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EVALUATION OF AGRONOMIC TRAITS AND GENETIC DIVERSITY OF COMMON BEAN GENOTYPES UNDER IRRIGATED AND RAINFED CONDITIONS

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Abstract

This study was conducted to determine agronomic performance of ten commercial common bean varieties (Karaman 2016, Adabeyazı, Akın, Göksun, Bulduk, Akman 98, Zirve, Göynük 98, Özmen and Topçu), and two advanced lines (KF-Arp and KF-Arj) under rainfed and irrigated conditions for two years in a split plot randomized block design with four replications. Özmen, Zirve and Adabeyazı cultivars had the highest grain yields (irrigated conditions; 4152, 4018 and 3691 kg ha^{-1}, rainfed conditions; 1456, 1318 and 1322 kg ha^{-1}, respectively) in terms of grain yield according to the average data of the two years under irrigated and rainfed conditions. Eight Inter Simple Sequence Repeat (ISSR) markers were used to reveal the genetic diversity of the genotypes. The ISSR markers used in the study produced 140 polymorphic alleles, while the allele number per primer was found as 17.5 and the average PIC value was 0.96. A dendrogram was created for common bean genotypes that consisted of two main groups, as Akın was the only cultivar in the first group, and the remaining eleven cultivars were grouped together in the second main group with 11% genetic similarity.

Key words: grain yield, *Phaseolus vulgaris* L., genetic variability, ISSR marker

Introduction. Common bean (*Phaseolus vulgaris* L.) is an important food source due to the protein, vitamins, minerals and dietary fibre content and has

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a crucial importance for human nutrition. Globally, common bean is planted in 34.8 million ha, produces 27.5 million tons and average yield is 790 kg ha^{-1} [1]. In Turkey, it is planted in 107 796 ha, produces 305 000 tons and average yield is 2830 kg ha^{-1} [2].

Most of the common bean production in Turkey (69%) is grown in the Central Anatolia region under irrigated conditions. More than 60% of common bean cultivation in the world is carried out in non-irrigated conditions and it is estimated that drought stress causes 80% yield losses in these areas [3]. The narrow genetic diversity in breeding studies limits the expected rate of genetic progression in some plants, and this is also true for common bean [4]. Since bean is mostly self-pollinated species, studies were carried out using genetic markers such as isozyme and Restriction fragment length polymorphism (RFLP) in earlier studies, and relatively little information was obtained about the genetic structure. Today, reasons such as cost efficiency and ease of application have made SNP, SSR and AFLP markers the most common markers used to determine common bean genetic diversity [5].

Common bean, as one of the cultivated plants with a rich genetic diversity in Turkey is important among edible legume species and is potentially beneficial for the economy. Determining the genetic relationships between genotypes and irrigation strategies will contribute to common bean breeding studies and the development of varieties with desired yield and quality traits. In this study, it was aimed to evaluate the performance of ten registered and two advanced common bean genotypes in terms of agronomic traits in rainfed and irrigated conditions, and to determine the genetic diversity among these genotypes.

Materials and methods. ***Field trials and data analysis.*** In this study, ten commercial common bean varieties (Karaman 2016, Adabeyazı, Akın, Göksün, Bulduk, Akman 98, Zirve, Göynük 98, Özmen and Topçu), and two advanced lines (KF-Arp and KF-Arj) with a total number of 12 dwarf (type-I) common bean genotypes were used as plant material. The field trials were carried out in 2017 and 2018 cropping years at Lüleburgaz-Kırklareli location, in Turkey. The experiment was set as rainfed (RF) and irrigated (IR) field conditions. The experiment was carried out in a split plot design with four replications. The trials were planted on May 1, 2017 in the first year and May 2, 2018 in the second year. The plots were four rows and planted 45 cm inter-row, and 8 cm intra-row apart. The irrigated trials were watered five times between flowering and grain filling period at field capacity by furrow irrigation system. The fertilizer was applied as diammonium phosphate (DAP) at 150 kg ha^{-1} (27 kg N $ha^{-1}$and 69 kg P_2O_5 ha^{-1}) by planting for both rainfed and irrigated trials. The harvest of the trials were on August 15, 2017 in the first year and September 1, 2018 in the second year. In the study, plant height (PH), first pod height (FPH), number of branches per plant (BPP), number of pods per plant (PPP) and number of grains per plant (GPP) were measured on randomly selected ten plants in each plot.

Days of flowering (DF), physiological maturity (PM), 100-grain weight (100GW) and grain yield (GY) were also investigated.

Statistical analysis. Based on two years data obtained from both trials were subjected to the variance analysis and Duncan test was used for comparison of the means [6].

Molecular assays and bioinformatics. Genomic DNA of the common bean genotypes were isolated from single seeds as described by [7]. In brief, four seeds from each genotype were seeded in a 12.5 cm pot and three of them removed at two leaves stage. The leaf tissues were collected and genomic DNA of the genotypes were isolated using a cetyl trimethyl ammonium bromide (CTAB) method, then diluted to 25 ng/µl and amplified with eight ISSR markers. Polymerase chain reaction (PCR) was performed using 0.2 ml vol. PCR plates. The PCR products were analyzed by 'QIAxcel Advanced System' fragment analyzer (Qiagen) and the DNA bands for each marker were obtained. A binary data was produced as the presence or absence of the ISSR markers and the DNA bands were scored as '1' or '0'. Polymorphism information content (PIC) was calculated using the formula described by [8]: PIC$= 1 - \sum P_i^2$ where P_i is the frequency of the i-th allele in the 12 common beans studied. Genetic diversity of the 12 common bean genotypes was calculated using Dice's index [9] with NTSYSpc ver. 2.21v [10]. A dendrogram was created using "Unweighted Pair Group of Arithmetic Means" (UPGMA).

Results and discussion. ***Comparing the genotypes according to the agronomic traits.*** In 2017, the experiment site had 106 mm precipitation, while it was 107.6 mm in 2018. The average temperature of the growing season was 21.5 °C in 2017 and 22.5 °C in 2018. In terms of flowering period, the average of genotypes was determined as the shortest 33.6 days, the longest 38.7 days in the first year, while the shortest 40.3 days and the longest 44.1 days in the second year. The longest flowering period was observed in Göksun (38.7 days), Topçu (38.5 days) and Bulduk (38.5 days) genotypes in the first year, and Bulduk (44.1 days), Akman 98 (44 days), Göksun (43.5 days) and Akın (43.5 days) genotypes in the second year. The shortest flowering period was detected in Akın (33.6 days) and KF-Arj (33.9 days) genotypes in the first year, and in Zirve and Özmen (40.3 days) genotypes in the second year. The average flowering period of the genotypes under rainfed conditions was 12.3 days earlier in the first year and 7.5 days earlier in the second year compared to the irrigated conditions (Table 1). Mideksa and Tesfaye [11] indicated that the flowering days decreased by 12.6% under stressed conditions.

Physiological maturity period was determined as 65.2 days in the first year, 74.2 days in the second year under rainfed conditions and 97.4 days in the first year, 92.3 days in the second year under irrigated conditions. The longest physiological maturity period was measured in the Akman 98 (83.5 days; 85.5 days) genotype in both years under rainfed and irrigated conditions. The lowest physi-

ological maturity period was determined in the Adabeyazı (62.5 days; 71.3 days) genotype in both years under rainfed conditions and in Özmen (96 days; 90.2 days) genotype in both years under irrigated conditions (Table 1).

Darkwa et al. [12] reported that the physiological maturity period decreased by 12.7% under drought conditions.

Plant height is affected by genotype and environment thus it is highly related with irrigation. In rainfed conditions, the lowest plant height was determined in the first year in the Karaman 2016 (22.3 cm) genotype, the second year in the Adabeyazı (30.5 cm) genotype, and the highest plant height in the Akman 98 (37.0 cm; 47.7 cm) genotype in both years. In irrigated conditions, the lowest plant height was measured in Adabeyazı (35.5 cm) genotype in the first year, the highest plant height in Topçu genotype (51.5 cm), the lowest plant height in Göksun (42.5 cm) genotype in the second year, and the highest plant height in Akın (51.3 cm) genotype (Table 1). The average plant height of the genotypes under irrigated conditions was higher than the average plant height obtained under rainfed conditions in both years. Emam et al. [13] determined the plant height as 26.37 cm under 25% irrigation conditions and 43.12 cm under 100% irrigation conditions.

In terms of first pod height, the average of genotypes was observed to vary between 10.3–14.9 cm in the first year and 11.0–19.4 cm in the second year (Table 1). The highest first pod height was determined in Topçu (12.5 cm) genotype in the first year, Akın (19.2 cm) genotype in the second year under rainfed conditions, while Akın (18.3 cm) genotype in the first year, and Göynük 98 (19.7 cm) genotype in the second year under irrigated conditions. The lowest first pod height was determined in the Zirve (9.2 cm) genotype in the first year, in the Göksun (11.2 cm) genotype in the second year under rainfed conditions, and KF-Arp (9.8 cm) genotype in the first year and in the Göksun (10.7 cm) genotype in the second year under irrigated conditions (Table 1). First pod height is a trait that is affected by genetic structure, and environmental factors affect the first pod height significantly. The high first pod height of tall genotypes indicates their suitability for machine harvesting [14].

It was observed that the average number of branches per plant of common bean genotypes varied between 6.1–12.1 in the first year and 7.8–15.6 in the second year (Table 2). The number of branches per plant is the highest in the first year under rainfed conditions, in KF-Arp (10.8) genotype, the lowest in Adabeyazı (4.5), and Adabeyazı (7.8) genotype in the first year under irrigated conditions, and the highest in Akın (16.3) genotype. The lowest number of branches per plant was measured in Göksun (5.5) genotype in the second year under rainfed conditions, the highest in Karaman 2016 (10.8), the lowest in Adabeyazı (8.7) genotype, and the highest in Bulduk (22.5) genotype under irrigated conditions (Table 2). Yeken et al. [15] reported that the number of branches per plant ranged from 4 to 11.

Table 1

Mean values related to days of flowering (DF), physiological maturity (PM), plant height (PH) and first pod height (FPH)

Genotypes/ Treatments	DF						PM					
	2017			2018			2017			2018		
	RF	IR	Mean	RF	IR	Mean	RF	IR	Mean	RF	IR	Mean
KF-Arp	29.0 jk	40.3 e	34.6 d	36.5 j	44.5 ef	40.5 ef	67.7 g	97.0 de	82.4 b	74.0 j	93.5 a	83.8 d
KF-Arj	28.0 lm	39.8 f	33.9 e	34.8 k	46.5 bc	40.6 ef	64.2 k	96.5 ef	80.4 d	74.0 j	92.0 cd	83.0 e
Zirve	29.8 ij	41.5 e	35.6 c	34.2 k	46.3 bcd	40.3 f	63.0 l	97.0 de	80.0 de	73.0 k	90.8 ef	81.8 gh
Özmen	28.7 kl	39.5 f	34.1 de	35.0 k	45.5cde	40.3 f	63.0 l	96.0 f	79.5 e	72.0 lm	90.2 f	81.1 i
Göynük 98	28.7 kl	42.2de	35.5 c	34.5 k	47.8 a	41.1 de	65.3 j	98.5 ab	81.9 bc	72.7 kl	92.7 abc	82.7 ef
Adabeyazı	29.5 ijk	42.7 cd	36.1 c	37.5 j	45.2 de	43.4 d	62.5 l	97.5 cd	80.0 de	71.3 m	92.0 cd	81.6 hi
Göksun	30.2 i	47.2 a	38.7 a	41.5 g	45.5 cde	43.5 ab	63.0 l	96.5 ef	79.8 e	72.3 kl	92.3bcd	82.3 fg
Akman 98	31.7 h	43.3 c	37.5 b	44.0 f	44.0 f	44.0 ab	67.8 g	99.2 a	83.5 a	77.5 g	93.5 a	85.5 a
Topçu	32.0 h	45.0 b	38.5 a	41.3 gh	45.5 cde	43.4 b	66.5 hi	97.0 de	81.7 c	74.8 ij	92.7 abc	83.8 d
Akın	27.8 m	39.5 f	33.6 e	40.0 i	47.0 ab	43.5 ab	65.8 ij	98.5 ab	82.1 bc	77.5 g	91.5 de	84.5 bc
Bulduk	34.0 g	43.0cd	38.5 a	40.3 hi	48.0 a	44.1 a	66.7 h	98.0 bc	82.4 b	75.3 i	93.0 ab	84.1 cd
Karaman 2016	29.5 ijk	42.2 de	35.8 c	40.5 ghi	43.8 f	42.1 c	67.0 gh	96.5 ef	81.7 c	78.2 h	93.5 a	84.9 b
Mean	29.9 b	42.2 a	36.1	38.3b	45.8 a	42.1	65.2 b	97.4 a	81.3	74.2 b	92.3 a	83.3
Treatment		**			**			**			**	
Genotype		**			**			**			**	
Genotype* Treatment		**			**			**			**	

Table 1

Continued

Genotypes/ Treatments	PH						FPH					
	2017			2018			2017			2018		
	RF	IR	Mean	RF	IR	Mean	RF	IR	Mean	RF	IR	Mean
KF-Arp	23.4 kl	49.2 ab	36.3 b-e	35.8 f-i	45.7 abc	40.8 bcd	10.9	9.8	10.3 c	12.8	13.7	13.2 def
KF-Arj	31.0 ij	43.5 cde	37.2 b	32.8 ghi	47.2 abc	40.0 d	12.3	12.0	12.1 bc	12.8	11.5	12.1 def
Zirve	25.8 kl	42.2 de	34.0 c-f	31.3 hi	48.2 ab	39.7 d	9.2	14.3	11.8 bc	16.3	12.3	14.3 bcd
Özmen	31.0 ij	43.0cde	37.0 bc	37.3 e-h	46.8 abc	42.0 bcd	10.8	12.5	11.6 bc	12.5	11.2	11.9 def
Göynük 98	27.5 jk	40.0 ef	33.7 ef	33.0 ghi	48.8 ab	40.8 bcd	10.5	13.0	11.8 bc	18.3	19.7	19.0 a
Adabeyazı	25.3 kl	35.5 gh	30.4 g	30.5 i	45.0 abc	37.8 d	11.5	12.0	11.8 bc	14.0	11.8	12.9 def
Göksun	24.8 kl	40.7 ef	32.8 fg	30.2 d-g	42.5 b-e	40.4 cd	9.3	12.5	10.8 c	11.2	10.7	11.0 f
Akman 98	37.0 fg	37.8 fg	37.3 b	47.7 ab	43.0 b-e	45.4 ab	12.2	16.0	14.1 ab	16.0	16.2	16.1 bc
Topçu	31.2 hij	51.5 a	41.4 a	40.8 c-f	49.0 ab	44.9 abc	12.5	15.2	13.9 ab	16.7	16.0	16.4 b
Akın	34.0 ghi	49.5 ab	41.8 a	45.0 abc	51.3 a	48.1 a	11.5	18.3	14.9 a	19.2	19.5	19.4 a
Bulduk	26.5 kl	47.3 abc	36.9 bcd	34.5 f-i	48.5 ab	41.5 bcd	11.0	12.5	11.8 bc	11.5	11.5	11.5 ef
Karaman 2016	22.3 l	45.5 bcd	33.9 def	37.0 e-i	44.7 a-d	40.8 bcd	10.8	14.5	12.6 abc	15.0	12.5	13.7 cde
Mean	28.3 b	43.8 a	36.1	37.0 b	46.7 a	41.9	11.0 b	13.5 a	12.3	14.7	13.9	14.3
Treatment		**			**			**			ns	
Genotype		**			**			*			**	
Genotype* Treatment		**			**			ns			ns	

IR: Irrigated, RF: Rainfed, ** Significant at $P < 0.01$ probability level, * Significant at $P < 0.05$ probability level, ns: not significant

The number of pods per plant of the genotypes varied between 12.5–16.8 pods in the first year and between 8.5–20.1 pods in the second year (Table 2). The lowest number of pods was measured in KF-Arp (8.1) in the first year, Topçu (5.5) in the second year, the highest number of pods in Göksun (11.5) genotype in the first year, and Karaman 2016 (11.8) in the second year under rainfed conditions. In irrigated conditions, the lowest number of pods was recorded in Akman 98 and Adabeyazı (15.8) genotypes in the first year, the highest in KF-Arj (24.8) genotype, the lowest in Akman 98 (10.8) in the second year, and the highest in Özmen (31.2) genotype (Table 2). Mideksa [16] reported that the number of pods per plant decreased by 11.5–40.7% due to water stress of genotypes.

In terms of the number of grains per plant, the average of common bean genotypes varied between 27.9–39.6 in the first year and 19.8–43.1 in the second year. Under rainfed conditions, Özmen (36.3) genotype had the highest number of pods and KF-Arp (23.1) genotype had the lowest in the first year, in the second year, Göynük 98 (13.0) genotype had the lowest, and Zirve (35.5) genotype had the highest number of pods. Under irrigated conditions, KF-Arp (32.7) genotype was the lowest in the first year, while Karaman 2016 (50.5) genotype was the highest, in the second year, Özmen (54.0) genotype was the highest and Akın (25.7) genotype was the lowest (Table 2). Darkwa et al. [12] noted that the number of grains per plant decreased by 2% compared to non-drought conditions.

It was determined that the average of genotypes in terms of 100 grain weight ranged between 25.8–38.8 g in the first year and between 25.5–33.3 g in the second year. Under rainfed conditions, 100 grain weight was the lowest in Göksun (22.7 g) genotype, highest in Göynük 98 (35.6 g) genotype in the first year, while highest in KF-Arj (30.6 g) genotype and lowest in Topçu (23.3 g) genotype in the second year. Under irrigated conditions, the highest 100 grain weight was determined in KF-Arp (43.6 g) genotype in the first year, in Zirve genotype (38.2 g) in the second year, and the lowest 100 grain weight in Topçu (28.6 g and 27.7 g) genotype in both years (Table 2). Darkwa et al. [12] and Mideksa [16] reported a decrease in water stress as 10.7% and 13%, respectively.

In terms of grain yield, the lowest average of common bean genotypes was 1911 kg ha^{-1} in the first year, and the highest 2903 kg ha^{-1}, while the lowest was 1109 kg ha^{-1} and the highest was 2771 kg ha^{-1} in the second year. In the first year of the experiment, the highest grain yield was determined in Özmen (4232 and 1575 kg ha^{-1}) genotype, and the lowest grain yield was determined in Bulduk (2761 and 1061 kg ha^{-1}) genotype in both rainfed and irrigated conditions. In the second year, the lowest grain yield was obtained from Topçu (693 kg ha^{-1}) genotype, the highest grain yield from Özmen (1337 kg ha^{-1}) genotype under rainfed conditions, the lowest grain yield was obtained from Akın (1422 kg ha^{-1}), the highest grain yield was determined from Zirve (4295 kg ha^{-1}) and Özmen (4071 kg ha^{-1}) genotypes under irrigated conditions (Table 3). In previous studies

Table 2

Mean values related to number of branches per plant (BPP), number of pods per plant (PPP), number of grains per plant (GPP) and 100 grain weight (100GW)

Genotypes/ Treatments	BPP						PPP					
	2017			2018			2017			2018		
	RF	IR	Mean	RF	IR	Mean	RF	IR	Mean	RF	IR	Mean
KF-Arp	10.8 d-g	13.5 bc	12.1 a	7.0 g-j	12.0 cde	9.5 def	8.1 g	23.7 ab	16.4 a	8.5 gh	17.7 c-f	13.1 b-e
KF-Arj	8.0 h-k	10.3 e-i	9.1 de	6.2 hij	9.3 e-h	7.8 f	9.8 g	24.8 a	16.8 a	6.7 h	19.8 bcd	13.2 b-e
Zirve	7.0 jkl	11.5 c-f	9.3 de	6.8 g-j	14.3 c	10.5 bcd	11.0 g	20.0 b-e	15.5 ab	7.2 gh	26.3 ab	16.8 ab
Özmen	6.0 kl	12.0 b-e	9.0 de	7.3 gj	12.2 cde	9.7 c-f	11.3 g	17.5 de	14.4 ab	9.0 gh	31.2 a	20.1 a
Göynük 98	8.3 g-k	14.2 ab	11.3 abc	6.5 hij	14.0 cd	10.3 b-e	8.2 g	17.7 de	13.0 b	6.2 h	14.5 d-g	10.3 cde
Adabeyazı	4.5 l	7.8 ijk	6.1 f	6.8 g-j	8.7 f-i	7.8 f	10.3 g	15.8 ef	13.0 b	8.3 gh	25.5 ab	16.9 ab
Göksun	7.0 jkl	9.0 f-j	8.0 e	5.5 j	11.0 def	8.2 ef	11.5 fg	17.0 de	14.3 ab	8.0 gh	23.2 bc	15.6 ab
Akman 98	9.0 f-j	10.3 e-i	9.6 cde	5.7 ij	18.0 b	11.8 bc	9.3 g	15.8 ef	12.5 b	7.5 gh	10.8 fgh	9.1 de
Topçu	9.0 f-j	13.5 bc	11.3 abc	9.7 efg	14.3 c	12.0 b	9.8 g	18.7 cde	14.3 ab	5.5 h	22.0 bc	13.7 bcd
Akın	7.0 jkl	16.3 a	11.6 ab	10.5 ef	19.5 ab	15.0 a	9.0 g	21.0 a-d	15.0 ab	6.0 h	11.0 fgh	8.5 e
Bulduk	7.5 jk	13.0 bc	10.2 bcd	8.7 f-i	22.5 a	15.6 a	10.5 g	22.5 abc	16.5 a	7.8 gh	17.7 c-f	12.8 b-e
Karaman 2016	6.5 jkl	10.5 d-h	8.5 de	10.8 ef	19.0 b	14.9 a	10.3 g	22.3 abc	16.2 a	11.8 e-h	19.0 b-e	15.4 abc
Mean	7.5 b	11.8 a	9.7	7.6 b	14.5 a	11.1	9.9 b	19.7 a	14.8	7.7 b	19.9 a	13.8
Treatment		**			**			**			**	
Genotype		**			**			*			**	
Genotype* Treatment		**			**			**			**	

T a b l e 2

Continued

Genotypes/ Treatments	GPP						100GW					
	2017			2018			2017			2018		
	RF	IR	Mean	RF	IR	Mean	RF	IR	Mean	RF	IR	Mean
KF-Arp	23.1 n	32.7 i-l	27.9 c	25.0	36.5	30.7 c	31.6 i	43.6 a	37.6 b	28.2 h	35.3 bc	31.8 b
KF-Arj	27.5 lmn	39.0 d-i	33.3 b	25.7	44.3	35.0 bc	35.0 ef	42.4 ab	38.7 a	30.6 ef	36.1 b	33.3 a
Zirve	36.0 f-j	43.3 b-e	39.6 a	35.5	50.0	42.8 a	27.9 klm	37.4 d	32.6 d	25.9 j	38.2 a	32.1 b
Özmen	36.3 e-j	42.2 b-f	39.3 a	32.3	54.0	43.1 a	24.1 n	29.6 j	26.8 f	23.9 k	31.0 e	27.4 d
Göynük 98	24.0 mn	49.3 ab	36.6 ab	13.0	26.5	19.8 e	35.6 e	42.1 b	38.8 a	30.4 ef	34.7 c	32.5 ab
Adabeyazı	28.0 k-n	45.3 a-d	36.6 ab	21.0	40.0	30.5 c	26.8 m	34.2 fg	30.5 e	26.8 ij	31.1 de	30.0 c
Göksun	33.5 h-l	34.8 g-k	34.1 b	27.8	50.7	39.3 ab	22.7 o	28.9 jk	25.8 g	23.6 k	28.7 gh	26.1 e
Akman 98	25.0 mn	47.8 abc	36.4 ab	20.3	35.8	28.0 cd	28.5 jkl	31.9 hi	30.2 e	26.2 j	28.3 gh	27.3 d
Topçu	30.5 j-m	45.3 a-d	37.9 ab	19.8	40.0	29.8 c	23.8 no	28.6 jk	26.2 fg	23.3 k	27.7 hi	25.5 e
Akın	25.5 mn	41.5 c-g	33.5 b	16.5	25.7	21.1 de	32.9 gh	39.3 c	36.1 c	29.4 fg	35.8 bc	32.6 ab
Bulduk	30.2 j-m	40.0 d-h	35.1 ab	25.0	36.0	30.5 c	27.2 lm	35.0 ef	31.1 e	26.3 j	31.4 de	28.9 c
Karaman 2016	25.3 mn	50.5 a	37.9 ab	27.2	42.5	34.9 bc	24.2 n	37.9 d	31.0 e	26.8 ij	32.2 d	29.5 c
Mean	28.7 b	42.6 a	35.7	24.1 b	40.2 a	32.2	28.4 b	35.9 a	32.2	26.8 b	32.6 a	29.7
Treatment		**			**			**			**	
Genotype		**			**			**			**	
Genotype* Treatment		**			ns			**			**	

IR: Irrigated, RF: Rainfed, ** Significant at $P < 0.01$ probability level, * Significant at $P < 0.05$ probability level, ns: not significant

Table 3

Mean values for grain yield (kg ha^{-1})

Genotypes / Treatments	2017			2018		
	IR	RF	Mean	RF	IR	Mean
KF-Arp	3429 bc	1068 h	2248 cde	729 k	2143 ef	1436 e
KF-Arj	3153 cde	1177 h	2164 def	927 h-k	2514 e	1721 de
Zirve	3741 b	1389 gh	2565 b	1246 ghi	4295 a	2771 a
Özmen	4232 a	1575 g	2903 a	1337 gh	4071 a	2704 a
Göynük 98	2915 ef	1257 gh	2086 def	783 jk	3179 cd	1981 cd
Adabeyazı	3539 b	1352 gh	2445 bc	1292 gh	3843 ab	2567 ab
Göksun	3372 bcd	1286 gh	2329 bcd	991 g-k	3505 bc	2248 bc
Akman 98	3038 def	1162 h	2100 def	1028 g-k	2992 d	2010 cd
Topçu	3100 c-f	1214 gh	2157 def	693 k	3006 d	1849 d
Akın	2819 ef	1228 gh	2023 ef	797 ijk	1422 g	1109 f
Bulduk	2761 f	1061 h	1911 f	801 ijk	2047 f	1424 ef
Karaman 2016	3006 def	1281 gh	2143 def	1225 g-j	2295 ef	1760 d
Mean	1254 b	3259 a	2257	987 b	2943 a	1965
Treatment		**			**	
Genotype		**			**	
Genotype*Treatment		**			**	

IR: Irrigated, RF: Rainfed, ** Significant at $P < 0.01$ probability level, * Significant at $P < 0.05$ probability level

on grain yield in common bean plants, it is reported that drought stress reduced grain yield by 39–54% [12,17].

Genetic diversity of common bean genotypes. DNA markers were widely used to identify genetic diversity for many crop plants. Inter simple sequence repeat (ISSR) markers are identified as dominant markers. This tool has been used in the studies such as genetic diversity, variety identification, gene tagging and genetic mapping. As a result of the study, the polymorphic allele number was 140 the same as total allele numbers, while the allele number per primer was found as 17.5. The ISSR-1 and ISSR-3 primers had the lowest allele number with 5 alleles. On the other hand, the ISSR-11 primer had the highest allele number that produced 38 alleles. In a previous study average allele number was reported as 5.26 [18]. The highest PIC value was 0.99 obtained from ISSR-1, ISSR-3, ISSR-4, ISSR-5, ISSR-11, ISSR-12, and ISSR-13 primers, while the lowest one was 0.76 from ISSR-7 primer. The average PIC values were reported as 0.98 [19].

A dendrogram was created using 140 alleles obtained from eight ISSR markers (Fig. 1). According to the dendrogram common bean genotypes consisted of two main groups as Akın was the only cultivar in the first group, while the remaining eleven cultivars were grouped together in the second main group with 11%

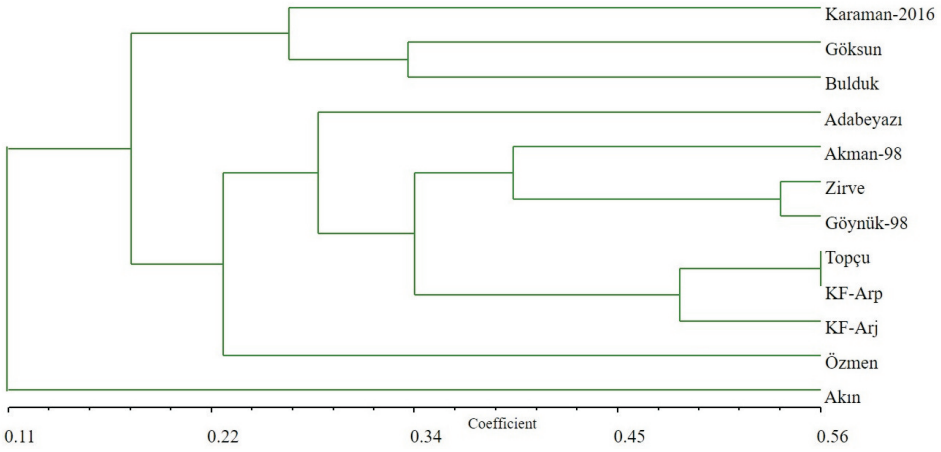

Fig. 1. A dendrogram was created using Dice's index

similarity. The second group was of two clusters the first one including Karaman 2016, Göksun and Bulduk, and the other group had Adabeyazı, Akman 98, Zirve, Göynük 98, Topçu, KF-Arp, KF-Arj, and Özmen genotypes. Topçu and KF-Arp genotypes were found as the most similar genotypes with a 56% similarity, while Zirve and Göynük 98 genotypes were found similar by 53%. It is concluded that the ISSR markers were able to differentiate the common bean genotypes. The researchers using ISSR markers indicated similarity between 48 and 97% in common bean genotypes [20].

Conclusions. In the current study, the genotypes had lower values for flowering period, physiological maturity period, plant height, number of branches per plant, number of pods per plant, number of grains per plant, 100-grains weight and grain yield under rainfed conditions. The first pod height was found higher in irrigated conditions in the first year, while it was higher under rainfed conditions in the second year. Özmen, Zirve and Adabeyazı genotypes had the highest grain yield in both the first year and the second year. Common bean genotypes were found genetically variable as ISSR markers revealed an 11% similarity. The study concludes that, new common bean lines with high yield potential might be obtained as a result of breeding studies to be carried out between genotypes that are genetically distant from each other under both irrigated and rainfed conditions.

REFERENCES

[1] FAOSTAT (2022) Food and Agriculture Organization of the United Nations, Statistics Division. Retrieved in December 12, 2022 from `https://www.fao.org/faostat/en/`.

[2] TUIK (2022) Turkish Statistical Foundation, Crop production statistics. Retrieved in December 11, 2022 from https://www.tuik.gov.tr/.
[3] Kazai P., C. Nuolus, E. Khah, D. Vlachostergios (2019) Yield and Seed Quality Parameters of Common Bean Cultivars Grown under Water and Heat Stress Field Conditions, AIMS Agriculture and Food, **4**(2), 285–302.
[4] Broughton W. J., G. Hernandez, M. Blair, S. Beebe, P. Gepts, J. Vanderleyden (2003) Beans (Phaseolus spp.) – Model food legumes, Plant Soil, **252**, 55–128.
[5] Assefa T., A. A. Mahamma, A. V. Brown, E. K. S. Cannon, J. C. Rubyogo et al. (2019) A Review of Breeding Objectives, Genomic Resources and Marker-Assisted Methods in Common Bean (*Phaseolus vulgaris* L.), Mol. Breeding, **39**, 20.
[6] SAS (2020) JMP® 15 Design of Experiments Guide, Cary, NC 27513 USA.
[7] Uysal A., Z. Dumlupinar (2022) Characterization of Foreign and Turkish Originated Bread and Durum Wheat Landraces by Disease Resistance and Quality using Factional Markers, KSU J. Agric. Nat., **25**(4), 766–777.
[8] Weir B. S. (1996) Genetic Data Analysis II: Methods for Discrete Population Genetic Data, 2nd ed. Sunderland, MA, USA: Sinauer Associates Inc.
[9] Dice L. R. (1945) Measures of the Amount of Ecologic Association between Species, Ecology, **26**(3), 297–302.
[10] Rohlf F. J. (2005) NTSYS-pc: Numerical Taxonomy and Multivariate Analysis System Version 2.21v. setauket, Exeter publishing, New York.
[11] Mideksa A. E., K. Tesfaye (2018) Morpho-Physiological Characterization Related to Drought Tolerance of Common Bean (*Phaseolus vulgaris* L.) Genotypes, International Journal of Advanced Biological and Biomedical Research, **6**(1), 39–46.
[12] Darkwa K., D. Ambachew, H. Mohammed, A. Asfaw, M. W. Blair (2016) Evaluation of Common Bean (*Phaseolus vulgaris* L.) Genotypes for Drought Stress Adaptation in Ethiopia, The Crop Journal, **4**(5), 367–376.
[13] Emam Y., A. Shekoofa, F. Salehi, A. H. Jalali (2010) Water Stress Effects on Two Common Bean Cultivars with Contrasting Growth Habits, American-Eurasian J. Agric. & Environ. Sci., **9**(5), 495–499.
[14] Sozen O., M. Yagmur, B. Turkmen (2021) Evaluating Agro-Morphological Properties of Advanced Dry Bean (*Phaseolus vulgaris* L.) Genotypes, COMU J. Agric. Fac., **9**(2), 327–337.
[15] Yeken M. Z., M. A. Nadeem, T. Karakoy, F. S. Baloch, V. Ciftci (2019) Determination of Turkish Common Bean Germplasm for Morpho-Agronomic and Mineral Variations for Breeding Perspectives in Turkey, KSU J. Agric Nat., **22**(Suppl 1), 38–50.
[16] Mideksa A. (2016) Evaluation of Morphological Aspects of Common Bean (*Phaseolus vulgaris* L.) Genotypes for Post-Flowering Drought Resistance in Rift Valley of Ethiopia, African Journal of Agricultural Research, **11**(32), 3020–3026.
[17] Assefa T., J. Wu, S. E. Beebe, I. M. Rao, D. Marcomin et al. (2015) Improving Adaptation to Drought Stress in Small Red Common Bean: Phenotypic Differences and Predicted Genotypic Effects on Grain Yield, Yield Components and Harvest Index, Euphytica, **203**(3), 477–489.
[18] Ozkan G., K. Haliloglu, A. Turkoglu, H. I. Ozturk, E. Elkoca et al. (2022) Determining Genetic Diversity and Population Structure of Common Bean (*Phaseolus vulgaris* L.) Landraces from Türkiye using SSR Markers, Genes, **13**(8), 1410.

[19] Aydemir G., Z. Dumlupinar, I. Yuce, T. Narli, S. Sunulu et al. (2020) Evaluation of F5 Individuals Obtained from B28 × Kunduru-1149 Reciprocal Cross Population by Functional Markers, KSU J. Agric. Nat., **23**(4), 1005–1011.
[20] Kahraman A., M. Onder (2009) Genetic Diversity in the Dwarf Dry Bean (*Phaseolus vulgaris* L.) Populations Grown in Konya, First International Symposium on Sustainable Devel., **3**(8–10), 13–19.

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