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A Study on Morphological and Agronomic Traits of Sainfoin Populations (*Onobrychis sativa* Scop.) in Semi-Arid Conditions

Yarı Kurak Koşullarda Korunga Genotiplerinin (*Onobrychis sativa* Scop.) Morfolojik ve Agronomik Özellikleri Üzerine Bir Araştırma

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Abstract: Plant species belonging to the leguminous family are very important for the quality and quantity of rangelands in semiarid regions. New varieties should be developed from the delicious, long-lasting, and high-quality plant species in this family for our rangelands that have rapidly deteriorated due to mismanagement. For this reason, sainfoin breeding study was initiated to develop new cultivars. In the first period, the seven collected sainfoin populations from the rangeland areas of the Central and Eastern Anatolia Regions were planted with control cultivars, Özerbey-03 and Lütfibey, in a nursery plot at the research station located in the Gölbaşı district of Ankara in 2015. At the initiating period of this breeding study (in 2016 and 2017), morphological (plant height, stem diameter, and stem number) and agronomic traits (fresh forage and dry forage yields) were determined. According to the obtained results, The L-1787 had the highest values in plant height, fresh forage, and dry forage yields of all populations. Moreover, among all populations, L-1747 had the lowest fresh forage and dry forage yield. The L-1781 had the highest stem number, while Lütfibey had the lowest. The Özerbey-03 and L-1781 had the thickest stems. L-1781, L-1787 anwd L-1788 populations exhibited higher fresh and dry feed yield due to higher stem number and larger stem diameter compared to control varieties. These populations can also be utilized for future breeding studies to develop new cultivars. Additionally, the methods of Cluster Analysis and Principal Component Analysis were used to identify similar traits and their similarity levels.

Keywords: Sainfoin populations, morphological traits, agronomic traits, cluster analysis, principal component analysis

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Öz: Baklagiller familyasına ait bitki türleri, yarı kurak bölgelerdeki meraların kalitesi ve miktarı için çok önemlidir. Yanlış yönetim nedeniyle hızla bozulan meralarımız için bu familyada yer alan lezzetli, uzun ömürlü ve kaliteli bitki türlerinden yeni çeşitler geliştirilmelidir. Bu doğrultuda yeni çeşitlerin geliştirilmesi amacıyla korunga ıslah çalışması başlatılmıştır. Bu amacı gerçekleştirmek için korunga ıslah çalışması yeni çeşitlerin geliştirilmesi amacıyla başlatılmıştır. İlk aşamada, Orta ve Doğu Anadolu Bölgelerinin mera alanlarından toplanan yedi korunga populasyonu, 2015 yılında Ankara'nın Gölbaşı ilçesinde bulunan araştırma istasyonunda tesis edilen bir gözlem bahçesinde kontrol çeşitleri olan Özerbey-03 ve Lütfibey ile birlikte ekilmiştir. Projenin ikinci ve üçüncü yılarında (2016 ve 2017), morfolojik (bitki boyu, sap kalınlığı ve sap sayısı) ve agronomik özellikler (yeşil ot ve kuru ot verimleri) tespit edilmiştir. Elde edilen sonuçlara göre, L-1787 tüm populasyonlar arasında bitki boyu, yeşil ot ve kuru ot verimi bakımından en yüksek değerlere sahip olmuştur. Ayrıca, tüm popülasyonlar arasında L-1747 en düşük yeşil ot ve kuru ot verimine sahip olmuştur. L-1781 en yüksek sap sayısına sahipken, Lütfibey en düşük sap sayısına sahiptir. Özerbey-03 ve L-1781 en kalın sapa sahip olmuştur. L-1781, L-1787 ve L-1788 populasyonları, kontrol çeşitleriyle karşılaştırıldığında, daha fazla sap sayısı ve daha geniş sap çapı nedeniyle daha yüksek yeşil ve kuru ot verimi sergilemiştir. Bu populasyonlar, yeni çeşitlerin geliştirilmesi için gelecekte yapılacak ıslah çalışmalarında da kullanılabilir. Ayrıca benzer özelliklerin ve benzerlik düzeylerinin belirlenmesi amacıyla Kümeleme Analizi ve Temel Bileşenler Analizi yöntemleri kullanılmıştır.

Anahtar Kelimeler: Korunga populasyonu, morfolojik özellikler, agronomik özellikler, kümeleme analizi, temel bileşenler analizi

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INTRODUCTION

Sainfoin (*Onobrychis sativa* Scop.) is one of the most significant forage legumes, and farmers respect it for its great palatability, nutritional content, and non-bloating characteristics (Delgado et al., 2008; Tan and Sancak, 2009; Gea et al., 2011; Özkan and Bilgen, 2019; Açıkgöz, 2021). Sainfoin has been cultivated for hay in many regions of the world including Asia, Europe and North America for hundreds of years (Frame et al., 1998; Bhattarai et al. 2016; Açıkgöz, 2021). Sainfoin, also known as holy clover, is a perennial forage legume with deep roots that is frequently grown alongside forage grasses to lessen the risk of bloat and to increase soil fertility as a result of its capacity to fix nitrogen (Lu et al., 2000; Tan and Sancak, 2009; Bhattarai et al., 2016; Özkan and Bilgen, 2019; Açıkgöz, 2021). The dry forage yield of sainfoin ranges between 2.5 and 10 ton ha-1 depending on ecological, climatic, and soil conditions (Açıkgöz, 2021; Çaçan et al., 2023). For the first cut, traditional harvesting of sainfoin is typically done between the bud and mid-flowering stages, producing about 70% of the annual yield (Mohajer et al., 2013; Açıkgöz, 2021). The sainfoin plant is one of the most important forage crops in Türkiye, as it grows in semiarid conditions and can be used in rangeland improvement and artificial pasture establishment (Anonymous, 2023a). For this reason, there is a need for registered sainfoin cultivars that can be planted as a mixture and alone. In Türkiye, 10 sainfoin cultivars have been registered (Anonymous, 2023b). By making use of our rich genetic resources, it will be possible to develop new varieties suitable for the arid conditions of the region and present them to production, thus contributing to more economical and sustainable livestock breeding. Agriculture and plant breeding are undergoing a revolution in response to calls for the development of more diverse, sustainable, agricultural systems. A key part of this is plant breeding, the improvement of existing crops and development of new ones that provide agronomic products and critical ecosystem services (Butkutė al., 2018; Schlautman et al., 2018). Breeding forage crops have some problems, such as being used for many different purposes, being perennial, weak seedling development, and taking a long time to develop cultivars (Sabancı and Tosun, 2009; Tan and Serin, 2009). Plant genetic resources serve as crucial sources of genetic variation that are essential for augmenting the nutritive value, yield potential, and resilience of crop species through artificial selection (Schlautman et al., 2018). For each species, breeding populations need to be developed and selected to find genetic variation in important breeding traits and assess how the trait responds to selection (Miller and Hanna, 1995; Schlautman et al., 2018). Phenotypic selection involves identifying genetic variations for traits of interest and combining them to make distinct populations and/or genotypes (Demir and Turgut, 1999; Tucak et al., 2014; Schlautman et al., 2018). Recently two institutions, The Land Institute in the US and Adana Alparslan Türkeş Science and Technology University in Türkiye, conducted similar sainfoin studies to select phenotypes for improved seed yields and quality (Karabulut et al., 2023). In the present sainfoin breeding program, the collected seven populations from rangelands were used in Central and Eastern Anatolia regions. During the first period of that program, new nursery plots were established to assess materials collected under rained conditions. Here, one plant was planted in each well-spaced pit, thus ensuring the best-growing conditions for each plant. Plants showing good growth characteristics were selected here. Then, these plants will be planted under competitive conditions, that is, in rows, more frequently, and their morphological characteristics and yield potentials will be determined. This process will be continued for several generations to increase the chances of success in developing new varieties (Robins and Jensen, 2020). At the beginning of breeding programs, in order to select the desired plants, it is important to understand the relationships and similarities between populations and traits. Therefore, we conducted a cluster analysis and principal component analysis. The objective of this research was to (1) evaluate the morphological and agronomic traits of sainfoin populations and (2) identify the high-yield populations in semiarid regions for future breeding studies.

MATERIAL AND METHOD

Seven sainfoin populations from our country's semi-arid climate were employed in the study, as well as two control cultivars, Özerbey-03 and Lütfibey (Table 1). This study was conducted at the Field Crops Central Research Institute's Gölbaş İkizce Research and Application Farm in 2015, 2016, and 2017.

Table 1. Information about the locations of collected population seeds.
Çizelge 1. Toplanan populasyon tohumlarının yerleri hakkında bilgi.

Number	Genotypes code	Taken institute / responsible institute	Province	Location	Altitute (m)
1	L-1745	Eastern Anatolia Agricultural Research	Ardahan	Ardahan	1750
2	L-1746	Eastern Anatolia Agricultural Research	Kars	Kars	1900
3	L-1747	Eastern Anatolia Agricultural Research	Erzurum	Erzurum-Güzelyayla village	2150
4	L-1781	Centre Agriculture Research for Field Crops	Sivas	Sarkisla, Demirkopru village	1380
5	L-1782	Centre Agriculture Research for Field Crops	Erzurum	Kombet village, Guzelyurt village	2010
6	L-1787	Centre Agriculture Research for Field Crops	Erzurum	Pasinler, Buyukdere village	1750
7	L-1788	Centre Agriculture Research for Field Crops	Aksaray	Gülağaç, Aşıklı höyük	1118
8	Özerbey-03	Centre Agriculture Research for Field Crops	-	Released for semiarid conditions	-
9	Lütfibey	Eastern Anatolia Agricultural Research	-	Released for semiarid conditions	-

Sainfoin populations and control cultivars were planted in pots in the spring of 2015, March, 23-27. When seedlings grew up to 5 cm, twenty-four plants from each population were transferred to the field as one plant per the digging hole at 70x70 cm distances in the date 2015, May, 4-8. The plants transferred to the field were watered for establishment purposes. After transferring, 18 kg ha-1 N, and 46 kg ha^{-1} P_2O_5 fertilisers were implemented in the soil and the soil was pressed with a roller of ploughing. If necessary, weed control was performed manually. Data was not collected in the year 2015 when the seeding took place. Data was collected on the morphological and agronomic traits from May 9 to May 12, 2016, and May 12 to May 15, 2017. As plants reached the 50% flowering period, plant height (PH, cm), stem diameter (SD, mm), stem number (SN, number), were determined in the nursery parcel during the years of 2016 and 2017 (Ünal and Eraç, 2000; Anonymous, 2019). Then plants were cut and weighted to determine fresh forage per plant (FFY, g $plant^{-1}$). After fresh forage was weighed, the plants were placed in the drying cabinet at 70^{o}C for 48 h, and the dry forage weight was weighted to find dry forage yield per plant (DFY, g $plant^{-1}$) (Tekkanat and Soylu, 2005). In the research area, the soil texture is clayey-loam, the organic matter content is low at 1.31%, the phosphorus content is adequate at 94.7 kg ha^{-1}, the potassium content is high at 1498.6 kg ha^{-1}, and the soil is salt-free at 0.565 dS m^{-1}. However, the lime rate is excessively high at 31.31%, and the pH level is slightly alkaline at 7.70 (Anonymous, 2015). During the experimental seasons of 2016, and 2017, total precipitation, average temperatures, and average relative humidity were 537.2, 363.0 and 229.8 mm; 10.5, 10.6, and 9.9 ^{o}C; 63.8, 61.6, and 59.9% at Gölbaşı, Ankara, respectively (Anonymous, 2017) (Table 2). Long term average precipitation, temperatures, and relative humidity are 399.4 mm and 12.5 ^{o}C, and 59.2%

at Gölbaşı, Ankara, respectively. For long term on Gölbaşı location, average temperature was higher than those in trial years, but average relative humidity was lower than those in trial years. The annual precipitation amount was higher than in the trial years, except for the first year. During the experimental seasons of 2016, and 2017, total precipitation, average temperatures, and average relative humidity were 537.2, 363.0 and 229.8 mm; 10.5, 10.6, and 9.9 °C; 63.8, 61.6, and 59.9% at Gölbaşı, Ankara, respectively (Anonymous, 2017) (Table 2). Long term average precipitation, temperatures, and relative humidity are 399.4 mm and 12.5 °C, and 59.2% at Gölbaşı, Ankara, respectively. For long term on Gölbaşı location, average temperature was higher than those in trial years, but average relative humidity was lower than those in trial years. The annual precipitation amount was higher than in the trial years, except for the first year. Morphological and agronomic trait data of populations were evaluated by performing basic statistical analyses (mean, lowest and highest value, standard deviation, and coefficient of variation) in an Excel program in Microsoft Office 2016. Cluster Analysis (CA), and Principal Component Analysis (PCA) were performed study data set in JMP 2013 statistical program.

Table 2. Climatic data of the study area.
Çizelge 2. Çalışma alanının iklim verileri.

Months	Average temperature (°C)				Relative humidity (%)				Precipitation (mm)			
	2015	2016	2017	LT*	2015	2016	2017	LT	2015	2016	2017	LT
1	0.3	-1.3	-5.0	0.8	77.8	92.4	77.4	76.3	54.3	66.4	20.2	41.6
2	0.4	5.4	-0.3	2.5	70.4	83.3	70.1	70.2	39.0	18.6	5.4	36.3
3	4.7	5.7	5.2	6.7	66.3	76.5	62.1	61.8	92.1	67.0	31.4	42.5
4	6.9	12.0	8.1	11.7	53.1	54.0	54.4	58.4	25.0	12.0	16.0	49.7
5	14.6	13.0	13.0	16.4	61.4	60.9	56.9	54.5	67.2	59.0	27.6	46.7
6	16.3	19.0	17.3	20.9	65.8	50.0	57.6	48.7	133.7	7.2	25.2	29.4
7	21.6	22.1	22.6	24.6	39.1	41.6	41.8	42.8	5.1	1.8	0.4	9.8
8	22.4	22.5	21.9	24.6	43.9	47.7	48.8	43.2	25.4	27.2	26.0	10.8
9	21.3	16.1	19.8	19.3	48.6	49.5	40.0	49.2	29.1	42.3	30.4	23.3
10	12.8	11.3	9.8	13.1	78.8	54.9	57.4	61.0	58.5	7.7	9.8	36.0
11	7.1	4.6	4.7	7.3	69.9	56.2	73.7	69.3	5.6	19.6	11.2	31.8
12	-1.9	-2.9	2.0	2.6	90.6	72.4	78.6	75.3	2.2	34.2	26.2	42.1
Total / average	10.5	10.6	9.9	12.5	63.8	61.6	59.9	59.2	537.2	363.0	229.8	399.4

RESULTS AND DISCUSSION

Morphological Traits

The average, minimum, maximum, standard deviation and coefficient of variation values of plant height, stem diameter, and stem number of sainfoin populations are presented in Table 3. Moreover, in Figure 1, the morphological characteristics of the populations for the years 2016, and 2017, as well as two-year average values, are given in the graphs. When this table is evaluated, it can be seen that the variation in the number of stems (CV%=19.64) is quite wide among the traits considered. This gives us the opportunity to select populations having more stem numbers. In addition, populations are similar to each other in terms of other traits. When the sainfoin populations were evaluated in terms of plant height, the average was 70.5 cm. There was a difference between years and the second year had higher plant height than the first year. The L-1787 population had the tallest plant (Figure 1).

Table 3. Basic statistics in plant height, stem diameter and stem number of sainfoin populations.
Çizelge 3. Korunga genotiplerinin bitki boyu, sap çapı ve sap sayısına ilişkin temel istatistikler.

Basic statistics	Plant height (cm)			Stem diameter (mm)			Stem number (number)		
	2016	2017	Ave.	2016	2017	Ave.	2016	2017	Ave.
Average	65.8	75.1	70.5	5.6	5.5	5.6	29.1	53.8	41.5
Minimum	57.4	68.8	65.6	4.8	4.4	4.9	19.3	38.7	29.1
Maximum	73.7	83.6	77.7	6.6	6.4	6.3	40.6	72.0	56.3
Standard error	1.86	1.76	1.27	0.21	0.21	0.18	2.07	4.27	2.71
Variation coefficient (%)	8.51	7.06	5.41	11.38	11.80	9.81	21.35	23.81	19.64

The values of plant height in literatures were measured as follows: 30-90 cm (Davis, 1970); 81- 104 cm (Alibegoviç and Gatariç, 1989); 30-100 cm (Gülcan and Anlarsal, 1993); 105.2 cm (Karagöz, et al., 2001); 34–122 cm (Aygün et al., 2007); 12.25 – 107.28 cm (Balabanlı et al., 2007); 79.59 cm (Ünal et al., 2007). Moreover, some researchers found that the values of plant height were 61.14 cm (Tan and Sancak, 2009); 86.4cm (Erkovan et al., 2009); 70.23 -100.40 cm (Cebeci, 2011); 29 - 98 cm (Çeçen et al., 2015); 22.57-27.23 cm (İlgin, 2017). The present study data are higher than those of Tan and Sancak (2009) and İlgin (2017), but they are similar to other research data. The average stem diameter was 5.6 mm (Table 3). Özerbey and L-1781 had the thickest stem, while the stem of L-1747 and L-1746 populations was the thinnest (Figure 1). The stem's slender diameter is a favourable characteristic in terms of its quality. The stem diameter values in previous experiments were detected as follows: 6.6 mm (Karagöz et al., 2001); 4.53 mm (Ünal and Fırıncıoğlu, 2002); 4.0 mm (Albayrak and Ekiz, 2004); 3.13 mm (Ünal and Fırıncıoğlu, 2007). Furthermore, some authors stated that the stem diameter ranged from 6.0 to 9.1 mm (Ertuş et al., 2012); from 2.83 to 3.63 mm (İlgin, 2017); from 5.8 to 6.9 mm (Koç and Akdeniz, 2017). This study result was thicker than values of Ünal and Fırıncıoğlu, (2002); Albayrak and Ekiz, (2004); Ünal and Fırıncıoğlu, (2007), and İlgin, (2017). But it had lower than data of Karagöz et al. (2001), and Koç and Akdeniz (2017). The number of stems was measured as 41.5 on a two-year average. It is seen that there is a significant difference between years, and the value in the second year is higher. The rainfall in March 2016 was sufficient, but the fact that the temperature was above the average in April and the precipitation and relative humidity were below the average put stress on the plants. In this case, the plants were forced to develop rapidly and prevented normal development. The effect of this current situation was clearly negatively seen in the plant height and number of stems. Although precipitation was below average in March and April 2017, lower temperatures allowed plants to develop slowly and benefit more from existing moisture in the soil. These two factors had a positive impact on plant growth. As the Lütfi Bey cultivar had the lowest number of stems, population L-1781 had the highest number of stems, followed by population L-1787. This trait has a strong relationship with dry yield (Figure 1). Therefore, it's essential for yield. It is seen that it is correct to choose the number of stems with the highest variation among the traits examined, and it is appropriate to choose the populations with the highest number of stems. Bakoğlu et al. (1999); Ünal and Fırıncıoğlu., (2007); Balabanlı et al. (2007) reported that the number of stems was 19.74; 13.00; 15.77, and 0.00– 6.40, respectively. This study result was more stem number than values of previous trials. The reason for this is that since this study was carried out in the nursery plot, each plant has an area where it can grow comfortably and therefore has more moisture and nutrients. In addition, Cebeci (2011); Ertuş et al. (2012); Parlak et al. (2014); Koç and Akdeniz, (2017) counted stem numbers as follows 21.44-80.40; 8.70-28.80; 2.20-6.20; 15.00-18.00, respectively. According to Elçi et al. (1996), plants with a high number of stems are an essential selection factor in sainfoin breeding and are resistant to insects that harm the sainfoin. Higher stem number discovered in studies conducted in a variety of ecologies show that populations and environmental conditions have an impact on the number of stems (Delgado et al., 2008).

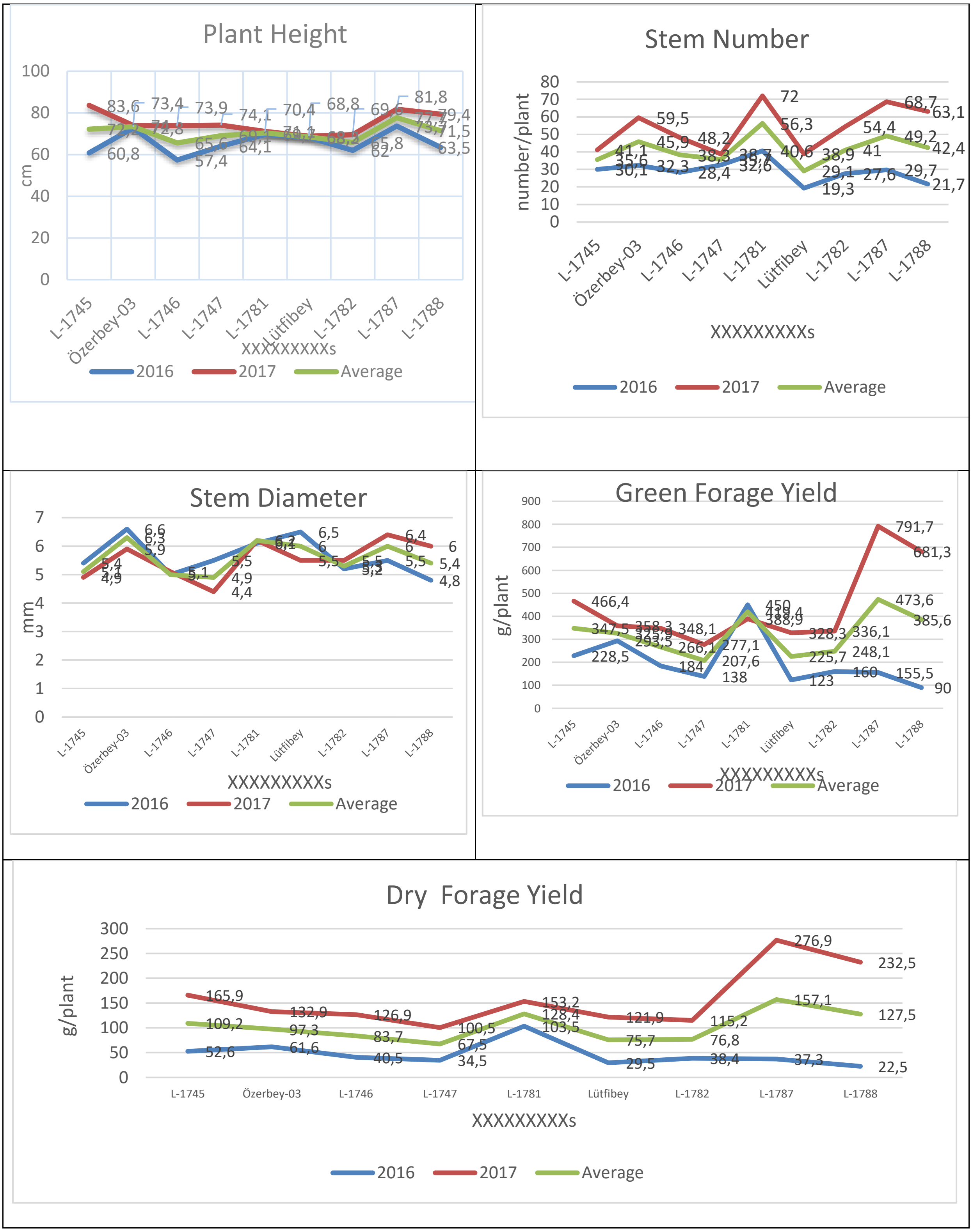

Figure 1. Values of morphological, and agronomic traits of the populations in 2016, 2017, and two-year average.
Şekil 1. Genotiplerin morfolojik ve tarımsal özelliklerinin 2016, 2017 yılı değerleri ve iki yıllık ortalama değerleri.

Agronomic Traits

The average, minimum, maximum, standard deviation and coefficient of variation values of fresh and dry forage yields belonging to the populations are given in Table 4. Furthermore, in Figure 1, the agricultural characteristics of the populations for the years 2016, and 2017, as well as two-year average values, are shown in the graphs. When this table is looked, it can be seen that the variation is similar in FFY and DFY. This gives us the chance to select populations with higher yields. When the sainfoin populations were evaluated in terms of fresh forage yield (FFY), the average was 322.2 g plant^{-1} (Table 4). A difference was observed between the years, with the second year showing a larger FFY than the first. In the previous section, it was explained that productivity in the first year was lower than in the second year due to stress conditions. In addition, in the second year, temperature increases were both slower and less in March and April. L-1787 exhibited the highest fresh forage yield of all the populations. The population L-1781 and L-1788 had the second and third turn for DFY, respectively as well as more than two cultivars. In previous researches, fresh forage yields were determined to be 87-170 g plant^{-1} (Ünal and Fırıncıoğlu, 2002); 94-297 g plant^{-1} (Ertuş et al., 2012) in literatures. The average dry forage yield was 102.6 g plant^{-1}, L-1747 and L-1787 had the lowest and highest dry forage yield (DFY), respectively (Table 4). L-1781 and L-1788 populations produced higher yields than the control cultivars and were ranked second and third for DFY. In earlier studies, dry forage yields were identified at 94.9 g plant^{-1} (Karagöz et al., 2001); 29.5-79.5 g plant^{-1} (Ertuş et al., 2012). The variability in yield is greatly influenced by environmental factors (Bato et al., 2021) as well as the genetic traits of the cultivars employed. Moreover, the high coefficient of variation in yield values shows that it is possible to choose productive cultivars.

Table 4. Basic statistical data in fresh and dry forage yields of sainfoin populations.
Çizelge 4. Korunga genotiplerinin yaş ve kuru ot verimlerine ilişkin temel istatistiksel veriler.

Basic statistics	Fresh forage yield (g plant^{-1})			Dry forage yield (g plant^{-1})		
	2018	2019	Ave.	2018	2019	Ave.
Average	202.5	441.8	322.2	46.7	158.4	102.6
Minimum	90.0	277.1	207.6	22.5	100.5	67.5
Maximum	450.0	791.7	473.6	103.5	276.9	157.1
Standard error	36.83	58.94	30.76	8.08	19.65	10.07
Variation coefficient (%)	54.58	40.02	28.64	51.94	37.21	29.46

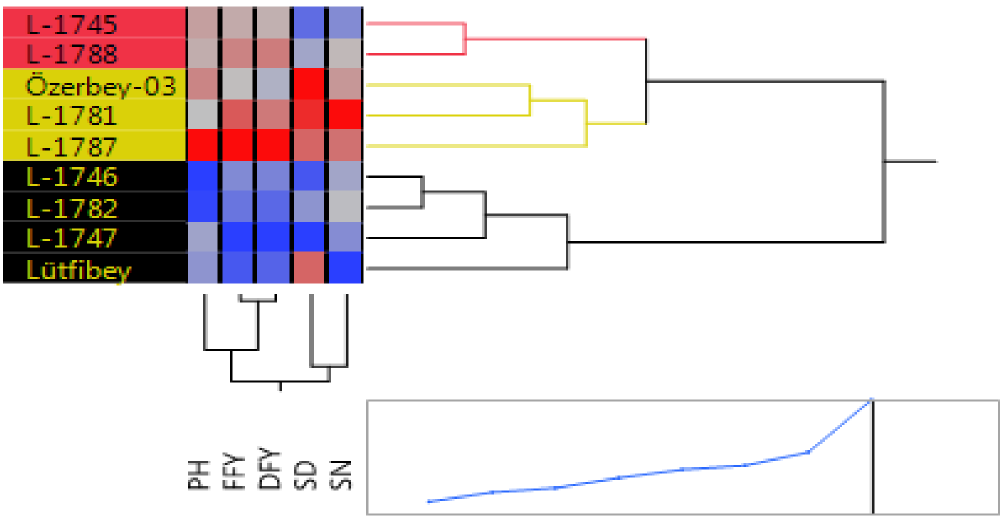

Figure 2. The results of cluster analysis of observed traits and XXXXXXXXXs.
Şekil 2. Gözlemlenen özelliklerin ve genotiplerin küme analizi sonuçları.

Principal Component Analysis (PCA)

The Principal Component Analysis (PCA) was conducted to examine the correlations between the traits measured and populations in the present study on the biplot graph, and to determine the percentage share of these traits and populations in the variation in the study data set (Figure 3). The analysis results of PCA related to the averages of measured traits and populations are illustrated in Figure 3. The two-year averages, namely PCA1 and PCA2, accounted for 72.2% and 13.9% of the total variation (86.1%), respectively. The traits PH, FFY, and DFY were in the same place (Group 1=G1) in the biplot graph due to their high level of similar correlation (Figure 3). Although the other two traits were close to the first group, they were settled down in separate places (Group 2=G2; Group 3=G3). Population L-1787 had the highest data in PH, FFY, and DFY traits. Özerbey and L-1781 had the thickest SD, while L-1746 and L-1747 had the thinnest SD trait (Figure 3).

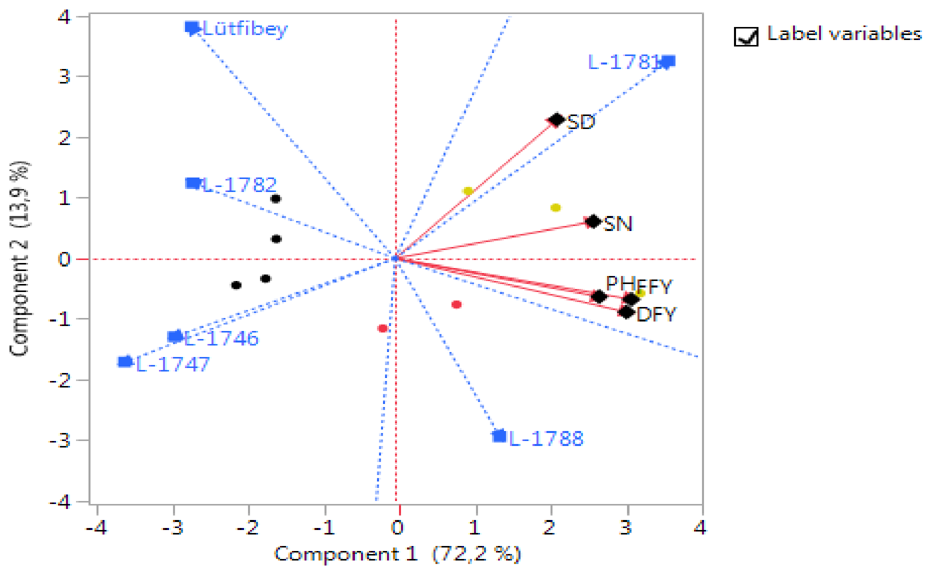

Figure 3. The results of principle component analysis of observed traits and populations.

Şekil 3. Gözlemlenen özelliklerin ve genotiplerin temel bileşen analizinin sonuçları.

CONCLUSIONS

In 2016 and 2017 of this breeding program, morphological traits such as plant height, stem diameter and number of stems, as well as agricultural traits such as fresh and dry forage yield, were determined. The plant height of L-1787 was the highest, while L-1746 and L-1782 had the lowest height. The L-1781 had the highest stem number, moreover, it was also the thickest with Özerbey-03. When the findings of this two-year study were analyzed, the L-1781, L-1787, and L-1788 populations produced the highest fresh and dry forage yields. Based on PH, FFY, and DFY, cluster analysis revealed that populations were split into two groups (A and B). Populations with high PH, FFY, and DFY were found in Group A. The observed attributes and populations according to the main component analysis were displayed in the biplot graph. The traits PH, FFY, and DFY were grouped together in Group 1 on the biplot graph due to their high correlation. Although the other two traits were close to the first group, they were situated in different locations. In this biplot graph, population L-1787 exhibited the highest plant height and the most significant yield of fresh and dry forage. As Özerbey and L-1781 had the thickest SD, L-1746 and L-1747 had the thinnest SD trait. When the results of this two-year study are evaluated, the L-1781, L-1787, and L-1788 populations with their superior performance compared to control varieties, are promising for the development of sainfoin cultivars. These populations should be tested in a variety of yield experiments, including micro-yield, yield, and regional studies.

CONFLICT OF INTEREST

There is no conflict of interest.

AUTHOR CONTRIBUTION

The corresponding author contributed to the field studies, taking observations, analysing the data and writing the article. The second author contributed to field studies, analysis and interpretation of data, and corrections in the article. The third and fourth authors contributed to field studies and observations.

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