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Evaluation of Genetic Variability of Some Local Grass Pea (*Lathyrus sativus* L.) Genotypes Using Different Statistical Analysis

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ABSTRACT

Background: The aim of this study was to determine the variation among local grass pea varieties in Türkiye by using some statistical analysis.

Methods: The investigation was carried out according to the randomized block design with three replications during the growing season of 2018 and 2019 with 9 different genotypes and 2 registered varieties of grass pea at the Batı Akdeniz Agricultural Research Institute. Days to flowering, green herbage yield, dry herbage yield, seed yield, thousand seed weight, plant main stem length, the number of pods per plant, the number of seeds per pod, straw yield, biological yield and harvest index were determined. Furthermore, the results of investigated features were subjected to correlation, regression, path and cluster analysis.

Result: The results showed sufficient variability in seed yield based on characteristics among the tested genotypes. Regression analysis showed that days to flowering, harvest index, number of pods per plant, straw yield and biological yield should be given more importance during selection. This study resulted in three clusters with the maximum intergenetic distance between genotypes Ls17 and Ls23. According to the results of the research, it was determined that genotypes Ls15 and Ls32 were equivalent to commercial cultivars in terms of the investigated characteristics.

Key words: Breeding, Grass pea, Statistical analysis, Yield.

INTRODUCTION

Grass pea (*Lathyrus sativus* L.) is the most cultivated and economically important species of the genus Lathyrus in the World (Basaran *et al*., 2011). While there are 160 *Lathyrus* species all over the world, 61 of them are found in Türkiye (Genç and Sahin, 2001). Lambein and Kuo-Genth (1997) stated that there are archaeological remains showing that the Grass pea (*Lathyrus sativus* L.) was cultivated in the Balkans, Türkiye and Iraq in 8000 BC. Easily growing in different soil types and at high altitudes and growing with as little as 250 mm of annual precipitation, grass pea is typically the last surviving plant in drought periods (White *et al*., 2002). Moreover, it can be successfully grown in marginal areas in many parts of the world in severe climatic conditions without needing much production input (Arslan, 2019). Beyond its yield potential, grass pea has been stated to have remarkable yield stability in the face of drought (Zhelyazkova *et al*., 2016). This crop is mainly used as animal feed, however, it is occasionally used for human consumption in some parts of Türkiye because of the high protein content in its seeds (Zhao *et al*., 1999; Basaran *et al*., 2010; Atıs and Acıkalın, 2020). These positive characteristics make it a superior crop for food security, particularly in the face of anticipated climate challenges (Gonçalves *et al*., 2022).

According to Turkish Statistical Institute data, 1662 tons of prunes were produced from 14 820 decares of land in Türkiye and the grain yield was 112 kg da^{-1} (TUIK, 2021). The low yield potential of the genetic material used can be shown as the most important reason for the low yield of green herbage and seeds obtained from the unit area. In the breeding studies to be carried out to develop new varieties with high yield potential, the breeding criteria aimed for the breeding of suitable varieties should be well defined and the characteristics that need to be improved should be well known. Besides, the relationship between the characteristics and the mutual influences on each other need to be well-diagnosed. Finally, the relationships between these criteria can be decisive in making the choice (Oten *et al*., 2017b). The correlation coefficient is used to reveal the simple relationships between the examined features and the path analysis is used to find in detail the direct and indirect effects affecting the yield. It is known that the correlation coefficient does not always give definite results in determining the selection criteria (Cakmakci *et al*., 1998).

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The aim of this study was to determine the variation among local grass pea varieties in Türkiye and to determine the prominent characteristics as selection criteria in the breeding program by using some statistical analysis.

MATERIALS AND METHODS

The study was conducted in the trial area of the field crops department of Batı Akdeniz Agricultural Research Institute (BATEM) between 2018 and 2019 in Aksu (36°94. 077 N, 30°89. 008 E) in Antalya province in the Mediterranean region of Türkiye. In the first year of the experiment, sowing was planted on on October 17 and in the second year of the experiment was planted on October 9. The climatic data of the experimental area, average temperatures, rainfall and relative humidity belong to 2018-2019 and the long period are given in Table 1.

The long-period average precipitation of the experimental area was 1069.8 mm. During the experiment in 2018 and 2019, total annual precipitation was measured as 538.0 and 1097.0 mm respectively. While the total amount of precipitation in 2019 was similar to the long-term average, it was lower in 2018. The relative humidity was higher than the long-period relative humidity. Moreover, the average temperatures of 2018 and 2019 were similar with long period 9 (Table 1).

The soil of the research area was silty-clay loam with moderate organic matter and slightly alkaline pH. Salinity in the research area was 0.205 (dS m^{-1}), pH 8.0, organic matter 2.17%, clay 31.0% and silica 50.0% (Table 2). In the research area, 4 kg N (Ammonium sulfate, 21%) and 8 kg P_2O_5 (Triple super phosphate, 42%) per decare were applied with sowing every year. During the growing seasons, no chemical was applied, since there were no pests or diseases in the study. Moreover, weeds were controlled by hand hoeing.

Grass pea seed samples obtained from the previous project (Grass pea Breeding Studies) were used as material in this study. Nine candidate grass pea genotypes collected from the natural flora of Antalya province and selected as superior due to their high performance were used with two varieties as a control. Field experiments were conducted in the randomized block design with three replications. Each plot consisted of 6 rows and was 5 m in length. Sowing was made at the end of October in both years with 30 cm row spacing and a 10 kg da^{-1} seeding rate. In the study, days to flowering (day), green herbage yield (kg da^{-1}), dry herbage yield (kg da^{-1}), plant main stem length (cm), number of pods per plant, number of seeds per pod, seed yield (kg da^{-1}), 1000 seed weight (g), straw yield (kg da^{-1}), biological yield (kg da^{-1}) and harvest index (%) were investigated. Morphological measurements were performed on ten plants randomly selected from each plot. The number of seeds per pod was evaluated on mature pods (5 pods per plant). All observations obtained in the study were taken according to the methods specified in TTSM (Anonim, 2001).

Statistical analyses of the obtained data were performed by SAS (2002) statistical software. The treatment means were compared by Duncan's multiple range test (Duzgunes *et al*., 1987). The correlation, regression and cluster analysis were performed using the SPSS 16 statistical software and path analysis were performed by Path2 statistical software correlation and cluster analysis.

RESULTS AND DISCUSSION

Mean values and Duncan groups in grass pea genotypes

The results of the Duncan groups are presented in Table 3. It is noteworthy that there was a large variation among genotypes in terms of days to flowering. Minimum and maximum values obtained from Ls36 (81.8 days) and Ls17 (119.2 days) are indicated in Table 3. Similarly, there was great variation among genotypes in terms of the amount of green herba yield. Another remarkable point is that the seed yield of the genotypes used in the research was high. It was observed maximum values on dry herbage yield values from Ls15 and Ls 32, thousends seed yield value from Gurbuz

Table 1: Climate data (2018 and 2019/Long period).

Years	Climate elements	Months											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
2018	Precipitation (mm)	93.0	91.0	94.0	2.0	19.0	65.0	18.0	0.0	13.0	24.0	57.0	156.0
	Relative humidity (%)	72.2	83.0	78.9	68.7	66.2	72.8	65.8	71.2	65.1	67.3	72.5	78.0
	Average temperature (°C)	10.8	12.8	15.0	18.5	23.2	25.5	28.5	28.0	25.9	20.4	15.7	11.5
	Maximum temperature (°C)	20.9	21.2	25.8	35.2	35.6	38.0	43.3	40.8	40.7	35.5	31.5	21.6
	Minimum temperature (°C)	1.7	3.4	6.8	6.7	11.9	16.3	18.2	17.2	15.2	7.2	7.2	0.0
2019	Precipitation (mm)	300.0	127.0	72.0	149.0	7.0	13.0	0.0	0.0	77.0	19.0	71.0	262.0
	Relative humidity (%)	85.1	80.1	76.7	75.6	71.9	69.4	62.5	63.5	67.3	72.4	80.0	81.0
	Average temperature (°C)	9.6	11.4	13.4	15.8	21.3	25.8	28.6	28.7	25.2	22.5	16.1	11.8
	Maximum temperature (°C)	17.6	20.6	27.4	27.6	36.3	39.7	40.9	42.8	36.4	37.5	30.0	23.1
	Minimum temperature (°C)	0.8	3.6	2.5	5.6	9.9	12.2	16.0	16.1	12.1	11.1	5.1	1.2
Long	Precipitation (mm)	224.9	156.3	96.2	58.3	31.8	7.9	3.0	2.4	13.7	78.8	137.1	259.4
period	Relative humidity (%)	9.80	10.4	12.7	16.1	20.5	25.4	28.4	28.2	24.7	20.0	14.9	11.3
	Average temperature (°C)	15.00	15.5	18.0	21.3	25.6	30.9	34.1	34.2	31.2	26.6	21.1	16.6
	Maximum temperature (°C)	5.90	6.20	8.0	11.1	15.00	19.6	22.6	22.6	19.3	15.2	10.6	7.5

variety, plant main stem length values from Ls15 and Ls 32, number of pods per plant value from Ls36, number of seeds per plant pod values from Ls41, straw yield value from Ls15, biological yield value from Corea variety and Ls15 and harvest index values from Corea and Gurbuz varieties. Based on the available data, it can be said that all genotypes were significantly different.

In previous studies on grass pea conducted in different ecologies of Türkiye, days to flowering were 99.5 to 120.5 days in Antalya (Arslan *et al*., 2022), green herbage yield was 813.3-2552.0 kg da^{-1} in Antalya (Oten *et al*., 2017b), dry herbage yield was 86.8-265.8 kg da^{-1} in Elazığ (Ozdemir, 2020), seed yield was 173.3-202.8 kg da^{-1} in Tokat (Karadag and Iptas, 2007), thousand seed weight was 85.3-154.0 g in Adana (Gedik, 2007), plant main stem length was 30.27-92.75 cm in Tekirdag (Tenikecier *et al*., 2017), the number of pods per plant was 16.63-24.87 in Yozgat (Kucukkaya and Dogrusoz, 2022), the number of seeds per plant pod was 3.0-3.7 in Diyarbakır (Seydosoglu *et al*., 2015), the straw yield was 231.30-299.33 kg da^{-1} in Elazığ (Kokten and Bakoglu, 2011), biological yield was 528.2-847.1 kg da^{-1} in Diyarbakır (Sayar and Han, 2015), harvest index was 5-82% in Bursa (Turk *et al*., 2007). It can be said that the genotypes used in the study were superior in terms of all the traits examined.

Table 2: Some physical and chemical characteristics of the soils of the experimental area.

pH	8.0	Slightly alkaline
Lime (%)	24.4	Very high
EC (dS m^{-1})	0.205	Saltless
Silica (%)	50.0	
Clay (%)	31.0	
Alluvion (%)	42.0	
Organic matter (%)	2.17	Medium

*BATEM, 2019.

Since as a result of variance analysis the interaction of years and genotypes*years was insignificant; correlation, regression, path and cluster analysis were carried out with the means of two years values.

Correlation coefficients

The correlation coefficients between pairs of investigated traits are presented in Table 4. High correlations were

Table 3: Combined (2018 and 2019) mean values and Duncan groups of the investigated characters of grass pea genotypes.

Genotypes	FD	GHY	DHY	SY	TSW	PMSL	NPP	NSP	SWY	BIY	HI
Ls15	109.2b	2531.3a	599.6a	350.2de	106.4c	125.8a	20.6d	3.6cd	428.6a	778.7a	0.44ef
Ls17	119.2a	1969.0ef	442.4de	331.2ef	119.1b	98.5cd	22.8cd	3.7c	318.1e	665.9de	0.50b
Ls23	102.5c	2300.8bc	547.8ab	298.8g	96.9g	112.0b	25.0bc	3.7c	397.3ab	696.1cd	0.43f
Ls25	99.0d	1629.0h	441.09e	244.8h	101.4de	95.5cd	20.9d	3.7c	316.2e	560.9f	0.44ef
Ls31	92.3e	2184.3cd	512.0bc	382.8c	134.4a	116.7b	26.9b	3.9bc	364.5b-d	747.3ab	0.51b
Ls32	99.7d	2535.3a	566.4a	356.5d	107.5c	125.8a	27.2ab	3.9c	409.7a	766.2ab	0.46de
Ls33	99.5d	1826.3fg	438.5e	310.2fg	104.5c-e	101.0c	23.0cd	3.3d	327.9de	638.1e	0.49bc
Ls36	81.8f	2126.0de	493.7cd	351.2de	105.8cd	111.3b	28.4a	3.7c	367.9bc	729.2bc	0.47cd
Ls41	109.5b	1739.3gh	431.8e	332.8df	100.6e-g	95.2cd	25.8a-c	4.3a	312.9e	662.4de	0.50b
Corea	109.8b	1865.0fg	497.0bc	434.7a	98.6fg	110.2b	24.7bc	4.3ab	355.5cd	790.2a	0.55a
Gurbuz	101.5c	2365.8ab	470.9c-e	409.2b	131.6a	92.3d	24.2bc	3.9bc	338.1c-e	747.2ab	0.55a

FD: Days to flowering, GHY: Green herbage yield, DHY: Dry herbage yield, SY: Seed yield, TSW: 1000 seed weight, PMSL: Plant main stem length, NPP: Number of pods per plant, NSP; Number of seeds per plant pod, SWY: Straw yield, BIY: Biological yield, HI: Harvest index.

Table 4: Correlation coefficients between selected observations values of grass pea.

	FD	GHY	HI	SY	TSW	PMSL	NPP	NSP	SWY	BIY	DHY
FD	1										
GHY	-0.227	1									
HI	0.098	-0.119	1								
SY	-0.084	0.414	0.783**	1							
TSW	-0.108	0.261	0.341	0.261	1						
PMSH	-0.263	0.708**	-0.272	0.313	-0.094	1					
NPP	-0.468*	0.390	0.449*	0.688**	0.069	0.358	1				
NSP	-0.053	0.282	0.502*	0.707**	0.016	0.240	0.761**	1			
SWY	-0.242	0.844**	-0.272	0.363	-0.090	0.899**	0.373	0.332	1		
BIY	-0.167	0.700**	0.429*	0.895**	0.140	0.649**	0.694**	0.688**	0.731**	1	
DHY	-0.189	0.859**	-0.230	0.397	-0.054	0.895**	0.375	0.370	0.987**	0.750**	1

FD: Days to flowering, GHY: Green herbage yield, DHY: Dry herbage yield, SY: Seed yield, TSW: 1000 seed weight, PMSL: Plant main stem length, NPP: Number of pods per plant, NSP; Number of seeds per plant pod, SWY: Straw yield, BIY: Biological yield, HI: Harvest index.

observed between green herbage yield and plant main stem length, straw yield, biological yield and dry herbage yield; biological yield with harvest index, seed yield, plant main stem height, number of pods per plant, number of seeds per plant pod and straw yield. On the other hand, the correlation was not determined on thousand seed weight with other investigated traits (Table 4). Sayar *et al*. (2013) observed a positive relationship between hay yield and green forage yield and a significant and negative relationship between hay yield and 50% flowering days. In another study, a positive and significant relationship was determined between seed yield and green herbage yield, dry herbage yield, straw yield, biological yield and harvest index (Oten *et al*., 2017a).

Regression analysis

In the breeding studies, it is of great importance to know the effective factors on yield and to reveal the relations between these factors and to direct the breeding programs accordingly (Oten *et al*., 2017a). However, not all observations considered in a study have a direct effect on the dependent variable as an independent variable (Khomari *et al*., 2017). With the regression analysis, the effect type and degree of each independent variable on the dependent variable is determined and also the possibility of estimating the dependent variable arises (Andales *et al*., 2007).

In the regression analysis, days to flowering, harvest index, number of pods per plant, straw yield and biological yield were determined as remaining characteristics (Table 5).

Table 5: Regression analysis results.

	Unstandardized coefficients		
	B	Std. error	t
Constant	-237.053	29.999	-7.902**
FD	-0.316	0.103	-3.055**
HI	585.752	53.339	10.982**
NPP	-0.995	0.341	-2.914*
SWY	-0.200	0.077	-2.602*
BIY	0.603	0.040	14.948**

FD: Days to flowering, HI: Harvest index, NPP: Number of pods per plant, SWY: Straw yield, BIY: Biological yield.

Yield estimation was obtained by using the factors affecting grain yield with this formula:

SY=-237.53-0316*FD+585.75*HI-0.995*NPP-0.200*SWY+0603*BIY

Path analysis

The remaining characteristics in the stepwise regression model were determined and path analysis was performed with the data belonging to the characteristics that were determined to have a direct effect on seed yield (Table 6). The study of path analysis indicated that the highest positive direct effect towards seed yield was exhibited due to biological yield (0.848) and harvest index (0.409). This finding indicates that the selection for these characters is likely to lead directly to a full improvement in seed yield. The features that have an indirect positive effect on seed yield through biological yield are harvest index and the days to flowering and the features that have an indirect negative effect are the number of pods per plant and straw yield. According to the path analysis results of Hakyemez (2000), it was reported that the highest direct effect on grain yield was provided by dry herb yield. In the study by Oten *et al*. (2017a), it was stated that biological yield provided the highest direct effect on grain yield and although there was a positive and significant correlation between grain yield and thousand-seed weight, the indirect effect was negative.

Cluster analysis

In this study, regression analysis existing between investigated characters suggested the need for cluster analysis in association with seed yield. Besides, cluster analysis is often used to assess genetic diversity and to classify species (Van Beuningen and Busch, 1997). The clusters that were done according to Ward Method were illustrated by a dendrogram (Fig 1). Cluster analysis was performed to provide that genotypes were exactly screened based on the investigated traits.

The genotypes were divided into three groups according to the clustering results with the remaining traits as a result of the regression analysis. Genotypes Ls17, Ls33 and Ls41 were in the first group. While the second group included only the Ls25 genotype, the third group included Ls15, Ls23, Ls31, Ls32 and Ls36 genotypes and Gurbuz and Corea varieties.

Table 6: Path analysis results.

	Direct	İndirect effect					
	effect	FD	HI	NPP	SWY	BIY	
FD	-0.041	-	0.04	0.024	0.032	-0.142	-0.084
HI	0.409	-0.004	-	-0.024	0.036	0.363	0.782
NPP	-0.053	0.018	0.184	-	-0.051	0.588	0.688
SWY	-0.136	0.009	-0.112	-0.02	-	0.62	0.363
BIY	0.848	0.006	0.175	-0.037	-0.1	-	0.895

FD: Days to flowering, HI: Harvest index, NPP: Number of pods per plant, SWY: Straw yield, BIY: Biological yield/ Residual effects 0.045.

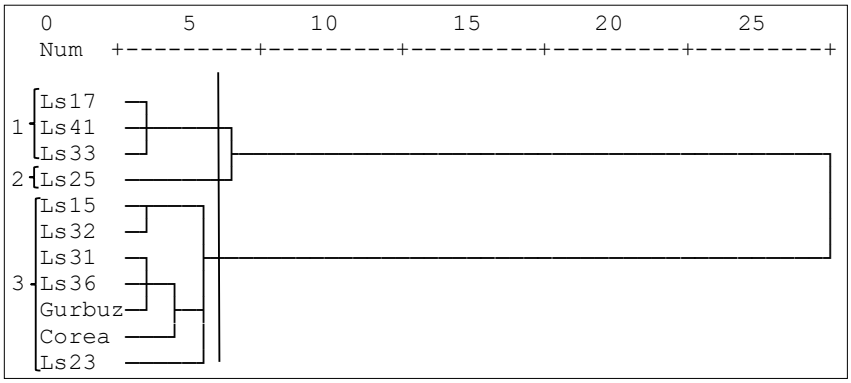


Fig 1: Dendrogram of cluster analysis results.

Furthermore, Ls17, which is one of the genotypes in the 1st group, was found high in terms of days to flowering, while it was determined between the second and third groups in terms of other characteristics. It is seen that genotype 25 in the second group had a lower value than the other genotypes in terms of all the examined traits, except for the days to flowering. It was determined that the genotypes in the 3rd group had higher values than the other groups in terms of the number of pods per plant, straw yield and biological yield features. Khosravi *et al*. (2022) stated that cluster analysis divided the genotypes into two separate groups, while Ahamed *et al*. (2012) divided the genotypes into ten separate groups in their study.

CONCLUSION

The results of this study, which was carried out to determine the variation among some local grass pea cultivars in Türkiye by using different statistical analyzes, showed that genotypes used in the study were superior in terms of all the traits and all the investigated characteristics were statistically significant. Although a low seed yield value was obtained from control cultivars, it was determined that genotypes had high values. It can be said that the Ls36 genotype was the earliest variety with 81.8 flowering days and this variety can be recommended for second-crop. Among genotypes, high correlations were observed between green herbage yield and plant main stem length, straw yield and biological yield. Furthermore, according to the results of the regression analysis, days to flowering, harvest index, number of pods per plant, straw yield and biological yield were determined as remaining characteristics. According to the results of the cluster analysis, it was determined that Ls15 and Ls32 genotypes in the third group were equivalent to commercial cultivars in terms of the investigated characteristics.

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