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Determination of Turkish Common Bean Germplasm for Morpho-agronomic and Mineral Variations for Breeding Perspectives in Turkey

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ABSTRACT

Turkey is lavished with hundreds of common bean landraces. The present study was aimed to investigate the agronomic and mineral variations in 80 common bean landraces collected from 11 different provinces of Turkey. Genotypic variation expressed as a range for some traits like days to maturity (90-141 days), plant height (25.25-361.50 cm), 1000 seeds weight (140-633 g), Iron (66.48-128.05 mg kg^{-1}), and Zinc (20.56-42.01 mg kg^{-1}). Positive and highly significant correlation of Magnesium with Iron and Zinc was observed and analytic results derived from the first 3 eigenvectors suggested that days to pod setting, Zinc, and 1000 seeds weight were main variation contributing traits. Among the provinces, landraces from Tunceli performed well for agronomic traits and Malatya provinces landraces were found enrich for mineral traits. Landraces E-26 and S-19 reflected higher Fe and Zn contents, and higher yield, respectively. Cluster analysis divided the studied germplasm on the basis of plant height and geographic. Information provided herein can be helpful for the development of candidate varieties having higher yield with greater mineral contents.

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Türkiye'deki Islah Çalışmaları İçin Türk Fasulye Genetik Kaynaklarının Morfo-Agronomik ve Mineral İçerik Varyasyonlarının Belirlenmesi

ÖZET

Türkiye yüzlerce farklı fasulye popülasyonuna sahiptir. Bu çalışmada, Türkiye'nin 11 farklı ilinden toplanmış 80 fasulye popülasyonunun agronomik ve mineral varyasyonlarının araştırılması amaçlanmıştır. Genotipik varyasyonun; olgunlaşma gün sayısı (90-141 gün), bitki boyu (25.25-361.50 cm), 1000 tohum ağırlığı (140-633 g), demir (66.48-128.05 mg kg^{-1}) ve çinko (20.56-42.01 mg kg^{-1}) arasında değiştiği tespit edilmiştir. Magnezyum, demir ve çinko ile pozitif ve oldukça anlamlı bir korelasyon göstermiş ve ilk 3 öz değerden elde edilen analitik sonuçlar, bakla bağlama gün sayısı, çinko ve 1000 tane ağırlığının varyasyona katkı yapan ana özellikler olduğunu ortaya koymuştur. İller arasında, Tunceli popülasyonları agronomik özellikler, Malatya popülasyonlarının ise mineral özellikler bakımından zengin olduğu tespit edilmiştir. E-26 ve S-19 fasulye popülasyonları yüksek demir, çinko ve verim özelliklerine sahip olmuşlardır. Kümeleme analizi, genetik kaynakları bitki boyu ve coğrafik özelliklerine göre ayırmıştır. Elde edilen bulguların, yüksek verim ve mineral içeriğe sahip aday çeşitlerin geliştirilmesinde kullanılabileceği düşünülmektedir.

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INTRODUCTION

Access to well-balanced food in sufficient quantity is a fundamental right of every human being on this planet. However, still it is reported that every day 800 million peoples living in developing countries go to bed hungry (Khush et al., 2012). It is estimated that half of the world population is facing micronutrient malnutrition or commonly known as hidden hunger and becomes serious challenge for the whole world. Deficiencies of important vitamins and minerals in the food are the main cause of malnutrition and vitamin A, Zinc (Zn) and Iron (Fe) are main components mainly deficient in the food of developing countries (Ronoh et al., 2017). Beside the malnutrition problems, the world population is increasing much faster and it is expected to be three times as much of today, or over by three times more, or by exceeding of 2.3 billion, between 2009-2050 (Godfray et al., 2010). Therefore, there is a need to boost the world production by 60-110% to meet the food demand in 2050 as well as to meet the nutritional requirement of 870 million peoples that are chronically undernourished (FAO, 2012). To mitigate these problems, there is need to harness the genetic diversity by charactering the germplasm and applying biofortification methodologies to produce higher food with greater nutritional quality. Among the various nutritionally important crops, common bean (*Phaseolus vulgaris* L.) is most widely grown legume crop nearly all around the world and source of high-quality nutrients for more than 300 million peoples (Petry et al., 2015). It is a good source of protein, vitamins, and minerals and known as “poor men’s meat” (Blair, 2013). Turkey is considered one of the best region of agriculture due to its geographic and climatic advantages (Arystanbekkyzy et al., 2018; Baloch et al., 2017). Annual common bean production of Turkey was 212.758 tons (FAO, 2010), and nearly 23 million × 106 tons of common bean was produced globally worldwide during 2012, making Turkey the 3rd most producer globally. During 2016, Turkey produced 651.094 tons sharing about 2.75% of total world production (FAO, 2016). Hundreds of common bean landraces are in use by the small farmers for their in-house activities and ultimately playing a key role in the country annual production (Aydin and Baloch, 2018; Nadeem et al., 2018; Yeken et al., 2018a). Different studies were conducted to explore the phenotypic variations and the micronutrients diversity in the common bean germplasm all around the world (Blair et al., 2009; Celmeli et al., 2018; Stoilova et al., 2013; Boros et al., 2014; Yeken et al., 2018a; Yeken et al.,2018b). Aim of this study was to explore the morpho-agronomic and mineral variations of Turkish common bean more comprehensively using greater germplasm.

MATERIALS and METHODS

Plant Material

Germplasm collections were assembled consisting of natural populations of 80 common bean (*Phaseolus vulgaris* L.) landraces collected from various farmers’ fields in different provinces (Bingöl, Bitlis, Tokat, Samsun, Elazığ, Hakkari, Van, Malatya, Muş, Sivas and Tunceli) of Turkey. The collection sites involved a variety of natural eco-geographical areas under different latitudes (Table 1) and variable ecological conditions.

Table 1. Passport data of Turkish common bean accessions used in this study.

Accession Number	Names of Landraces	Collection Site	District	Village	Altitude (m)	Coordinates
1	Bn-08	Bingöl	Merkez	Alatepe	1154 m	39º 03502/40º 45401
2	Bn-12	Bingöl	Merkez	Çobantaşi	1542 m	39º 04033 / 40º 48557
3	Bn-23	Bingöl	Kiğı	Güneyağıl	1489 m	39º 17427 / 40⁰ 20136
4	Bn-50	Bingöl	Yedisu	Kürdan	-	-
5	Bt-38	Bitlis	Hizan	Soğuksu	1365 m	38º 06783 / 42º 33292
6	Bt-56	Bitlis	Tatvan	Topköy	1752 m	38º 24217 / 42º 16295
7	Bt-68	Bitlis	Mutki	Kavakbaşi	1303 m	38º 28884 / 41º 48924
8	Bt-73	Bitlis	Mutki	Çiftlikyol	1259 m	38º 30098 / 41º 46302
9	Bt-123	Bitlis	Güroymak	Yazlıkonak	1615 m	38º 19739 / 42º 14841
10	E-01	Tokat	Turhal	Çaylı	493 m	40° 40 / 36° 40
11	E-03	Tokat	Turhal	Eriklitekke	493 m	40° 40 / 36° 40
12	E-04	Tokat	Turhal	Şatıroba	493 m	40° 40 / 36° 40
13	E-05	Tokat	Turhal	Şenyurt	493 m	40° 40 / 36° 40
14	E-06	Tokat	Zile	Merkez	740 m	40°19 / 35° 27
15	E-07	Tokat	Zile	Kozdere	740 m	40°19 / 35° 27
16	E-10	Tokat	Zile	Büyükaköz	740 m	40°19 / 35° 27
17	E-11	Tokat	Zile	Derebaşı	740 m	40°19 / 35° 27
18	E-12	Tokat	Zile	Güzelbeyli	740 m	40°19 / 35° 27
19	E-14	Tokat	Zile	Söğütözü	740 m	40°19 / 35° 27
20	E-15	Tokat	Başçiftlik	Merkez	1459 m	40° 330 / 37° 100
21	E-17	Tokat	Başçiftlik	Hatipli	1459 m	40° 330 / 37° 100

22	E-21	Tokat	Başçiftlik	Asar	1459 m	40° 330 / 37° 100
23	S-12	Tokat	Zile	Çiftliköy	740 m	40°19 / 35° 27
24	T-78	Tokat	Almus	Üçgöl	835 m	40° 220 / 36° 550
25	T-82	Tokat	Erbaa	Akça	248 m	40° 300 / 36° 300
26	T-86	Tokat	Erbaa	Cibril	248 m	40° 300 / 36° 300
27	T-88	Tokat	Erbaa	Küplüce	248 m	40° 300 / 36° 300
28	T-89	Tokat	Turhal	Merkez	493 m	40° 40 / 36° 40
29	T-90	Tokat	Turhal	Akçatarla	493 m	40° 40 / 36° 40
30	T-91	Tokat	Zile	Merkez	740 m	40°19 / 35° 27
31	T-92	Tokat	Zile	Kozdere	740 m	40°19 / 35° 27
32	E-23	Samsun	Kavak	Başalan	600 m	41° 425 / 36° 225
33	E-24	Samsun	Kavak	Karaaslan	600 m	41° 425 / 36° 225
34	E-25	Samsun	Kavak	Kazancı	601 m	41° 425 / 36° 226
35	E-26	Samsun	Kavak	Köseli	602 m	41° 425 / 36° 227
36	E-29	Samsun	Kavak	Tepecik	603 m	41° 425 / 36° 228
37	E-30	Samsun	Kavak	Yenigün	604 m	41° 425 / 36° 229
38	E-31	Samsun	Kavak	Yeralan	605 m	41° 425 / 36° 230
39	E-32	Samsun	Tekkeköy	Merkez	240 m	41° 310 / 35° 350
40	El-11	Elazığ	Maden	Gezin	1266 m	38º 31233 / 39º 31880
41	Hk-08	Hakkâri	Merkez	Otluca	2096 m	37^{0} 36105 / 43^{0} 41643
42	Hk-18	Hakkâri	Merkez	Üzümcü	1135 m	37^{0} 29773 / 43^{0} 34389
43	Hk-33	Hakkâri	Merkez	Bay	1832 m	37^{0} 32687 / 43^{0} 43333
44	Hk-77	Hakkâri	Merkez	Bay	1832 m	37º 32687 / 43º 43333
45	Vn-16	Van	Çatak	Bilgi	1702 m	38º 05736 / 43º 15575
46	Vn-28	Van	Başkale	Albayrak	2072 m	38º 08452 / 44º 12332
47	Vn-48	Van	Çatak	Merkez	1502 m	38º 00451 / 43º 03619
48	Ml-20	Malatya	Doğanşehir	Elmalı	1410 m	38^{0} 03339 / 37^{0} 44688
49	Ml-30	Malatya	Doğanşehir	Güroba	1459 m	38^{0} 05052 / 37º 57494
50	Ml-44	Malatya	Akçadağ	Ören	1158 m	38^{0} 14905 / 37^{0} 55605
51	Ml-60	Malatya	Doğanşehir	Kurucaova Bel.	1369 m	37^{0} 59707 / 38º 01503
52	Ms-24	Muş	Hasköy	Merkez	1350 m	38º 37925 / 41º 45735
53	S-14	Sivas	Akıncılar	Ortaköy	1114 m	40°44908 / 38° 20499
54	S-19	Sivas	Akıncılar	Sapanlı	1114 m	40°44908 / 38° 20499
55	S-22	Sivas	Doğanşar	Merkez	1297 m	40° 130 / 37° 327
56	S-23	Sivas	Doğanşar	Alan	1298 m	40° 130 / 37° 328
57	S-26	Sivas	Doğanşar	Ortaköy	1299 m	40° 130 / 37° 329
58	S-29	Sivas	Hafik	Merkez	1350 m	39° 510 / 37° 230
59	S-31	Sivas	Hafik	Yakaboyu	1350 m	39° 510 / 37° 230
60	S-32	Sivas	Hafik	Tepeköy	1350 m	39° 510 / 37° 230
61	S-33	Sivas	Hafik	Gülpınar	1350 m	39° 510 / 37° 230
62	S-35	Sivas	Kangal	Akpınar	1540 m	39° 130 / 37° 240
63	S-36	Sivas	Kangal	Aktepe	1540 m	39° 130 / 37° 240
64	S-38	Sivas	Kangal	Tatlıpınar	1540 m	39° 130 / 37° 240
65	S-39	Sivas	Divriği	Merkez	1250 m	39° 240 / 38° 70
66	S-41	Sivas	Divriği	Arıkbaşı	1250 m	39° 240 / 38° 70
67	S-42	Sivas	Divriği	Bahçeli	1250 m	39° 240 / 38° 70
68	S-43	Sivas	Divriği	Günbahçe	1250 m	39° 240 / 38° 70
69	S-48	Sivas	İmranlı	Gökdere	1650 m	39° 5248 / 38° 758
70	S-49	Sivas	İmranlı	Toklucak	1650 m	39° 5248 / 38° 758
71	S-51	Sivas	Yıldızeli	Merkez	1400 m	39° 5248 / 36° 379
72	S-52	Sivas	Yıldızeli	Akpınar	1400 m	39° 5248 / 36° 379
73	S-58	Sivas	Yıldızeli	Banaz	1400 m	39° 5248 / 36° 379
74	S-59	Sivas	Yıldızeli	Menteşe	1400 m	39° 5248 / 36° 379
75	S-61	Sivas	Zara	Merkez	1285 m	39°45 /37°1
76	S-63	Sivas	Zara	Büyükköy	1285 m	39°45 /37°1
77	S-64	Sivas	Zara	Bolucan	1285 m	39°45 /37°1
78	S-66	Sivas	Gemerek	Merkez	1150 m	39° 100 / 36° 60
79	S-72	Sivas	Gemerek	Tatlıpınar	1150 m	39° 100 / 36° 60
80	Tn-08	Tunceli	Pertek	Beydamı	1100 m	38°51′54″/ 39°19′37″
81	Önceler-98	x				
82	Göynük-98	x				
83	Göksun	x				
84	Karacaşehir-90	x				

X: Commercial cultivar

Crop Sowing and Experimental Design

The experiment was arranged in augmented design with four replicates in 2015 growing season at the experimental farm of Bolu Abant Izzet Baysal University, Turkey. Landraces and cultivars were sown on 28th of April 2015 in 2m long single rows 60 cm apart, with 10 cm between plants within a row. The commercial cultivars were used as a control group in previous study conducted by Khaidizar et al. (2012). The soil of the experimental area was clay-loam with a pH value of 7.5, 1.6% organic matter content, lime 2.8%, soluble salts 0.008%, 23.74 phosphorus and 38 kg da^{-1} potassium (Anon, 2015a). The soil of the field zone was found rich in terms of potassium and phosphorus. For this reason, a fertilizer of 3-4 kg $da^{-1}$of nitrogen was given at the time of sowing in the form of ammonium nitrate (26% N). Average climatic data of Bolu in 2015 were recorded as 19.10 ℃ temperature, 259.1 mm rainfall, 71.8% humidity during the vegetation period (Anon, 2015b). Local standard agronomic practices were applied equally in all the plots. Morphological and agronomic characterization of landraces/cultivars (DF: Days to flowering, DPS: Days to pod setting, DM: Days to maturity, BPP: Number of branches per plant, PPP: Number of pods per plant, PL: Pod length, PH: Plant height, BY: Biological yield, SPP: Seeds per pod, SL: Seed length, SW: Seed width, SY: Seed yield and 1000SW: 1000 seed weight) were performed according to Çiftçi et al. (2012) and (Anon, 2001) on 5 representative individual plants from each landrace.

Micro- and Macronutrient Analysis

Mineral contents (N, P, K, Ca, Mg, Cu, Mn, Fe and Zn) in seeds obtain from common bean landraces/cultivars were analyzed. Seed samples were collected from each landrace/cultivar, and bulked. Samples (0.2 g) were first digested using 5 mL of concentrated nitric acid (65%) and 2 ml of hydrogen peroxide (35%) in Microwave Digestion System (ETHOS EASY, Milestone, Italy) (Gesto-Seco et al., 2009). Afterward, solutions were transferred to flasks and made up to a final volume of 20.0 mL with ultra-pure water. Then, solutions were analyzed by Atomic Absorption Spectrophotometer (Shimadzu AA-7000) for mineral contents (K, Ca, Mg, Cu, Mn, Fe and Zn). The P content of the bean seeds was measured calorimetrically at 430 nm in the spectrophotometer (Murphy and Riley, 1962). Additionally, crude protein content was determined by using a Kjeldahl device in bean seeds. The values were multiplied by the 6.25 (N × 6.25) conversion factor, and calculated as a percentage (%) according to AOAC (1984). Mineral contents of each sample were analyzed in triplicates.

Statistical Analysis

Data obtained from all traits of landraces/cultivars were subjected to statistical analysis, and descriptive statistics (minimum, maximum, mean) were calculated with the aid of Minitab version 17 statistical software (Minitab Inc., State College, PA, USA). Correlations coefficients of all traits were determined using the Pearson correlation (PC), and Principal component analysis (PCAs) based on morphologic characters and mineral elements was used to identify the patterns of variance within the landraces/cultivars using XLSTAT 2016 (Addinsoft, New York, USA). Additionally, cluster constellation plot and scatter plot were performed using JMP 14.1.0 statistical software (2018, SAS Institute Inc., Cary, NC, USA) and XLSTAT 2016 (Addinsoft, New York, USA).

RESULTS and DISCUSSION

To explore the morpho-agronomic and mineral traits in Turkish common bean landraces, various statistical analysis was performed. Minimum, maximum and mean values of the traits are presented in Table 2. With regard to DF, E-30 was determined as the latest flowering (69 days), and Hk-33 and S-33 were detected as the earliest landraces with 45 days. Although the highest DPS was recorded in E-30, the lowest landraces were found as Hk-18, Hk-33 and S-41, and the mean DPS was being 59.92 days. The mean DM for all landraces/cultivars recorded was 103.81 days with the highest DM being in Bn-08 and the lowest landraces being in Bt-68, E-25, Hk-08, Hk-18 and ML-30. The mean BPP was 6.63 pieces/plant, and it ranged from 3.20 pieces for Bn-23 to 10.78 pieces for El-11. PPP ranging between 6.67 (Ml-20) and 63.00 (S-19) pods $plant^{-1}$, the average PPP was 19.76 pods $plant^{-1}$. The average PL was 12.57 cm with the shortest PL being in T-92, and the highest value Bn-23. While the shortest PH was recorded as 25.25 cm for Hk-33, the highest value was noted as 361.50 cm for Bn-23, and the mean PH was detected as 88.80 cm. BY was observed among bean landraces/cultivars ranging from 21.00 (T-92) to 206.67 (Vn-28) g $plant^{-1}$. The average BY was 80.18 g $plant^{-1}$. The mean, minimum and maximum of SPP was determined as 4.15, 2.13 for E-17 and 8.43 seeds pod^{-1} for S-31, respectively. The average SL was found as 13.49 mm, and it ranged from 8.35 mm for Karacasehir-90 to 17.58 mm for E-12. SW was varied between 5.06 - 9.74 mm (Ml-60 and Tn-08), and the mean was 7.60 mm. Although the highest SY was observed in S-19, the lowest was found in E-29, and the average SY was being 29.95 g $plant^{-1}$. The average 1000SW was observed as 383.14 g of bean landraces/cultivars. While the highest 1000SW was seen in T-90, the lowest 1000SW was determined in S-26 followed by Karacasehir-90. N, P and K contents of common bean landraces/cultivars were varied between 22.75-29.75%, 0.33-0.48%, 3.90-5.68%, respectively.

Table 2. Values of mean, maximum and minimum for various morpho-agronomic and nutritional traits in the Turkish common bean germplasm

Variable	Minimum	Maximum	Mean
DF (day)	45.00	69.00	55.54
DPS (day)	53.00	73.00	59.92
DM (day)	90.00	141.00	103.81
BPP (pieces plant^{-1})	3.20	10.78	6.63
PPP (pods plant^{-1})	6.67	63.00	19.76
PL (cm)	7.50	23.29	12.57
PH (cm)	25.25	361.50	88.80
BY (g plant^{-1})	21.00	206.67	80.18
SPP (seeds pod^{-1})	2.13	8.43	4.15
SL (mm)	8.35	17.58	13.49
SW (mm)	5.06	9.74	7.60
SY (g plant^{-1})	6.46	121.98	29.95
1000SW (g)	140.00	633.00	383.14
N (%)	22.75	29.75	25.88
P (%)	0.33	0.48	0.40
K (%)	3.90	5.68	4.76
Ca (mg kg^{-1})	1.22	1.54	1.35
Mg (mg kg^{-1})	0.63	0.94	0.79
Cu (mg kg^{-1})	2.19	14.10	6.11
Mn (mg kg^{-1})	16.54	34.38	24.86
Fe (mg kg^{-1})	66.48	128.05	93.01
Zn (mg kg^{-1})	20.56	42.01	27.80

DF: Days to flowering, DPS: Days to pod setting, DM: Days to maturity, BPP: Number of branches per plant, PPP: Number of pods per plant, PL: Pod length, PH: Plant height, BY: Biological yield, SPP: Seeds per pod, SL: Seed length, SW: Seed width, SY: Seed yield, 1000SW: 1000 seed weight, N: Protein, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Cu: Copper, Mn: Manganese, Fe: Iron, and Zn: Zinc

Some other parameters varied as in Ca content 1.22-1.54 (mg kg^{-1}), Mg content 0.63-0.94 (mg kg^{-1}), Cu content 2.19-14.10 (mg kg^{-1}), Mn content 16.54-34.38 (mg kg^{-1}). Additionally, the Fe content was ranged from 66.48 (mg kg^{-1}) for S-52 to 128.05 (mg kg^{-1}) for E-26. Although the lowest Zn content was found as 20.56 (mg kg^{-1}) for T-89, the highest was 42.01 (mg kg^{-1}) for Karacasehir-90. To visualize the variations on the broader spectrum, performance of landraces for all traits were also calculated on the provinces level and a good level of variations were observed for all traits (Table 3). For the morpho-agronomic traits, landraces from Tunceli showed better response for various traits and landraces belonging to Malatya provinces were found rich with the mineral contents. Correlations among all traits in landraces/cultivars is presented in Table 4. 1000SW was highly positively correlated with SL and SW, and weakly correlated with DM and BY. Additionally, a negative correlation was found between 1000SW and Cu, Mn and Zn, respectively. SY was associated positively with DF, DPS, DM, PPP, PH, BY and SPP. Although PH was significantly correlated with DF, DPS, DM, PPP, BY, SPP and SY, negatively associated with BPP, SL, Mn and Fe. DF, DPS, PPP, PH, BY, SY and 1000SW were significantly correlated with DM. On the other hand, a negative correlation was found between N and Cu. P, Ca and Mg was not correlated with any of the other traits K was positively associated with Cu, Mn, Fe and Zn. A positive and significant relations were found between Zn and Fe, Zn and Mn, Cu and Mn, Fe and Mn, SY and Cu (Table 4).

The patterns of variation were assessed by Principal Component Analysis (PCAs) using landraces/cultivars and based on all traits. The first 5 components for all traits explained 60.55 of cumulative variance (Table 5). Overall, 22.21 % of the variation was explained by the first component (PC1). DPS and DM sustained the highest eigen values in the PC1. Mn and Zn were positively correlated in the second component (PC2), but SL and 1000SW was negatively correlated in the PC2, and accounted for 14.99% of the variability. BPP and 1000SW sustained the highest eigen values in the third component (PC3). PPP and N, SPP and SY had the highest contributions in PC4 and PC5, respectively. The first 5 components were crucial accounting for nearly 60.55 % of the total variability. Scatter plot (Figure 1) was applied to understand the distribution of Fe and Zn among the landraces of various provinces. Samsun and Sivas provinces reflected higher Fe and Zn contents, respectively. Cluster constellation plot analysis of all traits produced two main groups (A and B) (Figure 2). Group A included two subgroups, while Group B consisted of Bn-08, 12, 23; Bt-38, 73, 123; Hk-77; Vn-16, 48; Ml-44; Ms-24; S-19, 42; Tn-08. Each subgroup in Group A formed two subgroups (A1 and A2). Group A1 contained 31 landraces and Önceler-98. On the other hand, Göynük-98, Göksun, Karacaşehir-90 and 36 landraces formed closely related A2 (Figure 2). Although the highest distance (16.93) among all genotypes determined between Bn-08 and Bn-50, the lowest found between S-38 and S-48 (1.58).

Table 3. Averaged values of various traits for Turkish common bean germplasm based on the collection provinces in Turkey

Provinces	DF (day)	DPS (day)	DM (day)	BPP (pieces plant-1)	PPP (pods plant-1)	PL (cm)	PH (cm)	BY (g plant-1)	SPP (seeds pod-1)	SL (mm)	SW (mm)
Bingol	60.00±2.48	63.50±1.94	118.00±10.34	4.83±0.56	23.86± 3.83	15.00±2.88	254.68 ±68.24	124.69±26.12	4.04±0.91	13.78± 1.06	7.47±0.37
Bitlis	59.60±3.19	63.80±3.06	112.00±6.80	5.17±0.77	27.26±5.70	12.54±1.16	174.02±52.48	119.05±28.16	4.67±0.65	13.61±0.81	8.04±0.14
Tokat	56.27±0.90	60.50±0.92	104.05±1.86	7.23±0.30	21.74±2.21	12.18±0.51	57.70±5.63	73.86±6.84	3.34±0.17	14.14±0.42	7.84±0.12
Samsun	58.25±2.64	62.25±2.19	104.00±3.79	6.54±0.47	13.06±1.71	12.04±0.69	48.55±3.83	60.56±9.96	3.96±0.39	14.15±0.63	7.24±0.34
Hakkari	52.75±4.59	57.75±4.11	100.50±9.53	5.66±0.39	17.93±3.06	12.28±1.08	104.27±67.38	68.13±28.73	4.44±0.70	12.98±0.99	7.14±0.55
Van	58.33±1.76	63.33±2.67	120.67±6.44	5.56±1.72	15.61±1.67	12.58±3.80	260.83±3.63	124.78±41.00	5.04±0.78	13.66±1.97	8.20±0.32
Malatya	52.75±1.93	57.50±2.18	98.75±7.76	5.92±0.81	15.98±3.11	13.25±1.71	69.77±36.01	98.63±34.92	4.93±0.41	13.63±0.49	6.82±0.79
Sivas	53.04±1.01	57.63±0.89	96.93±1.44	7.01±0.23	18.87±2.18	12.77±0.30	53.44±7.26	69.68±6.39	4.33±0.27	13.15±0.30	7.58±0.12
Muş	57.00±3.85	63.25±2.92	121.75±2.75	5.26±0.56	25.93±1.78	11.34±0.53	229.42±14.90	97.57±10.04	4.53±0.79	11.73±0.62	8.56±0.37
Elazığ	52.00±0.48	56.00±0.71	105.00±5.40	10.78±1.07	10.43±2.44	13.92±0.43	42.00±1.99	46.44±7.35	4.69±0.37	13.21±0.72	6.91±0.159
Tunceli	61.00±1.89	65.00±2.26	128.00±7.53	3.86±0.65	27.29±5.19	12.10±0.46	296.00±10.93	174.57±13.41	4.74±1.17	12.99±0.52	9.74±0.35
Cultivars	55.63±3.49	60.31±3.35	107.81±4.67	7.42±0.23	23.58±1.80	11.81±0.30	100.57±30.39	73.65±5.59	4.83±1.07	11.43±1.48	6.79±0.59

DF: Days to flowering, DPS: Days to pod setting, DM: Days to maturity, BPP: Number of branches per plant, PPP: Number of pods per plant, PL: Pod length, PH: Plant height, BY: Biological yield, SPP: Seeds per pod, SL: Seed length, and SW: Seed width.

Table 3. Cont.

Provinces	SY (g plant-1)	1000SW (g)	N (%)	P (%)	K (%)	Ca (mg kg-1)	Mg (mg kg-1)	Cu (mg kg-1)	Mn (mg kg-1)	Fe (mg kg-1)	Zn (mg kg-1)
Bingol	35.69 ± 7.29	394.75±35.61	26.16±0.953	0.406±0.018	4.623±0.103	1.265±0.033	0.756±0.056	4.938±0.709	22.90±2.24	80.82±4.72	26.66±1.66
Bitlis	53.93±11.39	451.20±20.48	25.73±0.63	0.406±0.016	4.673±0.142	1.380±0.025	0.750±0.022	5.288±0.493	21.57±1.27	89.54±2.55	24.80±0.89
Tokat	26.91±2.69	403.27±20.34	25.68±0.41	0.392±0.006	4.829±0.072	1.357±0.020	0.815±0.018	6.377±0.374	25.53±0.54	94.64±2.10	28.44±0.92
Samsun	20.13±4.09	373.25±22.73	25.81±0.69	0.413±0.010	5.010±0.091	1.319±0.030	0.778±0.031	7.059±0.923	26.68±0.78	100.89±5.22	29.30±1.41
Hakkari	29.86±12.39	334.25±35.32	27.15±1.01	0.428±0.012	4.532±0.105	1.295±0.062	0.725±0.020	5.443±0.695	25.18±2.24	88.60±4.59	25.54±0.90
Van	34.12±4.45	452.33±1.76	23.96±0.86	0.363±0.012	4.644±0.378	1.386±0.069	0.797±0.067	5.970±1.191	22.24±2.63	85.33±7.72	28.24±3.01
Malatya	24.96±6.10	320.75±27.96	24.61±0.98	0.400±0.018	5.013±0.116	1.447±0.046	0.838±0.069	7.460±0.982	26.81±1.77	97.58±4.51	31.07±2.57
Sivas	28.91±4.19	373.85±20.94	26.42±0.36	0.405±0.008	4.683±0.080	1.332±0.014	0.793±0.019	5.810±0.444	24.70±0.46	93.48±2.31	26.60±0.78
Muş	50.293±5.67	450.50±36.69	26.16±0.89	0.471±0.025	4.543±0.088	1.265±0.037	0.935±0.074	6.06±0.390	19.98±0.89	89.78±4.22	29.00±0.83
Elazığ	17.11±3.34	350.00±25.84	23.89±0.83	0.352±0.014	4.337±0.146	1.325±0.048	0.665±0.065	4.46±0.782	22.75±1.38	80.41±6.74	25.57±2.29
Tunceli	63.68±9.44	492.00±41.38	26.60±0.63	0.441±0.024	4.568±0.082	1.41±0.057	0.784±0.019	6.86±1.556	19.31±1.15	94.14±7.43	22.94±2.19
Cultivars	28.78±1.77	286.39±50.90	25.06±0.80	0.428±0.014	4.997±0.120	1.409±0.021	0.772±0.017	6.57±0.672	27.49±2.54	90.93±1.47	32.99±3.18

SY: Seed yield, 1000SW: 1000 seed weight, N: Protein, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Cu: Copper, Mn: Manganese, Fe: Iron, and Zn: Zinc.

Table 4. Correlation coefficients among the morphological and mineral parameters of Turkish common bean germplasm.

	DF	DPS	DM	BPP	PPP	PL	PH	BY	SPP	SL	SW	SY	1000SW	N	P	K	Ca	Mg	Cu	Mn	Fe	Zn
DF	1	0.965**	0.636**	-0.214	0.404**	-0.257*	0.549**	0.415**	0.063	-0.388**	-0.114	0.371**	-0.048	-0.078	0.060	0.103	0.050	-0.085	0.264*	-0.076	-0.086	0.278*
DPS		1	0.653**	-0.215*	0.430**	-0.261*	0.571**	0.452**	0.099	-0.396**	-0.103	0.420**	-0.020	-0.108	0.129	0.124	0.089	-0.081	0.264*	-0.073	-0.090	0.284**
DM			1	-0.198	0.438**	-0.060	0.752**	0.646**	0.120	-0.068	0.115	0.569**	0.235*	-0.094	-0.003	0.043	0.080	-0.109	0.136	-0.196	-0.144	0.100
BPP				1	0.017	-0.105	-0.458**	-0.137	-0.308**	0.207	-0.091	-0.151	0.174	0.084	-0.127	0.101	0.181	0.127	0.024	0.278*	0.197	0.092
PPP					1	-0.187	0.418**	0.542**	-0.058	-0.213	-0.011	0.778**	-0.092	0.175	0.125	-0.155	0.010	0.005	0.271*	-0.024	-0.179	0.007
PL						1	0.116	-0.074	0.231*	0.323**	0.011	0.035	0.182	0.060	-0.079	-0.230*	-0.115	-0.045	-0.367**	-0.083	-0.095	-0.243*
PH							1	0.632**	0.250*	-0.247*	0.130	0.568**	0.086	0.000	0.077	-0.110	-0.021	-0.055	0.043	-0.364**	-0.277*	0.019
BY								1	0.207	-0.050	0.267*	0.708**	0.257*	-0.096	0.007	-0.003	0.194	-0.086	0.227*	-0.148	-0.050	0.090
SPP									1	-0.292**	-0.142	0.330**	-0.188	-0.094	-0.054	-0.016	0.022	-0.174	0.076	0.077	0.026	0.121
SL										1	0.343**	-0.130	0.502**	0.039	-0.041	-0.149	0.09	-0.020	-0.269*	-0.078	0.045	-0.220*
SW											1	0.164	0.504**	0.110	-0.062	-0.015	0.096	0.038	-0.011	-0.347**	0.087	-0.180
SY												1	0.236*	0.099	0.111	-0.204	0.072	-0.103	0.228*	-0.173	-0.104	-0.124
1000SW													1	0.071	-0.095	-0.096	0.161	0.010	-0.215*	-0.294**	-0.080	-0.284**
N														1	0.084	-0.163	-0.035	0.213	-0.220*	-0.024	-0.188	-0.175
p															1	-0.124	-0.072	0.074	0.067	0.113	0.050	0.123
K																1	-0.034	-0.065	0.306**	0.313**	0.298**	0.438**
Ca																	1	0.117	0.014	-0.038	0.151	0.039
Mg																		1	0.063	0.042	0.148	-0.062
Cu																			1	0.310**	0.391**	0.389**
Mn																				1	0.425**	0.532**
Fe																					1	0.290**
Zn																						1

*p < 0.05, **p < 0.01, DF: Days to flowering, DPS: Days to pod setting, DM: Days to maturity, BPP: Number of branches per plant, PPP: Number of pods per plant, PL: Pod length, PH: Plant height, BY: Biological yield, SPP: Seeds per pod, SL: Seed length, SW: Seed width, SY: Seed yield, 1000SW: 1000 seed weight, N: Protein, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Cu: Copper, Mn: Manganese, Fe: Iron, and Zn: Zinc

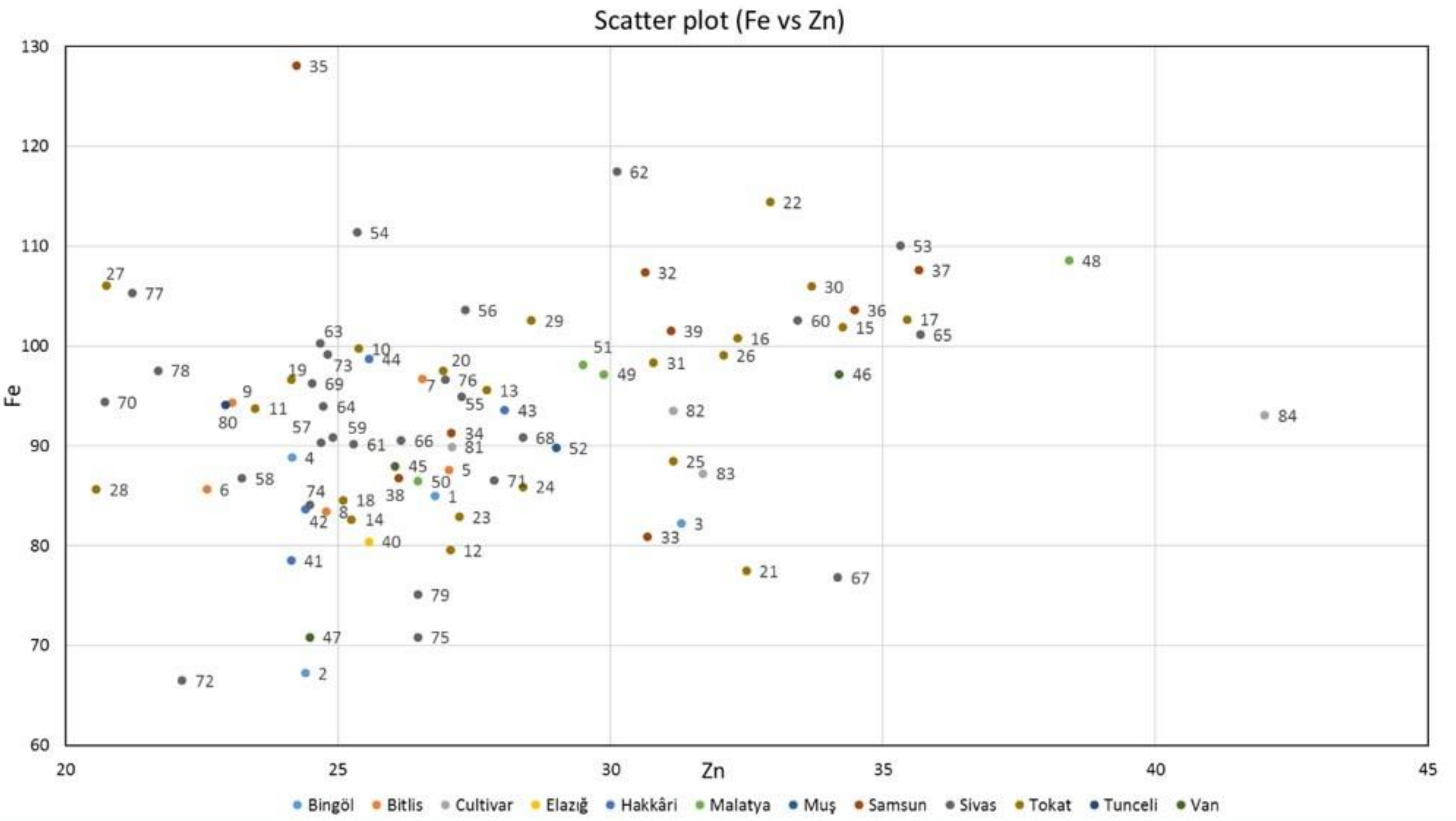

Figure 1. Scatter plot of Fe and Zn diversity in Turkish common bean germplasm for various Turkish provinces

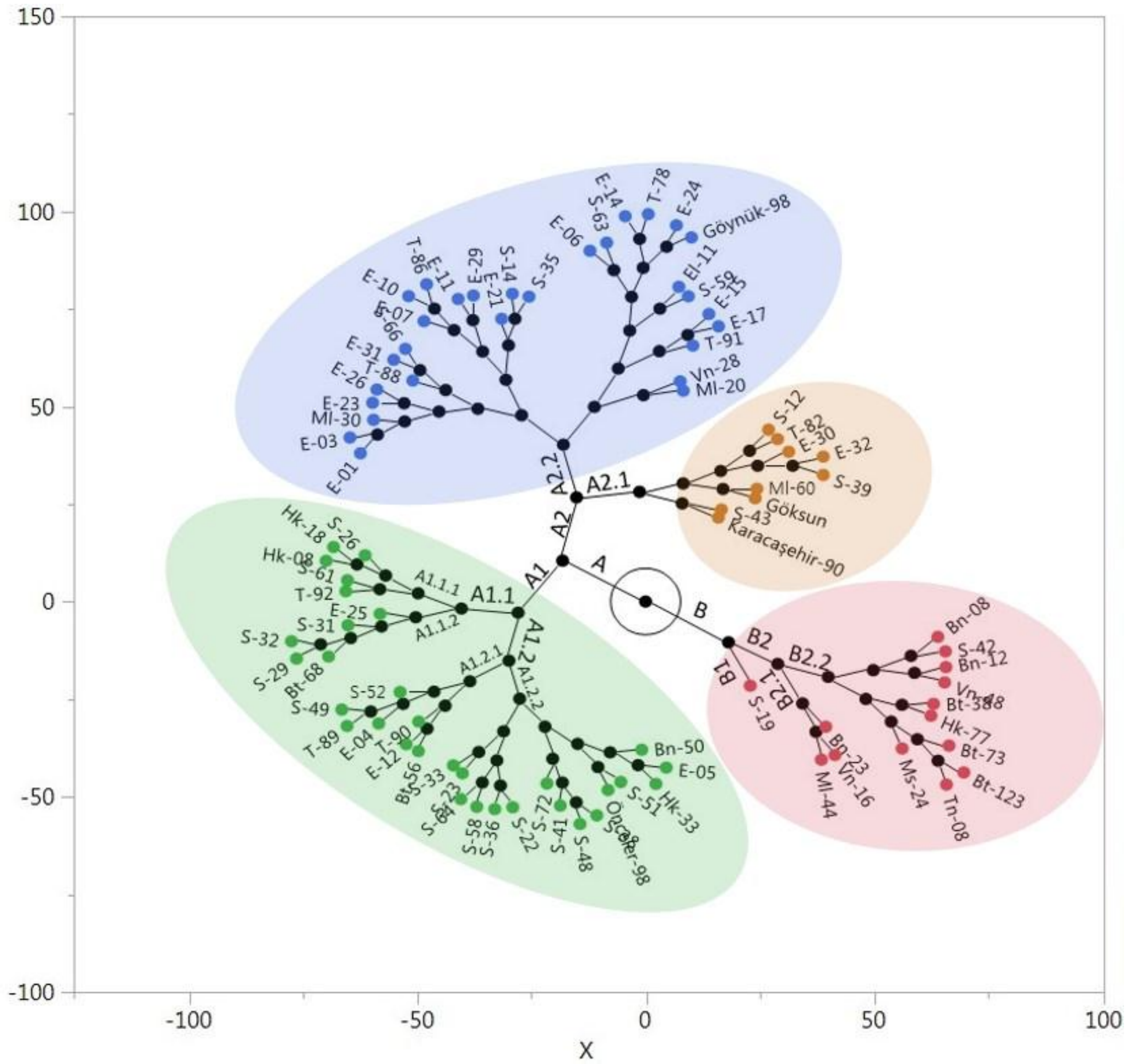

Figure 2. Cluster analysis of various morphologic and mineral traits in Turkish common bean germplasm

Biofortification is an important methodology commonly in use to improve the nutritional quality of any crop by breeding the varieties superior for various micronutrients especially for Zn, Fe and Vitamin A (Ronoh et al., 2017). Main goals of common bean biofortification are to develop varieties having 80% more iron content and 40% more zinc together with improving the various traits according to breeder, farmer and consumer perspectives (Blair et al., 2009). The extensive variability in the Turkish common bean germplasm (Table 2) can be very helpful to start the breeding activities for the common bean aiming to produce greater high-quality food. Genetic diversity for DPS, DM and PH was found much greater than the previous studies (Stoilova et al., 2005, 2013; Casquero et al., 2006). Seed traits are considered the determinants for the selection of any genotype and they also effect the preference of peoples for the commercial cultivar (Rana et al., 2015). Singh and Schwartz (2010) stated that 1000SW of common bean may vary between 150-900 g. According to Singh and Schwartz (2010), genotypes having 1000SW<250 g are considered small-seed navy bean, while medium and large seeded navy bean contains up to 400 g and over than 400g, respectively. 1000SW ranged between 140-633g with a mean of 383.14g and reflects the occurrence of small, average and large seeded common bean in Turkish common bean germplasm. Our results were found in line with the previous studies (Rana et al., 2015; Yeken et al., 2018a). Considering the great importance of common bean as a source of food for large population of world, it is important to characterize them with respect to their nutritional value for micronutrients. Mean N, P and K was found much lower as compared to achieved by the Bevilaqua and Antunes, (2015) and Paredes et al. (2009). Range of similar results was observed for the Ca and Mg concentration for both nutrients was found lower as compared to obtained by Paredes et al. (2009); Bevilaqua and Antunes (2015). However, Mg contents were found higher from the reported by Bevilaqua and Antunes (2015); Nwadike et al. (2018). Zn, Fe, Mn and

Cu have gained great importance as being of public health concern (Sanghvie et al., 2007) and great range of diversity was also observed for the concentrations of these elements also. Fe deficiency leads to Anemia and it is reported that higher numbers of anemic people are present in developing countries as compared to Europe and the USA just because of deficiency of this nutrient in their daily diet (Barclay et al. 1996). Our results were found in line with the reported by Celmeli et al. (2018) and Yeken et al. (2018b). Correlation coefficient is one of the most important statistics that is mainly applied to investigate the level of association between two traits (Rana et al., 2015). DF reflected positive and significant correlation DPS, DM, PPP, PH, BY, SY, Cu and Zn. A negative correlation was observed for the BPP, PL, SL, SW, 1000SW, N, Mg and Fe (Table 4). Mn reflected a significant and positive correlation with the Fe and Zn, while Fe reflected a significant correlation with Zn also. Results of this study are clearly describing that if common bean breeder will give importance to DF, breeder will obtain a good yield due to positive and significant association DF with other traits. Our results were found in line with previous studies (Bevilaqua and Antunes, 2015; Paredes et al., 2009). Generally, PCA is applied to investigate the degree and pattern of divergence among various populations in order to understand the evolutionary trends and the relative contribution of various components (Sharma et al., 2009). During this study, more importance was given to 1st five PCs because they accounted 60.54% of the total variations (Table 5). Among these five PCs, 1st PC accounted a total of 22.20% variations and DPS, DM and PH were the main contributor in this PC. Zn, Mn and Cu were found key factor in the 2nd PC and 14.98% was total variation accounted by this PC. 1000 SW, N and SPP were the main contributor in the 3rd, 4th and 5th PCs respectively. The analytic results obtained from the three eigenvectors suggested that DPS, Zn and 1000 SW are top three key traits that are responsible for the variations and can be used to characterize the common bean germplasm to identify the novel variations for the breeding activities. Scatter plot for Fe and Zn content two traits in the studied germplasm at the provinces levels was also evaluated (Figure 1). Samsun province of Turkey contains a great range of variations for the Zn and Fe contents and E-26 belonging to this province contains higher Fe contents. Landraces from Samsun and Sivas provinces are enriched with Zn and Fe content and these landraces can be used as candidate parents to start the breeding programs for the biofortification of common bean in near future. To investigate the level of variations and associations among the studied germplasm, cluster constellation plot analysis was performed using the various all traits. Cluster divided the studied germplasm into two main groups A and B (Figure 2) on the basis of PH and geographics. Cluster A was found larger than B by clustering a total of 70 landraces. Cluster A was further grouped in to A1 and A2 by clustering a total of 32 and 38 landraces respectively. A1 and A2 subgroups were further grouped into subgroups A1.1, A1.2 and A2.1 and A2.2 respectively. Geographical provinces and PH play an active role in the clustering of landraces, clustered in the A2.1 subgroup containing the landraces with bushy growth habit and lesser PH (except Göksun, Karacaşehir-90 and S-12). Landraces belonging to A1.1 and A1.2 subgroup grouped in to two separate cluster A1.1.1., A1.1.2 and A1.2.1., A1.2.2, respectively. Group A1.1.1. includes lower 1000SW (<300 g) than group A1.1.2. On the other hand, it was found that group A1.2.1. (>430 g) has large seed types, and contains higher than A1.2.2. in terms of 1000SW. On the other hand, group A2.1 contained higher mean Cu, Mn, Zn (8.27, 27.65 and 32.49 mg/kg) than other groups mean. Main group B cluster 14 landraces and all were found climbering in nature. Group B is extremely important because of mean SY which is higher than group A. The main group B was further divided into B1 and B2 subgroups. Subgroup B1 clustered only single and unique landrace S-19 (Figure 2). This landrace is semi-climber and resulted maximum SY among all genotypes, and can be suggested as candidate parent for the development of cultivar having higher yield. Subgroup B2 was further group into B2.1. and B2.2. containing 3 and 10 landraces, respectively on the basis of 1000SW (Figure 2). Cluster analysis used previous studies to reveal genetic diversity in common bean (Stoilova et al., 2005; Madakbas and Ergin; 2011). Very recently Nadeem et al. (2018) also confirms the clustering of common bean on the basis of their geographic, plant height, seed size and growth habit using genotypic and phenotypic information, and same was observed in our study.

CONCLUSION

This study comprehensively explained the morpho-agronomic and mineral variations in the Turkish common bean germplasm. E-26 and Karacasehir-90 were found superior due to their higher Fe and Zn contents in this study. Landrace S-19 has maximum seed yield among all genotypes. S-19 and E-26 can be used as potential or candidate parents for the development of improved common bean genotypes having higher yield, and higher Fe and Zn contents, respectively. Information provided here will be a source to start the breeding activities to develop common bean genotypes not only with high yield but also contains higher mineral contents especially Fe and Zn to overcome the malnutrition or “hidden hunger” problems.

Table 5. Principal component analysis (PCAs) for morphological and mineral parameters of Turkish common bean germplasm

Traits	PC1	PC2	PC3	PC4	PC5
DF (day)	0.797	0.235	-0.036	0.045	-0.353
DPS (day)	0.826	0.232	-0.016	0.038	-0.314
DM (day)	0.822	-0.132	0.154	-0.147	-0.118
BPP (pieces plant^{-1})	-0.341	0.147	0.527	0.289	0.021
PPP (pods plant^{-1})	0.670	-0.026	0.099	0.498	0.245
PL (cm)	-0.174	-0.455	-0.231	-0.332	0.407
PH (cm)	0.821	-0.251	-0.168	-0.121	-0.001
BY (g plant^{-1})	0.766	-0.158	0.314	-0.128	0.208
SPP (seeds pod^{-1})	0.260	0.096	-0.381	-0.449	0.543
SL (mm)	-0.371	-0.488	0.459	-0.166	0.062
SW (mm)	0.064	-0.463	0.514	-0.180	-0.035
SY (g plant^{-1})	0.766	-0.253	0.126	0.114	0.451
1000SW (g)	0.049	-0.601	0.558	-0.174	-0.099
N (%)	-0.065	-0.271	-0.029	0.576	0.159
P (%)	0.110	0.110	-0.087	0.345	0.204
K (%)	-0.008	0.554	0.258	-0.324	-0.230
Ca (mg kg^{-1})	0.074	-0.026	0.436	-0.021	0.015
Mg (mg kg^{-1})	-0.130	0.017	0.204	0.458	0.068
Cu (mg kg^{-1})	0.311	0.590	0.296	0.009	0.186
Mn (mg kg^{-1})	-0.206	0.687	0.138	0.044	0.375
Fe (mg kg^{-1})	-0.180	0.479	0.466	-0.199	0.301
Zn (mg kg^{-1})	0.160	0.724	0.139	-0.164	0.018
Eigenvalue	4.885	3.297	2.090	1.639	1.410
Variability (%)	22.207	14.985	9.498	7.448	6.409
Cumulative %	22.207	37.192	46.690	54.138	60.547

DF: Days to flowering, DPS: Days to pod setting, DM: Days to maturity, BPP: Number of branches per plant, PPP: Number of pods per plant, PL: Pod length, PH: Plant height, BY: Biological yield, SPP: Seeds per pod, SL: Seed length, SW: Seed width, SY: Seed yield, 1000SW: 1000 seed weight, N: Protein, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Cu: Copper, Mn: Manganese, Fe: Iron, and Zn: Zinc

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