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AYBEGÜN TON

TOLGA KARAKÖY

ADEM EMİN ANLARSAL

MELTEM TÜRKERİ

TÜBİTAK

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Genetic diversity for agro-morphological characters and nutritional compositions of some local faba bean (*Vicia faba* L.) genotypes

Aybegün TON[1,*], Tolga KARAKÖY[2], Adem Emin ANLARSAL[1], Meltem TÜRKERİ[3]

[1]Department of Field Crops, Faculty of Agriculturel, University of Çukurova, Adana, Turkey
[2]Faculty of Agricultural Sciences and Technologies, Sivas University of Science and Technology, Sivas, Turkey
[3]Eastern Mediterranean Agricultural Research Institute, Adana,Turkey

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Abstract: This study was carried out in Mediterranean climate and under rainfed conditions in Turkey for a period of three years throughout the growing seasons of 2014/2015, 2015/2016 and 2016/2017. It was conducted in a randomized complete block experimental design (RCBD) with three replications. In present study, genetic diversity for agro-morphological characters and macro/microelements were investigated in sixteen promising local faba bean genotypes originated from Turkey. According to the results of the study, mean grain yield varied from 2320 kg ha^{-1} (Tekirdağ-39) to 3130 kg ha^{-1} (Burdur-50). 100-grain weight and branches per plant had high heritability and genetic advance as a percentage of mean. As for path analysis; plant height, branches per plant and 100-grain weight had a major role in improving the grain yield of faba bean. Therefore, effective selection for mentioned traits can be made for increasing grain yield in faba bean. Wide diversity for macro and micronutrients in the studied local genotypes can be considered for improving new faba bean cultivars in Mediterranean climate conditions as well.

Key words: *Vicia faba* L., yield and yield components, heritability, path analysis, mineral content

1. Introduction

Faba bean (*Vicia faba* L.) is widely cultivated in China, Europe, and North Africa and it is vital for human and animal nutrition, since it contains high crude protein (20%–40%), carbohydrates (51%–68%), minerals (Fe, Zn, P, Ca), and vitamins (Alghamdi, 2009; Hendawey and Younes, 2013; Sheelamary and Shivani, 2015). Faba bean is fixing air nitrogen at high levels and it also increases the fertility of soil. It can be successfully grown as a winter crop through cropping systems under rainfed conditions in the Mediterranean region of Turkey (Türkeri, 2016; Yazar et al., 2017). Hence, improving new cultivars of faba bean that are high-yielding and that have rich mineral and protein content is important for the efficiency of faba bean production in Mediterranean climate conditions. Large-seeded faba bean originate in Turkey and the country has many faba bean landraces which are a valuable genetic resource for genetic variation. The plant genetic resources are vital for humanity for future food security and play important role for breeding cultivars (Zia-Ul-Haq et al., 2013; Biswas et al., 2020; Tuna et al., 2020). Mineral elements are very important for human nutrition and immune system (Talukderet al., 2010; Baloch et al., 2014) and increasing the amount of mineral element as well as the yield is critical for breeding faba bean. Determining the selection criteria is essential for the selection of desirable genotypes. As is known, yield is influenced by environmental conditions and genetic factors. Genetic variability of yield and yield components in the breeding material must be estimated for increasing grain yield of faba bean. Yet, genetic variability doesn't show the heritable portion of traits.Heritability indicates the magnitude of inheritance of traits, but does not indicate the amount of genetic progress (Hefny, 2013; Georgieva et al., 2016). For this reason, estimation of heritability coupled with genetic advance is essential for breeding programmes (Fikreselassie and Seboka, 2012; Sharma et al., 2017; Saxesena et al., 2014). High broad sense heritability was observed in days to flowering, plant height, number of pods per plant, 100-seed weight, and seed yield per plant (Bakhiet et al., 2015; Sheelamary and Shivani, 2015). Some studies reported that great genetic variation in seed mineral concentration was found among faba bean and common bean genotypes regarding seed mineral contents (Talukder et al., 2010; Baloch et al., 2014). Genotypic evaluation is significant for mineral concentration and can be increased

* Correspondence: aton@cu.edu.tr

by selection among genotypes (Bozokalfa et al., 2009; Baloch et al., 2017). The simple correlation coefficients between yield and yield components are inappropriate for determining selection criterion in crop breeding. The indicating effect and indirect effect via other traits on seed yield by using path analysis is prerequisite. Path coefficient analysis showed that 100-seed weight, number of pods per plant, and number of branches per plant had positive and direct effects on seed yield; however, plant height and days to flowering were found having direct negative effects on seed yield (Kumar et al., 2017).

Local faba bean genotypes collected from different regions of Turkey are important for cultivar breeding in Mediterranean climate conditions. Studies on faba bean breeding were limited Eastern Mediterranean region. Thus, the present study was conducted to determine the appropriate selection criteria for genotypes to improve the seed yield in faba bean. To this aim, the agronomic performances and mineral contents of some faba bean local genotypes in the Mediterranean climate conditions were investigated, and variability, heritability, and path coefficients between yield and yield components were estimated within the framework of the study.

2. Materials and methods

2.1. Experimental conditions

The study was carried out in the research area of the Department of Field Crops, Faculty of Agriculture, University of Çukurova, Adana, Turkey, for a three year period throughout the 2014/2015, 2015/2016, 2016/2017 growing seasons under rainfed conditions. The location of the research, Adana, had a typical coastal Mediterranean climate. The annual total precipitation was 625 mm and the mean temperature was 18.7 °C according to long term meteorological statistics. Meteorological values belonging to Adana for the years are presented in Table 1.

The texture of the research soil was sandy-loam. The values of pH and salt content were 7.78 and 0.33 mmhos cm^{-1}, respectively.

2.2. Plant material

Sixteen promising genotypes selected from a collection of faba bean landraces originated from Turkey provided by ICARDA (International Center for Agricultural Research in the DryArea) were used as plant material in the study. The promising genotypes obtained from Eastern Mediterranean Agricultural Research Institute, Adana were Elazığ-34, Muğla-47, Tekirdağ-65, Bursa-78, İzmir-49, Konya-36, Bursa-79, Kırklareli-64, Elazığ-35, Adana-85 (control), Burdur-50, Manisa-81, İzmir-68, Antalya-51, Tekirdağ-39, Tekirdağ-62. These landraces were local genotypes and they were named with the name of city where they are grown.

The study was conducted in a randomized complete block experimental design (RCBD) with three replications. Each local genotype was planted in 4 rows of 5 m length with an inter row spacing of 45 cm and an intra row spacing of 10 cm. The plot to plot distance was 1.80 m. Harvesting was applied in the middle of two rows after eliminating the border rows. Net plot area was 3.6 m^2 (4 × 0.9 m). Fertilizer was applied at a rate of 30 kg ha^{-1} N and 70 kg ha^{-1} P_2O_5 before seeding. The approximate planting and harvesting dates were last week of November and mid-May in all experimental years, respectively.

Seed samples (0.5 g) were taken from each block for chemical analysis in the first experimental year. Mineral element (N, P, K, Mg, Ca, Cu, Mn, Zn) analyses were carried out by using atomic absorption spectrophotometer (Seco-Gesto et al., 2007). Crude protein content was calculated by using the formula: CP = %N × 6.25 (nitrogen to protein conversion factor) (Karaca et al., 2011).

Observations were recorded on five plants that were randomly selected from each plot at maturity stage. Plant height (cm) was recorded from ground level to top of the plant. Number of grains per plant was counted in pods randomly selected from five plants. The number of pods per plant, the first podding height per plant were estimated from the same five plants. The number of branches per plant was counted in primary branches. The grain yield per plant (g) was determined from grains obtained five plants.

Table 1. Values of monthly average and total precipitation of Adana in experimental years.

Meteorological parameters	Years	November	December	January	February	March	April	May
Mean temperature (°C)	2014–2015	21.9	18.7	14.6	16.2	20.7	22.8	30.6
	2015–2016	24.6	18.8	13.4	20.2	21.7	27.5	27.1
	2016–2017	23.2	14.1	13.9	17.7	21.1	24.7	27.4
Total rainfall (mm)	2014–2015	66.5	106.4	107.5	122.0	135.1	21.5	65.7
	2015–2016	10.5	0.6	138.4	83.1	54.3	1.8	87.9
	2016–2017	11.9	147.1	52.0	0.8	65.4	65.9	45.9

The 100 grain weight (g) was recorded from random samples of 100 grains from each plot. The grain yield (kg ha^{-1}) was estimated in total weight grain obtained from each plot. Harvest index (%) was calculated using formula of grain yield/biological yield.

2.3. Statistical analysis

The data for morphological traits were analysed according to the RCBD over years using the MSTAT-C data analysis software. Comparisons among the means were made using LSD multiple range test at 0.05 probability level. Standard deviations (SD) were determined for the mineral content of each genotype by using SPSS statistical analysis program.

Phenotypic coefficients of variation (PCV%) and genotypic coefficients of variation (GCV%), broad sense heritability (h^2b%) of traits, and genetic advance in percentage of mean (GA%) were calculated with the method suggested by Blum and Lehrer (1973); Corleto (1976); Singh and Chaudhary (1985).

The phenotypic variance was calculated using following equation

$Vp = Vg+(Vgy/y)+(Ve/ry)$,

where:

Vg = genotypic variance; Vp = phenotypic variance; Ve = environmental variance, r = replication; y = years.

Vg and Ve were obtained from analysis of variance table according to (Comstock and Robinson, 1952).

$Vg = MS1–MS2/rxy$

MS1: mean square for genotype; MS2: mean square for genotype x year.

Broad heritability was estimated using following formula:

$h^2b = (Vg/Vp)\times100$

Genetic advance was calculated as following

$GA=h^2b \times K \times \sqrt{Vp}$,

where:

K = selection intensity at 5% (2.06).

GA as % of mean (GAM) = (GA/mean value) × 100.

Correlation coefficients and path coefficients analysis were done with TARPOPGEN computer-based statistics software (Ozcan and Açıkgöz, 1999). Correlation analysis was performed using three years of data together.

3. Results

3.1. Agro-morphological characters

The results of combined variance analysis over the years for yield and yield components in faba bean were given in Table 2 below.

There were significantly differences among the years, but not genotypes for plant height and first podding height. Number of branches per plant was significantly influenced by genotypes, but not by years. The other traits were affected by the genotypes and years at a significant level. None of the traits were affected by genotype × year interaction.

The mean values for plant height, first podding height of 16 local faba bean genotypes are exhibited in Table 3 below.

The values for plant height for genotypes varied from 73.7 cm (İzmir 68) to 80.1 cm (Antalya-51) by the average of years. The highest plant height was obtained in the first experimental year for this trait. The first podding height in local genotypes was ranged from 23.7 cm (Muğla-47) to 31.9 cm (Manisa-81). The first podding height was higher in the first experimental year than the other experimental years as in plant height.

The mean values for branches and pods per plant of 16 local faba bean genotypes in different experimental years are presented in Table 4 below.

The highest value for branches per plant was recorded over the years for (Elazığ-35) with 4.1 branches/plant followed by Adana-85 (control) with 3.7 branches/number, while the lowest value was obtained from İzmir-49 with 2.8 branches/plant.

Table 2. The means, range of variation and mean square of yield and grain yield components of faba bean genotypes.

Characters	Means	Range	Genotypes	Genotypes × year	Years	Error
Plantheight	77.3	75.9–80.1	34.30	32.09	35562.4**	39.100
First podding height	28.1	23.7–31.9	43.05	22.50	15984.7**	25.800
Branches number/plant	3.3	2.8–3.8	1.07**	0.40	1.749	0.368
Pods/plant	7.5	5.6–9.8	14.01**	6.70	328.07*	3.385
Grains/plant	17.9	14.2–21.8	52.35**	26.59	3336.1**	23.510
Grain yield/plant	19.7	15.1–25.4	59.19*	32.60	5263.0**	29.300
100-Grain weight	115.1	98.8–128.8	688.51**	84.67	9445.1**	73.260
Grain yield	268.0	232.1–313.7	4083.7**	1619.40	1085980.2**	1455.800
Harvest index(%)	41.9	36.6–47.5	52.18**	29.57	5406.6**	26.340

*,** significant at 5% and 1% levels, respectively.

Table 3. The mean values for plant height and first podding height of 16 local faba bean genotypes.

Genotypes	Plant height (cm)				First podding height (cm)			
	2014/15	2015/16	2016/17	Mean	2014/15	2015/16	2016/17	Mean
1.Elazığ-34	107.4	59.4	67.8	78.2	50.7	18.2	16.0	28.3
2.Muğla-47	115.6	57.2	62.3	78.4	44.2	15.3	11.7	23.7
3.Tekirdağ-65	111.2	59.8	67.0	79.3	54.6	18.0	18.6	30.7
4.Bursa-78	112.0	58.3	62.6	77.6	53.1	20.2	13.0	28.7
5.İzmir-49	106.8	58.7	65.3	76.9	46.6	19.9	15.0	27.2
6.Konya-36	111.2	51.9	61.6	74.9	57.2	16.7	17.2	30.4
7.Bursa-79	108.8	60.9	67.9	79.2	40.4	21.0	17.5	26.3
8.Kırklareli-64	107.9	59.6	64.9	77.4	52.0	21.1	19.5	30.9
9.Elazığ-35	103.5	57.2	63.7	74.8	47.6	18.0	13.3	26.3
10.Adana-85 (control)	103.6	59.1	63.3	75.3	45.4	16.8	16.9	26.4
11.Burdur-50	103.2	65.4	67.2	78.6	46.2	20.3	17.5	28.0
12.Manisa-81	109.5	61.6	68.0	79.7	53.8	20.8	21.1	31.9
13.İzmir-68	105.2	54.1	61.6	73.7	48.6	17.4	15.7	27.2
14.Antalya-51	111.6	62.2	66.5	80.1	48.7	20.9	17.4	29.0
15.Tekirdağ-39	112.5	51.1	64.2	75.9	47.0	16.5	13.9	25.8
16.Tekirdağ-62	105.5	56.6	67.3	76.5	49.8	22.4	15.0	29.1
Mean	108.5a	58.3b	65.1b	77.3	49.1a	19.0b	16.2b	28.1
CV%				8.0				18.4
LSD (5%) genotypes				N.S.				N.S.
Years				9.50				4.86
Genotype × year				N.S.				N.S.

The top mean number of pods per plant was achieved by the genotype Elazığ-34 (9.8 pods/plant) followed by Elazığ-35 (9.5 pods/plant) while the lowest value was determined in genotype Tekirdağ-65 (5.6 pods/plant) at the average of years. The number of pods in the first and third experimental years was higher than the second experimental year.

The mean values for grains per plant, and 100-grain weight of 16 local faba bean genotypes are demonstrated in Table 5.

Grains per plant varied from 14.2 (Tekirdağ-65) to 21.8 (Elazığ-34). This value was lower in the second year compared with the other experimental years.

The mean of 100-grain weight ranged between 98.8 (Konya-36) and 128.8 (Burdur-50 and Antalya-51). The 100- grain weight in the second year was lower than other years.

The mean values for grain yield per plant and grain yield of 16 local faba bean genotypes are given in Table 6.

Grain yield per plant was lower in the second experimental year, as in pods per plant grains per plant, 100 grain weight, harvest index, compared to the other experimental years. The highest grain yield per plant was achieved by Burdur-50 (25.4 g) followed by Elazığ-35 (23.7 g), whereas the lowest mean value for this trait was obtained from Tekirdağ-65 (15.1 g). Maximum grain yield was produced by Burdur-50 (3130 kg ha^{-1}), followed by Antalya-51 (2970 kg ha^{-1}), İzmir-49 (2820 kg ha^{-1}) and Bursa-78 (2800 kg ha^{-1}), while the lowest grain yield was obtained from Tekirdağ-39 (2320 kg ha^{-1}). Grain yield was lower in the second year compared with the other years.

The mean values for harvest index of 16 local faba bean genotypes are given in Table 7.

Genotype Burdur-50 had the highest harvest index with 47.5% followed by Muğla-47 (44.6 %) and İzmir-49 (44.0%). The lowest harvest index was found for Bursa-78 with 36.6%.

3.2. Mineral element content

The mean values and standard deviations for macro and microelements (N, P, K, Mg, Ca) in 16 local faba bean genotypes are presented in Table 8.

The mean phosphorus content (%) of all the faba bean genotypes was 0.41%, whereas the values varied between 0.26% (Tekirdağ-65) and 0.59% (İzmir-68). The average

Table 4. The mean values for number of branches and pods per plant of 16 local faba bean genotypes.

Genotypes	Number of branches per plant				Number of pods per plant			
	2014/15	2015/16	2016/17	Mean	2014/15	2015/16	2016/17	Mean
1.Elazığ-34	3.8	3.0	3.8	3.5 bc	11.6	4.7	13.0	9.8 a
2.Muğla-47	2.9	2.7	3.1	2.9 de	8.0	5.4	10.0	7.8 b-e
3.Tekirdağ-65	3.0	2.8	3.1	3.0 c-e	5.2	4.7	6.9	5.6 f
4.Bursa-78	3.4	3.1	3.9	3.4 b-d	8.7	4.4	9.0	7.4 c-e
5.İzmir-49	2.9	2.9	2.7	2.8e	8.7	4.7	6.8	6.7 c-f
6.Konya-36	3.6	3.4	3.2	3.4 b-d	11.8	5.6	10.8	9.4 ab
7.Bursa-79	4.4	3.2	3.0	3.5 bc	9.4	3.6	7.5	6.8 c-f
8.Kırklareli-64	3.5	3.6	2.7	3.2 b-e	8.4	4.7	7.5	6.8 c-f
9.Elazığ-35	4.5	4.0	4.0	4.1 a	13.6	4.4	10.4	9.5 ab
10.Adana-85 (control)	4.0	4.1	3.2	3.7 ab	12.0	4.4	8.6	8.3 a-c
11.Burdur-50	3.5	3.0	2.8	3.1 c-e	9.8	3.7	7.4	7.0 c-f
12.Manisa-81	3.2	3.5	3.2	3.3 b-e	7.4	3.8	7.8	6.3 ef
13.İzmir-68	3.4	3.2	2.4	3.0 c-e	8.5	4.1	6.0	6.2 ef
14.Antalya-51	3.4	2.7	3.2	3.1 c-e	6.7	5.4	7.5	6.5 d-f
15.Tekirdağ-39	2.9	2.5	3.6	3.0 c-a	8.2	4.2	12.0	8.1 a-d
16.Tekirdağ-62	3.8	3.2	3.2	3.4 b-d	8.2	3.4	9.6	7.1 c-f
Mean	3.5	3.2	3.2	3.3	9.1a	4.4 b	8.8 a	7.4
CV%				18.2				14.5
LSD (5%) Genotypes				0.56				1.72
Years				N.S.				1.96
Genotype × Year				N.S.				N.S.

value of potassium content was 1.79%. The maximum value was obtained from (Tekirdağ-65) with 2.18%, while minimum value was attained from (Kırklareli-64) with 1.49%. The mean value for Mg content was 0.32% and the values ranged between 0.29% (Tekirdağ-62) and 0.36% (Tekirdağ-65). The mean of calcium content of all the genotypes was found to be 0.54% and the highest value was 0.59% (Tekirdağ-65), while the lowest value was 0.50% (Tekirdağ-62). The mean nitrogen content was 6.3%, while the maximum value was found to be 7.20% (Elazığ-34) and the minimum value was 5.22% (Adana-85).

The mean values and standard deviations for microelements (Cu, Mn, Zn, Fe) and crude protein in 16 local faba bean genotypes are presented in Table 9.

Protein content was recorded 39.38% as the mean of the all genotypes and the values varied from 32.65% (Adana-85) to 44.98% (Elazığ-34). The mean of Cu contents was 18.28 mg $kg^{-1}$and the values ranged between 8.63 mg kg^{-1}(Kırklareli-64) and 31.07 mg kg^{-1} (Tekirdağ-62). Mn contents were found to be between 12.96 mg kg^{-1}(Konya-36) and 25.41 mg kg^{-1} (Adana-85) and the mean value of the all genotypes was 20.36 mg kg^{-1}. Zn contents in genotypes were higher than other micronutrients except for Fe. The mean value was 45.10 mg kg^{-1} and varied from 36.55 mg kg^{-1} (Muğla-47) to 55.17 mg kg^{-1} (Antalya-51). The highest micronutrient was found for iron and the values ranged between 71.13 mg kg^{-1}(Elazığ-34) and 109.00 (Bursa-79) mg kg^{-1}. The mean value for Fe concentration was 84.54 mg kg^{-1}.

Mg, Ca contents were higher in genotypes Tekirdağ-65 and Konya-36 compared with Adana-85 (local). Genotypes Elazığ-34 and Muğla-47 had high protein content, while Bursa-79 and Antalya-51 were rich for Fe and Zn. The wide diversity for macro- and microelements in the studied genotypes can be benefited for improving new faba bean cultivars in Mediterranean climate conditions.

3.3. Genetic variability and heritability

Genetic variability and broad sense heritability for quantitative traits are presented in Table 10.

The highest phenotypic coefficient of variation (PCV%) was calculated for number of pods per plant (16.59%), followed by grains per plant (13.40%) and grain yield per plant (13.01%). Moderate PCV was estimated for number of branches per plant (10.00 %). Plant height

Table 5. The mean values for grains per plant and 100-grain weight of 16 local faba bean genotypes.

Genotypes	Number of grains per plant				100-grain weight (g)			
	2014/15	2015/16	2016/17	Mean	2014/15	2015/16	2016/17	Mean
1.Elazığ-34	27.0	9.1	29.3	21.8 a	119.9	102.1	127.8	116.6 b-e
2.Muğla-47	22.2	10.0	22.3	18.1 a-e	132.3	100.1	115.8	116.1 b-e
3.Tekirdağ-65	16.1	9.2	17.3	14.2 e	110.3	100.5	111.2	107.3 fg
4.Bursa-78	24.4	7.8	19.4	17.2 b-e	118.3	91.6	117.4	109.1 ef
5.İzmir-49	25.4	9.5	17.2	17.4 a-e	139.4	99.7	133.1	124.0 ab
6.Konya-36	30.5	9.2	25.1	21.6 ab	102.9	71.5	112.0	98.8 h
7.Bursa-79	23.6	8.3	18.8	16.9 c-e	129.9	107.1	128.5	121.8 a-c
8. Kırklareli-64	24.7	9.0	18.6	17.4 a-e	120.8	102.0	126.7	116.5 b-e
9.Elazığ-35	34.0	8.5	22.5	21.6 ab	121.4	99.3	120.7	113.8 df
10.Adana-85 (control)	26.8	9.0	20.1	18.6 a-e	119.9	101.5	126.4	116.0 c-e
11.Burdur-50	29.9	8.5	21.8	20.1 a-c	140.0	117.1	129.4	128.8 a
12.Manisa-81	18.7	7.0	17.7	14.5 e	129.0	97.8	127.7	118.2 b-d
13.İzmir-68	24.8	9.0	16.0	16.6 c-e	131.2	94.8	124.4	116.8 b-e
14.Antalya-51	19.5	8.4	17.6	15.2 de	143.0	111.4	131.9	128.8 a
15.Tekirdağ-39	22.9	7.6	26.6	19.0 a-d	111.3	79.0	109.5	99.9 g-h
16.Tekirdağ-62	23.1	7.4	20.2	16.9 c-e	112.2	97.6	118.4	109.4 ef
Mean	24.4 a	8.6b	20.6 a	17.9	123.9 a	98.9 b	122.6 a	115.1
CV%				16.9				7.4
LSD (%5) genotypes				4.54				8.01
Years				4.57				12.6
Genotype × year				N.S.				N.S.

Table 6. The mean values for grain yield per plant and grain yield of 16 local faba bean genotypes.

Genotypes	Grain yield per plant (g)				Grain yield (kg ha^{-1})			
	2014/15	2015/16	2016/17	Mean	2014/15	2015/16	2016/17	Mean
1.Elazığ-34	28.2	7.9	31.6	22.6 a-c	3810	1006	3400	2740 b-d
2.Muğla-47	25.9	8.9	26.4	20.4 a-d	3630	927	2750	2430 de
3.Tekirdağ-65	19.6	8.8	17.0	15.1 e	3650	957	2890	2500 c-e
4.Bursa-78	27.8	6.3	20.7	18.2 c-e	4210	1193	3020	2800 a-c
5.İzmir-49	29.7	7.8	22.8	20.1 b-e	3840	1103	3540	2820 a-c
6.Konya-36	25.8	7.1	25.1	19.3 b-e	3210	705	3520	2480 a-d
7.Bursa-79	28.0	7.9	22.0	19.3 b-e	3710	950	3660	2770 b-d
8.Kırklareli-64	28.2	9.8	21.0	19.6 b-e	3790	1039	3410	2750 b-d
9.Elazığ-35	37.8	7.0	26.3	23.7 ab	3550	942	3420	2640 b-e
10.Adana-85 (control)	26.3	8.4	25.6	20.1 b-e	3790	1017	3550	2780 a-d
11.Burdur-50	28.8	8.1	29.2	25.4 a	4440	1257	3710	3130 a
12.Manisa-81	21.4	6.7	21.3	16.5 de	3660	758	3390	2600 b-e
13.İzmir-68	17.6	7.2	19.6	18.1 c-e	3720	899	3220	2610 b-e
14.Antalya-51	28.3	9.0	22.2	19.8 b-e	4320	1125	3480	2970 ab
15.Tekirdağ-39	20.6	5.8	26.0	17.5 de	3610	701	2640	2320 e
16.Tekirdağ-62	26.2	7.7	23.0	19.0 b-e	3340	856	3200	2460 c-e
Mean	27.5 a	7.8 b	23.7 a	19.7	3770 a	960 c	3300 b	2680
CV%				17.4				15.10
LSD (%5) genotypes				5.0				376
Years				4.5				234
Genotype × year				N.S.				N.S.

Table 7. The mean values for harvest index of 16 local faba bean genotypes.

Genotypes	Harvest index (%)			
	2014/15	2015/16	2016/17	Mean
1.Elazığ-34	39.6	38.0	50.6	42.8 ab
2.Muğla-47	40.5	39.8	53.6	44.6 ab
3.Tekirdağ-65	38.3	34.8	48.6	40.6 bc
4.Bursa-78	35.4	24.3	50.0	36.6 c
5.İzmir-49	41.5	33.5	57.0	44.0 ab
6.Konya-36	34.6	30.4	56.0	40.3 bc
7.Bursa-79	39.7	32.6	52.6	41.6 b
8.Kırklareli-64	38.6	37.3	52.0	42.6 b
9.Elazığ-35	41.2	33.9	56.3	43.8 ab
10.Adana-85	36.3	28.8	59.0	41.3 bc
11.Burdur-50	45.5	38.0	59.0	47.5 a
12.Manisa-81	37.1	28.3	56.0	40.4 bc
13.İzmir-68	42.7	30.4	50.0	41.0 bc
14.Antalya-51	40.5	34.2	50.0	41.5 b
15.Tekirdağ-39	34.3	32.6	54.6	40.5 bc
16.Tekirdağ-62	38.1	31.4	53.3	40.9 bc
Mean	39.0 b	33.0 c	53.6 a	41.9
CV%				12.2
LSD (5%) genotypes				4.80
Years				4.27
Genotype × year				N.S.

(2.52%), harvest index (5.74%), 100-grain weight (7.59%), first podding height (7.78%), and grain yield (7.94 %) had lower magnitude of PCV. The highest genotype coefficient of variation was observed for pods per plant (12.00%), while the lowest value was determined in plant height (0.63%). Moderate estimates of GCV were observed for grains per plant (9.44%), grain yield per plant (8.71%), and branches per plant (8.01%). First podding height (5.37%) and harvest index (3.78%) had lower GCV than other traits. Broad sense heritability was estimated between 6.3% (plant height) and 87.7% (100-grain weight). Branches per plant (63.6%), grain yield (60.3%), pods per plant (52.3%), grains per plant (49.2%), grain yield per plant (44.9%), harvest index (43.3%) and first podding height (47.6%) exhibited high or moderate heritability. Genetic advance in percentage of mean varied from 0.33% (plant height) to 17.88% (pods per plant).

3.4 Correlations and path analysis

Correlation coefficients between grain yield and yield components, direct and indirect effects, and contributions (%) of various traits to grain yield are presented in Table 11.

Grain yield was positively and significantly correlated with plant height (0.582**), branches per plant (0.327**), pods per plant (0.395**), grains per plant (0.469**), 100-grain weight (0.586**), grain yield per plant (0.467**). There were no significant correlations between grain yield and harvest index (0.186), first podding height (0.068) as seen in Table 11.

The results of path analysis revealed that plant height (59.4%), branches per plant (42.9%), 100-seed weight (44.4%), and first podding height (33.1 %) had positive high direct effects on the grain yield. Direct effect of pods per plant, grains per plant, and harvest index was low and positive (21.1%, 17.9%, and 16.9%, respectively). Harvest index showed a great indirect effect through plant height and 100-grain weight (22.1% and 20.4%, respectively). Grains per plant and grain yield per plant had a great indirect positive effect on grain yield via 100-grain weight (24.1%,and 24.9 respectively).

4. Discussion

Plant height was higher in the first year than in the remaining years due to the greater rainfall in the vegetative

Table 8. The mean values and standart deviations for some mineral matters in 16 local faba bean genotypes.

Genotypes	P (%)		K (%)		Mg (%)		Ca (%)			N (%)
	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD
1.Elazığ-34	0.44	0.009	1.73	0.020	0.34	0.036	0.55	0.025	7.20	0.031
2.Muğla-47	0.31	0.007	1.69	0.025	0.33	0.015	0.56	0.025	7.03	0.153
3.Tekirdağ-65	0.26	0.002	2.18	0.015	0.36	0.015	0.59	0.015	6.38	0.010
4.Bursa-78	0.36	0.001	1.95	0.010	0.33	0.010	0.55	0.015	6.79	0.010
5.İzmir-49	0.45	0.001	1.88	0.010	0.34	0.010	0.55	0.015	6.36	0.031
6.Konya-36	0.43	0.002	1.86	0.010	0.33	0.020	0.58	0.020	6.46	0.021
7.Bursa-79	0.40	0.002	1.66	0.021	0.34	0.015	0.57	0.010	6.35	0.020
8.Kırklareli-64	0.47	0.003	1.49	0.002	0.32	0.020	0.53	0.015	5.56	0.025
9.Elazığ-35	0.51	0.003	1.50	0.003	0.32	0.020	0.54	0.015	6.17	0.020
10.Adana-85 (control)	0.39	0.002	1.92	0.002	0.31	0.026	0.54	0.020	5.22	0.059
11.Burdur-50	0.42	0.020	1.53	0.004	0.30	0.025	0.54	0.015	6.26	0.025
12.Manisa-81	0.54	0.002	1.89	0.002	0.34	0.010	0.53	0.015	6.00	0.025
13.İzmir-68	0.59	0.003	2.06	0.003	0.32	0.025	0.55	0.010	5.98	0.015
14.Antalya-51	0.29	0.003	2.04	0.017	0.30	0.025	0.54	0.015	6.49	0.020
15.Tekirdağ-39	0.33	0.003	1.88	0.003	0.32	0.021	0.53	0.030	6.38	0.030
16.Tekirdağ-62	0.46	0.002	1.53	0.025	0.29	0.015	0.50	0.015	6.19	0.015
Mean	0.41		1.79		0.32		0.54		6.30	
Min.	0.26		1.49		0.29		0.50		5.22	
Max.	0.59		2.18		0.36		0.59		7.20	
SD	0.09		0.21		0.02		0.02		0.49	

stage compared to the other experimental years. Field emergence date of genotypes in the second year due to late rainfall after sowing was later (January 5) compared with other years. Also, lower rainfall (1.8 mm) and higher mean temperature (27.5 °C) during the pod filling stage in April may have decreased the grain yield and yield components. Generative growth in the second year was poorer than other years. Therefore, pods per plant, grains per plant, 100-grain weight, grain yield, and harvest index in the second year were also lower than the other years. Some studies reported that heath stress during floral development reduced the seed yield of faba bean (Abdelmula and Abuanja, 2007; Bishop et al., 2016). Türkeri (2016) reported that grain yield varied from 2337 kg ha^{-1} to 2360 kg ha^{-1} in local faba bean genotypes according to years.

The range of macroelement was narrow compared to micro elements. The values of mineral content obtained in the study were in disagreement with the values found in other studies (Ali et al., 2014; Balochet al., 2014). The observed various in chemical composition may be due to differences in plant material, climate and soil conditions (Gunathilake et al., 2016; Abdul Rahman, 2018). The local genotypes had wide ranges for Cu, Fe, Zn, and protein content. Tekirdağ-65 had the highest value for K, Mg, and Ca content. The wide genetic variation for macro- and microelements in the various legumes was reported by some studies (Talukder et al., 2010; Karaköy et al., 2012; Baloch et al., 2014; Baloch et al., 2017). High variation in faba bean local genotypes provides good opportunities for breeding.

The highest genotype coefficient of variation was observed for pods per plant. High GCV value of pods per plant showed the possibility of improving this trait through selection (Bakhiet et al., 2015). Phenotypic coefficient of variation was greater than the genotypic coefficient of variation for all characters. PCV values were generally close to GCV values. These traits were slightly influenced by the environment (Ahmad et al., 2014; Bakhietet al., 2015). High broad sense heritability was estimated for 100-seed weight and branches per plant. Other traits exhibited moderate heritability. The results were in accordance with the findings by Mulualem et al. (2013), Bakhiet et al. (2015), Sharifi (2015). Heritability coupled genetic advance should be considered for successful selection (Fikreselassie and Seboka, 2012). The estimations of heritability coupled

Table 9. The mean values and standart deviations for some mineral matters and crude protein in 16 local faba bean genotypes.

Genotypes	Crude protein (%)		Cu (mg kg^{-1})		Mn (mg kg^{-1})		Zn (mg kg^{-1})		Fe (mg kg^{-1})	
	x̄	SD	x̄	SD	x̄	SD	x̄	SD	x̄	SD
1.Elazığ-34	44.98	0.191	18.45	0.42	19.46	0.258	39.37	0.217	71.13	0.306
2.Muğla-47	43.96	0.955	15.09	0.06	21.67	0.252	36.55	0.030	74.03	0.085
3.Tekirdağ-65	39.88	0.063	18.63	0.01	20.16	0.015	43.96	0.010	78.31	0.015
4.Bursa-78	42.44	0.063	16.53	0.02	18.94	0.015	45.46	0.015	86.05	0.010
5.İzmir-49	39.73	0.191	18.36	0.03	21.15	0.015	49.87	0.015	92.29	0.015
6.Konya-36	40.35	0.130	16.25	0.02	12.96	0.015	52.36	0.020	76.26	0.020
7.Bursa-79	39.69	0.125	21.92	0.03	21.04	0.015	44.78	0.025	109.0	0.085
8.Kırklareli-64	34.73	0.157	8.63	0.04	19.23	0.025	41.24	0.040	81.47	0.021
9.Elazığ-35	38.56	0.125	22.36	0.01	19.53	0.015	40.82	0.015	75.71	0.021
10.Adana-85	32.65	0.366	16.85	0.02	25.41	0.025	48.84	0.025	90.46	0.025
11.Burdur-50	39.10	0.157	12.74	0.02	21.07	0.040	48.76	0.031	79.23	0.021
12.Manisa-81	37.52	0.157	15.07	0.03	20.28	0.020	50.22	0.015	93.79	0.020
13.İzmir-68	37.35	0.095	16.32	0.03	18.70	0.015	39.88	0.025	75.88	0.020
14.Antalya-51	40.56	0.125	21.03	0.02	21.48	0.010	55.17	0.015	101.22	0.025
15.Tekirdağ-39	39.88	0.188	23.23	0.03	24.08	0.026	41.85	0.026	79.19	0.025
16.Tekirdağ-62	38.71	0.095	31.07	0.03	20.63	0.020	42.59	0.453	88.66	0.035
Mean	39.38		18.28		20.36		45.10		84.54	
Min.	32.65		8.63		12.96		36.55		71.13	
Max.	44.98		31.07		25.41		55.17		109.0	
SD	3.06		5.05		2.66		5.26		10.63	

genetic advance indicate additive and non additive gene effect for expression of traits (Saxesena et al., 2014). Genetic advance in percentage of mean and heritability was lowest for plant height. Similar to our findings, Hamza et al. (2017) reported that plant height had low heritability (5.70%) and genetic advance as a percent of mean. In the present study, 100-grain weight and branches per plant had high heritability and genetic advance as a percentage of mean. Influences of additive gene were great while environmental effects were little for these traits. Hence, an effective selection for mentioned traits can be made in an effort to increase grain yield in faba bean. High or medium heritability estimates for 100-grain weight were recorded in earlier studies (Aziz and Osman, 2015; Sheelamary and Shivani, 2015; Hamza et al., 2017). The pods per plant and grain yield per plant had moderate heritability and genetic advance as a percentage of mean. Additive gene and non additive gene action were effective, while the environmental effects were relatively little for these traits. Moderate heritability coupled low genetic advance was found for harvest index and first podding height because of low genotypic and phenotypic variance. The effect of epistatic gene action on these traits may account for this result. Hence, these traits were more affected by the environment and successful selection for these traits may not be rewarding.

The grain yield was positively and significantly correlated with plant height, branches per plant, pods per plant, grains per plant, 100-grain weight, grain yield per plant. Similar results were reported in faba bean and different legume crops such as pea and vetch (Badolay, et al., 2009; Sayar, 2014; Sheelamary and Shivani, 2015; Türkeri, 2016; Kumar et al., 2017; Sharma et al., 2017). However, in contrast to our finding, Abdulmela and Abuanja (2007) reported that they observed negative and significant correlations between seed yield and 100-grain weight.

The results of path analysis revealed that plant height, branches per plant and 100-grain weight had positive high direct effects on the grain yield. The results were in close agreement with the findings of some other reports (Sharifi, 2014; Sharifi, 2015; Sharma et al., 2017; Kumar et al., 2017; Khan et al., 2017) and thus, these traits can be used as selection criteria for improving grain yield in faba bean.

Table 10. Some genetic parameters for quantative characters in faba bean.

Characters	Vg	Vp	GCV(%)	PCV(%)	h^2 b(%)	GAM(%)
Plantheight	0.24	3.81	0.63	2.52	6.3	0.33
First podding height	2.28	4.78	5.37	7.78	47.6	7.62
Branches/plant	0.07	0.11	8.01	10.00	63.6	13.16
Pods/plant	0.81	1.55	12.00	16.59	52.3	17.88
Grains/plant	2.86	5.81	9.44	13.40	49.2	13.64
Grain yield/plant	2.95	6.57	8.71	13.01	44.9	12.03
100-grain weight	67.0	76.50	7.11	7.59	87.7	13.72
Grain yield	273.8	453.70	6.17	7.94	60.3	9.87
Harvest index	2.51	5.79	3.78	5.74	43.3	5.12

Vg: genotypic variance; Vp: phenotypic variance; GCV (%): genotypic coefficient of variation; PVC (%): phenotypic coefficient of variation; h^2 b (%): broad sense heritability; GAM (%): genetic advance in percentage of mean (5% selection intensity).

Table 11. Direct, indirect effects and contributions % of variations characters to grain in faba bean.

Character	Correlation coefficient	Direct effect	1	2	3	4	5	6	7	8
1.PH	0.582**	0.473	1.000	0.010	–0.102	0.052	0.057	0.060	0.035	–0.003
		59.4%		1.2%	12.9%	6.5%	7.2%	7.6%	4.4%	0.4%
2.FPH	0.068 ns	0.088	0.054	1.000	–0.042	0.014	0.041	0.020	–0.002	0.002
		33.1%	0.2%		16.0%	5.3%	15.3%	7.6%	0.9%	1.0%
3.BPP	0.327**	0.287	–0.169	0.013	1.000	0.046	0.045	0.054	0.050	0.002
		42.9%	25.4%	1.9%		6.8%	6.7%	8.2%	7.4%	0.2%
4.PPP	0.395**	0.175	–0.141	0.007	–0.075	1.000	0.122	0.134	0.169	0.003
		21.1%	17.0%	0.8%	9.0%		14.7%	16.2%	20.4%	0.4%
5.GPP	0.469**	0.169	–0.161	0.02	–0.076	0.126	1.000	0.156	0.228	0.005
		17.9%	17.1%	2.2%	8.1%	13.3%		16.5%	24.1%	0.5%
6.GYPP	0.467**	0.193	–0.149	0.009	–0.081	0.121	0.137	1.000	0.231	0.04
		20.8%	16.0%	1.0%	8.7%	13.1%	14.7%		24.9%	0.4%
7.100 GW	0.586**	0.342	–0.049	0.0006	–0.04	0.086	0.113	0.130	1.000	0.004
		44.4%	6.4%	0.1%	5.4%	11.2%	14.7%	16.9%		0.6%
8.HI	0.186 ns	0.036	0.048	0.007	–0.015	0.017	0.024	0.023	0.044	1.000
		16.9%	22.1%	3.2%	7.0%	8.1%	11.0%	10.9%	20.4%	

ns: non-significant, **$p < 0.01$.
1.PH: plant height (cm), 2.FPH: first podding height (cm), 3.BPP: branches per plant, 4.PPP: pods per plant, 5.GPP: grain per plant, 6. GYPP: grain yield per plant (g), 7.100 GW: 100 grain weight (g), 8.HI: harvest index (%)

Direct effect of pods per plant, grains per plant and grain yield per plant was low and positive. These characters showed a great indirect positive effect via 100 grain weight.

5. Conclusion

This study showed that maximum grain yield was produced by genotype Burdur-50 followed by Antalya-51, İzmir-49, and Bursa-78. Ranges for macroelements were narrow compared to micro elements. Yet, the faba bean local genotypes had wide ranges for Cu, Fe, Zn, and protein content. Wide diversity for macro- and microelement in the studied genotypes can be considered for developing new faba bean cultivars in Mediterranean climate conditions. The 100-grain weight and the primary branches per plant

had higher heritability and genetic advance as a percentage of mean than other traits. Influences of additive gene were great and environmental effects were little on these traits. According to the results of path analysis; plant height, branches per plant and 100-grain weight have major role in improving grain yield of faba bean.

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