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Assessment of Agro-Morphological Traits of Common Bean Genotypes Grown Under Organic Farming Conditions with Multi-Variate Analyses and Applications

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Abstract

Among the edible legumes, the common bean (*Phaseolus vulgaris* L.) has first place in the world in terms of production quantity and plays a great role in human nutrition. There is an ever-increasing interest in organically-grown foodstuffs, especially by dieticians and conscious consumers who wish to consume chemical residue-free products. This study was conducted in the 2018 and 2019 growing seasons under organic farming conditions without any chemical inputs to determine agro-morphological traits of 16 registered common bean cultivars and 4 local genotypes. Experiments were conducted in randomized blocks design with 3 replications. For agro-morphological traits, plant height (PH), first pod height (FPH), number of branches per plant (NBP), number of pods per plant (NPP), number of seeds per pod (NSPO), number of seeds per plant (NSPL), seed yield (SY), 100-seed weight (100-SW) and seed protein content (PC) were investigated. Experimental data were assessed through multi-variate analysis methods. Correlation analysis revealed the greatest positive correlation between NPP—NSPL (r = 0.8851) and the greatest negative correlation between NSPL—100 SW (r = –0.6118). In principal component analysis (PCA) the first principal component (PC1) axis had NSPL, NPP, NSPO, FPH and 100-SW parameters and explained 41.28% of the total variation. The first 3 principal components explained 76.29% of the total variation. Hierarchical cluster analysis, performed to determine genetic relationships among the genotypes, revealed 5 main clusters and Güzelöz genotype alone formed the 5th cluster. The greatest genetic distance of cultivars was encountered between Adabeyazı—Aras cultivars (6.963) and the greatest genetic distance of local genotypes was seen between Güzelöz—Aras genotypes (4.944).

Keywords Bean · PCA · Cluster analysis · Correlation · Morphological parameters

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Bewertung von agromorphologischen Merkmalen von Genotypen der gemeinen Bohnen, die unter Bedingungen des ökologischen Landbaus angebaut werden, mit multivariaten Analysen und Anwendungen

Zusammenfassung

Unter den essbaren Hülsenfrüchten, die Gemeine Bohne (*Phaseolus vulgaris* L.) hat weltweit den ersten Platz in Bezug auf die Produktionsmenge und spielt eine große Rolle in der menschlichen Ernährung. Das Interesse an Lebensmitteln aus biologischem Anbau wächst ständig, insbesondere von Ernährungswissenschaftlern und bewussten Verbrauchern, die Produkte ohne chemische Rückstände konsumieren möchten. Diese Studie wurde in den Vegetationsperioden 2018 und 2019 unter Bedingungen des ökologischen Landbaus ohne chemische Zusätze durchgeführt, um agromorphologische Merkmale von 16 registrierten gemeinen Bohnensorten und 4 lokalen Genotypen zu bestimmen. Die Experimente wurden in einem randomisierten Blockdesign mit 3 Wiederholungen durchgeführt. Für agromorphologische Merkmale, Pflanzenhöhe (PH), die erste Podhöhe (FPH), Anzahl der Blätter pro Pflanze (NBP), Anzahl Schoten pro Pflanze (NPP), Anzahl Samen pro Schote (NSPO), Anzahl der Samen pro Pflanze (NSPL), Samenertrag (SY), 100-Samen-Gewicht (100-SW) und Samenproteingehalt (PC) wurden untersucht. Versuchsdaten wurden durch multivariate Analysemethoden bewertet. Die Korrelationsanalyse ergab die größte positive Korrelation zwischen NPP – NSPL (r=0,8851) und die größte negative Korrelation zwischen NSPL–100 SW ($r = -0{,}6118$). In der Hauptkomponentenanalyse (PCA) hatte die erste Hauptkomponentenachse (PC1) NSPL-, NPP-, NSPO-, FPH- und 100-SW-Parameter und erklärte 41,28 % der Gesamtvariation. Die ersten drei Hauptkomponenten erklärten 76,29 % der Gesamtvariation. Eine hierarchische Clusteranalyse, die durchgeführt wurde, um genetische Beziehungen zwischen den Genotypen zu bestimmen, ergab fünf Hauptcluster, und der Güzelöz Genotyp allein bildete den fünften Cluster. Die größte genetische Distanz von Genotypen wurde zwischen Adabeyazı-Aras Genotypen (6.963) und die größte genetische Distanz lokaler Genotypen wurde zwischen Güzelöz-Aras Genotypen (4.944) festgestellt.

Schlüsselwörter Bohne · PCA · Clusteranalyse · Korrelation · Morphologische parameter

Introduction

In agriculture, Leguminosae family is the second most important family after Gramineae family (Singh 2007). Phaseolus genus of Leguminosae family is composed of 76 species worldwide (Freytag and Debouck 2002). Among these species, tepary bean (*P. acutifolius* A. Gary), runner bean (*P. coccineous* L.), lima bean (P. Lunatus L.), year-bean (*P. polyanthus* Greenman) and common bean (*P. vulgaris* L.) are commonly cultivated in the world (Smykal et al. 2015). Majority of *Phaseolus* species have $2n = 2x = 22$ morphologically similar chromosomes and small seed sizes (1–4 µm) (Venora et al. 1999). Following independent domestications various local races that may cause changing local adaptation, morphological and genetic traits have emerged (Iwata-Otsubo et al. 2016). Several different genotypes with different morpho-agronomic traits have been developed in time. Such a diversity is used in breeding and expansion of gene pool (Sinkovic et al. 2019). The primary purpose of breeding studies is to investigate the genetic diversity and molecular markers have been used to support such studies on P. vulgaris. Up until now, about 390 SSR markers have been used in beans (Blair et al. 2012; Nadeem et al. 2018). Local varieties constitute unique genetic resources for current and future breeding programs. Local varieties with their own flavor are produced and consumed by local producers (Celmeli et al. 2018).

Common bean (*Phaseolus vulgaris* L.) is the most widely grown leguminous plant worldwide. It is a high-quality food source for more than 300 million people (Petry et al. 2015). It is also a good source of protein, vitamins and minerals and is known as "poor men's meat" (Blair 2013). It was reported that daily legume consumption regulated LDL cholesterol (Ha et al. 2014), total cholesterol (Bazzano et al. 2011), reduced blood pressure body weight, glycemic index (GI), insulin resistance (Tor-Roca et al. 2020). The primary purpose of biological enrichment is to improve various properties of products based on producer and consumer perspectives (Blair et al. 2009). Therefore, morphological characterization allows for clarify genetic similarities of local varieties and genetic relationships between agronomic traits of these varieties to be used in breeding programs (Karaağaç and Balkaya 2013). Multivariate analyses offer significant tools in determination the differences and similarities of genotypes and the selection of proper genotypes for special purposes (Benlioğlu and Özkan 2022).

In this study, agronomic performances of registered varieties and local genotypes, intensively produced and consumed in the region, were screened under organic farming

Table 1 Climate parameters of the experimental years and long-term averages

Months	Monthly average temperature (°C)			Monthly relative humidity (%)			Monthly total precipitation (mm)		
	2018	2019	1931–2019	2018	2019	1931–2019	2018	2019	1931–2019
May	*16.7*	17.4	*15.0*	*61.2*	50.2	*61.0*	*51.9*	*23.7*	*51.5*
June	*20.4*	21.3	*19.0*	*56.7*	55.8	*55.8*	*78.8*	*55.2*	*40.2*
July	*24.1*	21.6	*22.2*	*45*	49.1	*49.3*	*0.6*	*35.9*	*10.6*
August	*22.9*	22.3	*22.0*	*42.3*	50.3	*49.1*	–	*12.1*	*8.7*
September	*19.2*	17.4	*17.4*	*45.5*	51.2	*53.7*	*2.9*	*10.6*	*14.5*

Source: Kayseri Provincial Directorate of Meteorology

Table 2 Soil physical and chemical properties

Years	pH	Organic matter %	Lime %	Texture	P_2O_5 kg/da	EC mmhos/cm
2018	8	0.66	2.38	Sandy-Loam	6.785	0.112
2019	8	0.67	2.38	Sandy-Loam	6.806	0.117

conditions with the use of multi-variate analyses and applications.

Material and Method

In present experiments, registered varieties of Akman 98, Adabeyazı, Alberto, Altın, Aras 98, Arslan, Batallı, Berrak, Cihan, Dermason, Göynük 98, Noyanbey 98, Önceler 98, Özdemir, Özmen and Şahin 90 (registered between the years 1990–2017) with determinate type of growth and local genotypes of Çomaklı, Gömeç, Kızık and Güzelöz with indeterminate type of growth extensively produced and consumed in Kayseri province, were used as the plant materials.

Method

Experiments were conducted over the experimental fields of Erciyes University. Research site with an average altitude of 1094 m is located between 340 56′–360 59′ east longitudes and 370 45′–38 18′ north latitudes. Experiments were conducted in randomized blocks design with 3 replications under organic farming conditions without chemical inputs in 2018 and 2019 growing seasons. Experimental plots have 6 plant rows of 3 m long. Row spacing was 30 cm and on-row plant spacing was 10 cm. One meter spacing was provided between the blocks and 0.5 m between the plots. Following the manual sowing, sprinkler irrigation was practiced until emergence and the first manual weed control, then drip irrigation was practiced through drip lines placed by each row. Morphological traits (plant height, first pod height, number of main branches, number of pods per plant, number of seeds per pod and number of seeds per plant) were determined on 10 plants randomly selected from each plot. Seed yield, 100-seed weight and protein ratios were calculated over the entire plot area.

Climate of the Study Area

In the first year, monthly average temperatures varied between 16.7–24.1 ℃ and monthly average relative humidity values varied between 42.3–61.2%. In the second year, monthly average temperatures varied between 17.4–22.3 °C and monthly average relative humidity values varied between 49.1–55.8%. The total amount of precipitation during the vegetation period was recorded as 134.2 mm in the first year, 137.5 mm in the second year and long-term average was 125.5 mm. Precipitation encountered especially in June, July and August of the second year extended the vegetation period (Table 1).

Soil Characteristics of the Study Area

Soil samples were taken from 0–30 cm soil depth at different points as to represent the research site. Air dried samples were passed through 2 mm sieves and subjected to soil analyses (Table 2).

Experimental soils were sandy-loam in texture with available phosphorus contents of between 6.785–7.80 kg/da, pH values of between 7.91–8.0, organic matter contents of between 0.30–0.67%, lime contents of between 1.59–2.38% and EC values of between 0.109–0.117 mmhos (Table 2).

Statistical Analysis

Experimental data were subjected to statistical analyses separately in each year. Multi-variate analyses (correla-

tion, principal component analysis (PCA), biplot and cluster analysis) were used to evaluate the relationships between agro-morphological traits. Statistical analyses were conducted with the use of JMP 13.2.0 software. Significant means were compared with the use of Tukey's test ($p \leq 0.05$) (Steel and Torrie 1980; Chen et al. 2020; Ozaktan 2021).

Results and Discussion

Mean values of investigated morphological traits of bean cultivars and local genotypes for the first and the second year, average of years and F values and significance levels over combined years are provided in Tables 3 and 4.

As the average of years, plant heights varied between 26.2–74.47 cm, the first pod heights between 7.77–21.47 cm, number of main branches per plant values between 1.33–2.47, number of pods per plant values between 8.10–27.37, number of seed per plant values between 21.50–119.73, number of seeds per pod values between 2.11–5.17, seed yields between 82.1–468.6 kg da^{-1}, 100-seed weights 28.32–68.03 g and protein contents between 19.05–31.98%.

In both years, the highest number of pods per plant was obtained from Akman cultivar and the greatest 100-seed weight was obtained from Güzelöz genotype; the lowest number of seeds per pod was obtained from Cihan cultivar, the lowest 100-seed weight from Özmen and the lowest number of pods per plant from Özdemir cultivar. In terms of seed yields, Noyanbey 98 cultivar had the highest value (260.7 kg/da) in the first year and Akman 98 cultivar (468.6 kg/da) in the second year; Güzelöz genotype was also placed into the highest group in both years. In terms of general averages, seed yield of genotypes was calculated as 180.8 kg/da in the first year and 288.4 kg/da in the second year. Such a big difference was mainly attributed to 45 days longer growing season of the second year because of climate parameters. Among the genotypes, Güzelöz was placed into the highest plant height group (73.56 cm), it had

Table 3 Plant height, first pod height, number of branches per plant, number of pods per plant and number of seeds per plant of registered cultivars and local genotypes

Cultivar/ Genotypes	Plant height, PH (cm)		First pod height, FPH (cm)		Number of branches per plant, NBP		Number of pods per plant, NPP		Number of seeds per plant, NSPL	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
Adabeyazı	41.49 ef	29.07 c–f	13.67 e–h	10.33 a–d	1.63 cd	1.83	17.80 ab	17.33 a–d	52.92 ab	67.33 a–g
Akman 98	57.94 bc	42.47 abc	12.43 h	10.97 a–d	2.17 abc	2.07	22.77 a	27.37 a	53.73 ab	119.73 a
Alberto	47.96 c–f	34.47 a–f	16.32 c–g	9.93 bcd	2.13 abc	1.70	14.19 b–f	17.47 a–d	50.79 ab	59.97 b–g
Altın	40.55 ef	36.03 a–f	14.41 d–h	11.07 a–d	1.87 a–d	2.00	16.90 bc	19.83 a–d	52.23 ab	80.37 a–g
Aras 98	50.03 c–f	29.87 b–f	21.47 a	13.80 ab	2.20 abc	1.83	15.77 b–e	11.67 cd	49.54 ab	42.83 efg
Arslan	45.11 c–f	29.93 b–f	15.88 c–h	10.43 a–d	1.93 a–d	1.73	17.56 b	18.10 a–d	62.33 a	78.50 a–g
Batallı	38.59 ef	32.13 a–f	14.67 d–h	10.30 a–d	1.97 a–d	1.80	14.13 b–f	22.27 ab	41.30 abc	99.73 abc
Berrak	41.84 ef	37.87 a–f	12.95 gh	7.77 d	2.33 abc	2.30	13.50 b–f	20.50 a–d	46.29 abc	98.80 a–d
Cihan	48.39 c–f	26.20 f	18.49 abc	12.20 abc	2.27 abc	1.83	14.21 b–f	13.13 bcd	29.90 bc	30.43 g
Çomaklı	55.79 bcd	36.73 a–f	13.27 fgh	8.10 cd	1.33 d	2.03	11.77 d–g	19.00 a–d	36.72 abc	75.23 a–g
Dermason	71.31 a	44.77 a	14.26 d–h	10.13 bcd	1.70 bcd	1.97	11.92 c–g	20.47 a–d	34.58 bc	86.00 a–f
Gömeç	46.18 c–f	31.73 a–f	12.38 h	9.93 bcd	2.11 abc	1.93	13.89 b–f	18.40 a–d	42.82 abc	93.23 a–e
Göynük 98	51.88 cde	32.43 a–f	20.82 ab	12.03 a–d	2.04 a–d	1.90	14.10 b–f	15.20 bcd	44.96 abc	50.80 b–g
Güzelöz	73.56 a	40.30 a–d	16.68 c–f	14.43 a	2.00 a–d	1.73	10.58 fg	11.33 cd	21.50 c	33.60 fg
Kızık	67.63 ab	39.90 a–e	12.95 gh	9.90 bcd	1.97 a–d	2.03	11.63 d–g	16.37 bcd	36.71 abc	64.17 b–g
Noyanbey 98	49.15 c–f	26.73 ef	21.07 ab	11.70 a–d	2.17 abc	1.97	17.25 b	13.87 bcd	43.97 abc	47.33 c–g
Önceler 98	48.08 c–f	27.50 def	17.81 bcd	11.23 a–d	2.47 a	1.93	16.75 bcd	11.63 cd	54.12 ab	39.50 fg
Özdemir	74.47 a	42.90 ab	13.08 gh	11.97 a–d	1.93 a–d	2.00	8.10 g	10.30 d	28.05 bc	42.30 efg
Özmen	44.38 def	38.97 a–f	13.52 fgh	11.10 a–d	2.40 ab	1.97	14.96 b–f	21.57 abc	61.30 a	101.6 ab
Şahin 90	36.67 f	27.40 def	17.22 cde	9.90 bcd	1.87 a–d	1.83	11.43 efg	12.90 bcd	30.09 bc	46.90 d–g
					Averages					
1st year	51.55 A		15.67 A		2.02		14.46 B		43.69 B	
2nd year	34.37 B		10.86 B		1.92		16.94 A		67.92 A	
					F values					
Year (Y)	152.805*		156.941*		3.476		38.447*		161.989*	
Genotype (G)	21.400**		15.731**		3.130*		9.564**		9.014**	
Y x G	6.140**		5.386**		2.698*		3.536**		4.409**	

Table 4 Number of seeds per pod, seed yield, 100 seed weight and protein content of registered cultivars and local genotypes

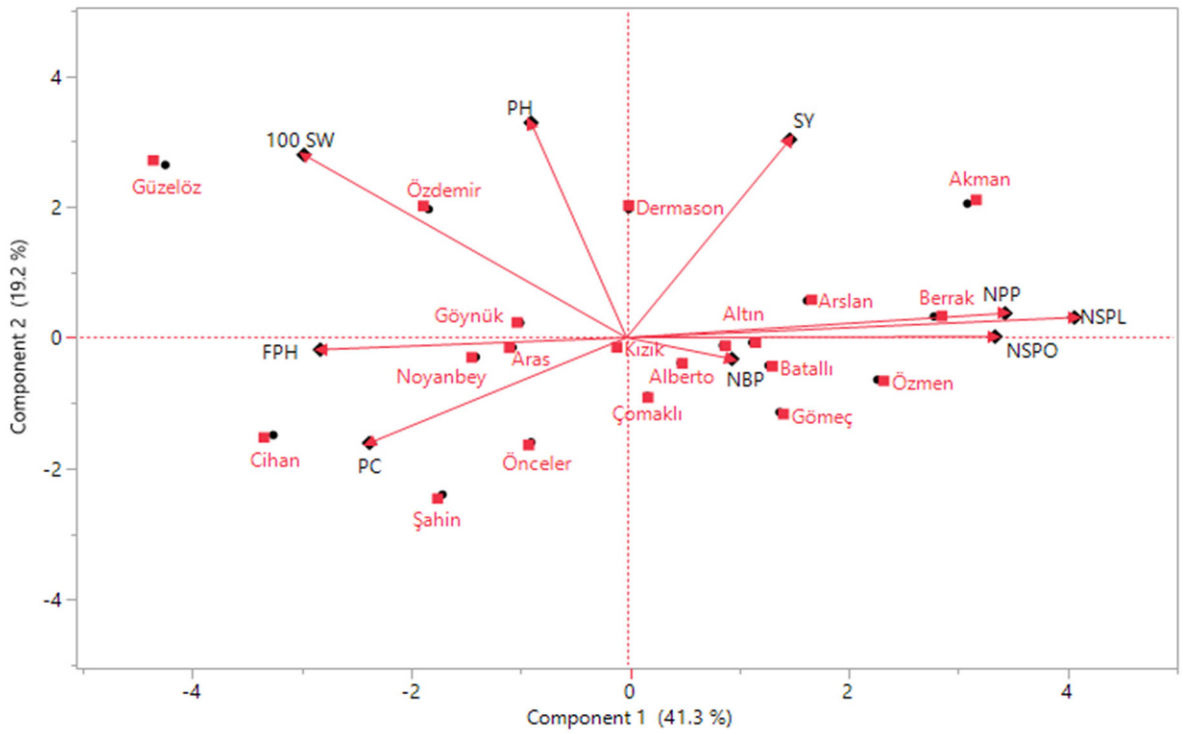
Cultivar/Genotypes	Number of seeds per pod, NSPO		Seed yield, SY (kg/da)		100-Seed weight, SW (g)		Protein content, PC (%)	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
Adabeyazı	2.99 abc	3.90 a–d	196.9 c–g	291.9 b–e	32.80 e–ı	38.17 c–f	24.06 abc	19.65
Akman 98	2.37 bc	4.40 abc	195.3 c–g	468.6 a	36.58 de	35.20 d–h	21.28 c	21.43
Alberto	3.58 ab	3.53 bcd	128.6 jk	277.4 b–e	30.01 f–ı	34.60 e–h	24.34 abc	19.05
Altın	3.05 abc	4.03 abc	197.2 c–g	289.6 b–e	34.58 d–ı	35.83 d–h	24.31 abc	20.49
Aras 98	3.13 abc	3.60 a–d	233.4 a–d	263.9 b–e	35.42 d–h	37.10 c–g	24.18 abc	21.00
Arslan	3.53 ab	4.33 abc	236.5 abc	359.3 abc	35.76 d–g	35.37 d–h	24.36 abc	19.34
Batallı	2.92 abc	4.47 abc	174.0 ghı	322.5 a–d	35.55 d–h	33.20 e–h	25.75 abc	20.94
Berrak	3.40 ab	4.80 ab	179.4 f–ı	419.0 ab	29.32 hı	30.73 fgh	23.56 bc	19.78
Cihan	2.11 c	2.33 d	185.3 e–h	179.9 de	43.11 c	40.50 cde	31.98 a	21.63
Çomaklı	3.12 abc	3.97 abc	82.11	210.0 cde	30.10 f–ı	30.50 fgh	25.92 abc	20.92
Dermason	2.90 abc	4.20 abc	192.8 d–h	363.1 abc	43.21 c	44.13 c	25.57 abc	21.40
Gömeç	3.07 abc	5.17 a	142.4 ab	248.7 b–e	29.63 ghı	31.57 fgh	26.61 abc	21.85
Göynük 98	3.19 abc	3.30 bcd	174.5 ghı	314.4 a–d	36.06 def	43.10 cd	24.97 abc	20.13
Güzelöz	2.05 c	2.97 cd	249.9 ab	332.3 a–d	68.03 a	63.57 a	29.71 ab	21.00
Kızık	3.07 abc	3.93 abc	93.5 kl	244.5 b–e	30.16 f–ı	33.33 e–h	24.63 abc	21.44
Noyanbey 98	2.55 bc	3.40 bcd	260.7 a	266.4 b–e	39.83 cd	40.53 cde	29.04 abc	20.58
Önceler 98	3.23 abc	3.40 bcd	218.1 b–f	200.1 cde	33.15 e–ı	29.77 gh	29.09 abc	22.91
Özdemir	3.46 ab	4.07 abc	152.6 hıj	293.1 b–e	51.79 b	55.37 b	22.65 bc	21.98
Özmen	4.11 a	4.70 ab	225.2 a–e	293.1 b–e	28.32 ı	28.33 h	27.04 abc	23.78
Şahin 90	2.56 bc	3.63 a–d	96.8 kl	129.1 e	30.14 f–ı	38.30 c–f	26.20 abc	22.07
Averages								
1st year	3.02 B		180.8 B		36.68		25.76 A	
2nd year	3.91 A		288.4 A		37.96		21.07 B	
F values								
Year (Y)	105.149*		687.311**		2.992		18.409*	
Genotype (G)	7.454**		10.837**		85.224**		3.153*	
Y x G	2.402*		5.158**		3.032*		1.865*	

Table 5 Correlations coefficients between morphological traits

	PH	FPH	NBP	NPP	NSPL	NSPO	SY	100-SW	PC
PH	1.0000	–0.1590	–0.0874	–0.2216	–0.0372	–0.1661	0.2270	0.5866*	–0.0977
FPH	–0.1590	1.0000	0.0603	–0.3849	–0.6241*	–0.5959*	0.0632	0.4029	0.3541
NBP	–0.0874	0.0603	1.0000	0.1637	0.1832	0.2120	0.2942	–0.2304	0.1968
NPP	–0.2216	–0.3849	0.1637	1.0000	0.3576	0.8851**	0.5026*	–0.5094*	–0.3767
NKPL	–0.0372	–0.6241*	0.1832	0.3576	1.0000	0.7407*	0.1732	–0.5459*	–0.4475*
NSPL	–0.1661	–0.5959*	0.2120	0.8851**	0.7407*	1.0000	0.4544*	–0.6118*	–0.4496*
SY	0.2270	0.0632	0.2942	0.5026*	0.1732	0.4544*	1.0000	0.2648	–0.3157
100-SW	0.5866*	0.4029	–0.2304	–0.5094*	–0.5459*	–0.6118*	0.2648	1.0000	0.1843
PC	–0.0977	0.3541	0.1968	–0.3767	–0.4475*	–0.4496*	–0.3157	0.1843	1.0000

*$P \leq 0.05$, **$P \leq 0.01$

the lowest number of number of seeds per plant (21.50) and the highest first pod height (14.43 cm) in the second year. On the other hand, Çomaklı had the lowest values in terms of main branches (1.33) and seed yield (82.1 kg/da) in the first year. Gömeç genotype was placed into the lowest first pod height (12.38 cm) group in the first year and it had the highest number of seeds per pod (5.17) in the second year (Tables 3 and 4). Yeken et al. (2019) reported plant heights as between 25.25–361.5 cm, number of branches per plant as between 3.2–10.78, number of pods per plant as between 6.67–63.0, number of seeds per pod as between 2.13–8.43, 100-seed weights as between 14.0–63.3 g and protein contents as between 22.75–29.75%. Present findings on morphological traits also comply with the values of



Weight values in components

Number	Eigenvalue	Percent	Cum Percent
1	3.7152	41.279	41.279
2	1.7322	19.247	60.527
3	1.4185	15.761	76.288
4	0.9571	10.634	86.922
5	0.5836	6.484	93.406
6	0.3424	3.805	97.211
7	0.2074	2.304	99.515
8	0.0400	0.445	99.960
9	0.0036	0.040	100.000

	Prin1	Prin2	Prin3	Prin4	Prin5	Prin6	Prin7	Prin8	Prin9
PH	-0.10752	0.59271	-0.23506	0.41986	0.16507	-0.24830	0.55599	-0.08597	-0.01360
FPH	-0.34452	-0.03281	0.44712	-0.34174	-0.35973	0.14068	0.61350	0.19039	-0.04118
NBP	0.11848	-0.05859	0.60674	0.58113	-0.25184	-0.39064	-0.16920	0.17878	-0.00818
NPP	0.42573	0.06724	0.22918	-0.31305	0.45735	-0.23047	0.16475	0.30065	0.53282
NSPO	0.41446	0.00319	-0.18197	0.33115	-0.38244	0.58544	0.16134	0.17779	0.37256
NSPL	0.50367	0.05576	0.08191	-0.03584	0.19315	0.17318	0.14366	0.27483	-0.75614
SY	0.18361	0.54622	0.44901	-0.15857	-0.03614	0.27893	-0.18938	-0.57035	0.03011
100 SW	-0.36282	0.50400	0.01627	-0.02172	0.06782	0.22591	-0.40608	0.62669	0.01797
PC	-0.28922	-0.29011	0.28719	0.36696	0.61748	0.45964	0.10626	-0.09393	0.04873

Fig. 1 PCA data and biplot for morphological traits and bean genotypes

Bozoğlu and Gülümser (2000), Elkoca and Kantar (2004), Ceyhan et al. (2009), Babağil (2011), Wani et al. (2017) and Çalışkan et al. (2018).

The highest positive correlation was seen between the number of pods per plant and number of seed per plant (r = 0.8851) and the greatest negative correlation was seen between number of seeds per pod and 100-seed weight (r = –0.6118). In addition, significant positive correlations were seen at 5% level between plant height and 100-seed weight (r = 0.5866), between number of pods per plant and seed yield (r = 0.5026), between number of seeds per pod and number of seeds per plant (r = 0.7407) and between number of seeds per pod and seed yield (r = 0.4544). Negative correlations were seen between the first pod height and number of seed per pod (r = –0.6241) and number of seeds per plant (r = –0.5959), between 100-seed weight and number of pods per plant (r = –0.5094), between 100-seed weight and number of seed per pod (r = –0.5459) and protein content (r = –0.4496) and between number of seeds per plant and protein content (r = –0.4496) (Table 5).

Yeken et al. (2019) reported significant positive correlations of seed yield with the number of pods per plant (r = 0.778**), plant height (r = 0.568**) and the number of seeds per pod (r = 0.330**). Loko et al. (2018) reported significant negative correlations between 100-seed weight and the number of seeds per pod (r = –0.49***). Marzooghian et al. (2012) significant negative correlations between the number of pods per plant and the number of seeds per plant (r = 0.93**), between 100-seed weight and the number of pods per plant (r = –0.41**) and the number of seeds per plant (r = –0.43**).

Principal component analysis (PCA) was applied to mean values of the measured traits to identify the most important factors and to explain the relationships between variables and observations. The biplot for beans and morphological traits, number of principal component (PC)

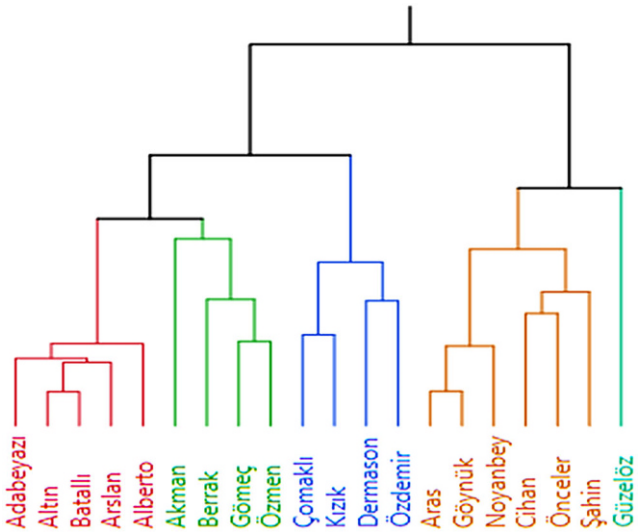


Fig. 2 Dendrogram for 20 genotypes of common bean for morphological traits

axes, eigenvalues, variance and total variance are presented in Fig. 1. Analyses revealed 3 PC axes with eigenvalues greater than 1 and 9 independent PC axes. The eigenvalues of the first 3 PC (PC1, PC2 and PC3) axes, explaining 76.29% of the total variation, varied between 1.42–3.72. On PC1 axis, NSPL, NPP, NSPO, FPH and 100-SW explained 41.28% of the total variation; on PC2 axis, PH, SY and 100-SW explained 19.25% of the total variation; on PC3 axis, NBP, SY and FPH explained 15.76% of the total variation. Since PH and 100-SW were placed in the same section and have close vector lengths, they had positive relationships and Güzelöz genotype and Özdemir cultivar had high values of these traits. Since NSPL and NPP had narrow vector angle between, closer vector lengths and placed in the same section of the graph, they had significant positive relationships 484,206. SY was also placed into the same section, thus had positive relationships with NSPL and NPP parameters, but larger angle with these parameters indicated the degree of relationship as low. For NSPL, NPP and SY parameters, Akman, Berrak and Arslan cultivars were clearly separated from the others. On NBP and PC axes, Özmen and Cihan cultivars were respectively identified as the most effective cultivars. NBP was the only parameter in a section and Alberto, Adabeyazı, Altın, Batallı and Özmen cultivars and Çomaklı and Gömeç genotypes were also placed into the same section with NBP parameter.

Marzooghian et al. (2012) conducted a study on agronomic and morphological traits of beans and identified 9 principal components and indicated that the first 3 components explained 72.832% of the total variation.

Hierarchically cluster analysis was performed for morphological traits in accordance with the Wards method to determine the genetic relationship between 4 local genotypes, commonly produced and consumed in Kayseri province and 16 existing standard cultivars. Resultant dendrogram revealed that Gömeç was placed into the 2nd Cluster, Çomaklı and Kızık in the 3rd Cluster, Güzelöz alone in the 5th Cluster. Güzelöz alone formed a single main cluster in the first sub-cluster belonging to two main clusters and differed significantly from the other cultivars (Fig. 2). In terms of genetic distance, the lowest (0.621) distance was encountered between Altın-Batallı cultivars and the greatest (6.963) between Adabeyazı-Aras cultivars. The genetic distances between cultivars/genotypes in clusters including local genotypes were recorded as Gömeç-Özmen with 1.546, Çomaklı-Kızık with 1.665 and Güzelöz-Aras with 4.944. Considering the average values of the clusters formed for the examined traits (Table 6), it was observed that the 5th cluster (Güzelöz) was prominent for plant height, seed yield, 100-seed weight and protein content; the 4th Cluster (Aras, Göynük, Noyanbey, Cihan, Önceler and Şahin) for the first pod height; the 2nd cluster (Akman, Berrak, Gömeç and Özmen) for number of branches per plant, number of pods per plant, number of seeds per pod and number of seeds per plant. Since the Alberto cultivar in the first cluster and Akman cultivar in the second cluster alone formed a single sub-cluster in their main clusters, they differed within the group in terms of morphological traits. Çomaklı and Kızık genotypes together formed a subgroup and such a case indicated that these genotypes might have the same ancestors. Pathak et al. (2010) and Pathak et al. (2011) reported similar results and suggested that genotypes in the same cluster might have the same ancestors. However, morphological variability has been evaluated by a couple of researchers and it was indicated that high genotype × environment interaction may not reveal accurate information about genetic diversity (Boghara et al. 2016). The close relationship between climate diversity and ge-

Table 6 Cluster means for analyzed parameters in common bean genotypes

Cluster	Count	PH (cm)	FPH (cm)	NBP	NPP	NSPO	NSPL	SY (kg da^{-1})	100-SW (g)	PC (%)
1	5	37.53	12.70	1.86	17.56	3.63	64.55	247.4	34.59	22.23
2	4	42.67	11.38	*2.16*	*19.12*	*4.00*	77.*19*	271.5	31.21	23.17
3	4	54.19	11.71	1.87	13.69	3.59	50.47	204.0	39.82	23.06
4	6	37.86	*15.65*	2.03	13.99	3.04	42.53	210.2	37.25	24.48
5	1	*56.93*	15.56	1.87	10.96	2.51	27.55	*291.1*	*65.80*	*25.36*

netic diversity (Ashgari and Vojdani 1997) makes Turkey rich in bean biodiversity (Canci et al. 2019).

Conclusion

In this study, morpho-agronomic variations of 16 registered common bean cultivars and 4 local genotypes grown under organic conditions were comprehensively explained with the use of multi-variate analyses. Cluster analysis for morphological traits confirmed the similarity of genotypes that are significantly similar to each other. In terms of seed yields, Noyanbey and Akman cultivars could be recommended for local producers for high yields under organic farming conditions. In addition, Güzelöz, Kızık and Gömeç genotypes with high values for investigated traits could be used in further breeding programs or production activities of the local growers.

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Conflict of interest H. Ozaktan, S. Uzun, O. Uzun and C. Yasar Ciftci declare that they have no competing interests.

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