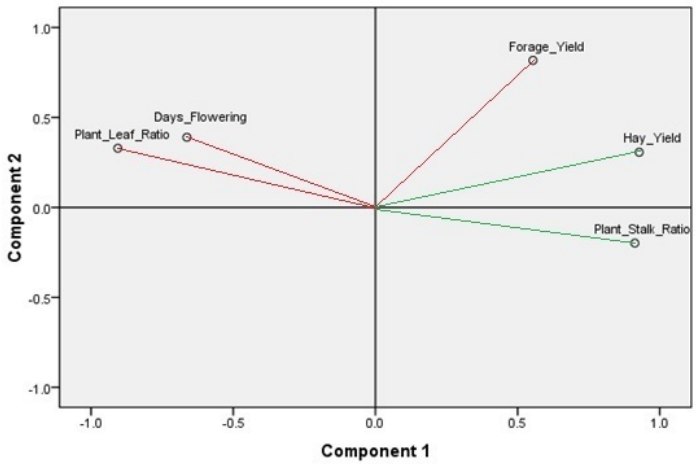


Figure 1. Grouping of studied sorghum traits based on factor analysis under variety*locations.

### Conclusion

Despite its superior characteristics, sorghum does not receive the attention it deserves in Turkey. Variety candidates that have come to the forefront as a result of the breeding program carried out for

years, were tested in different locations and the differences in yield between locations have been identified. Variety candidates Line 1 showed similar characteristics with cultivars in terms of earliness and forage yield. Besides results of correlation analysis indicated that the hay yield was found to be significantly correlated with all characters. As a result of the principal component analysis used to define the variation, it was determined that 2/3 of the variance was defined in the first two principal components and the most important descriptive element was the yielding character.

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