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Original article

Mineral concentrations of grain of bread wheat landraces originated from eastern Anatolia of Turkey

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Summary. The objectives of this research were to investigate the interrelationships among some mineral concentrations (Fe, Zn, B, Mn, Cu, Mo, K, Mg and Ca) in grain and to evaluate different eastern Anatolian bread landraces with application of the genotype × trait (GT) biplot methodology in visualizing research data. 69 bread wheat genotypes (67 pure lines and 2 cultivars). Fe, Zn, B, Mn, Cu, Mo, K, Mg and Ca contents of bread wheat genotypes changed at the levels between 32.54 and 51.25 mg kg^{-1}, 23.00 and 37.16 mg kg^{-1}, 6.62 and 14.67 mg kg^{-1}, 30.17 and 50.00 mg kg^{-1}, 4.04 and 6.88 mg kg^{-1}, 0.88 and 1.23 mg kg^{-1}, 2.19 and 5.62 g kg^{-1}, 1.04 and 1.72 g kg^{-1}, and 0.37 and 0.55 g kg^{-1}, respectively. Among minerals, B, Zn and Fe concentrations were the most discriminating with the longest vectors from the origin in the biplot. Landraces L10, L48, L2, L55, L17, L14, L36, L16, L53, L22, L32, L53 L65 and Kirik cultivar were the best or the poorest landraces in some or all of the traits since they had the longest distance from the origin of biplot. Among the mineral contents, Fe content was positively correlated with Zn and Mn content. The association of Zn with Mn was positive and significant. B content positive and significant correlated with Mo content. Both Zn and Fe content was negative significant correlated with Ca. The GT biplot method can be used to identify both ideal genotypes and mineral contents in other crops.

Key words: Turkey, bread wheat, landraces, mineral contents, biplot, correlations

Introduction

Recent archaeological excavations in Gobekli Tepe of Sanliurfa Province of Turkey have a potential to shed light on the periods prior to known date of agriculture, especially domestication of wheat (1). Different bread wheat landraces were used in Turkey for a long time in last decades (2). Wheat landraces comprise the major genetic resource of cultivated wheat in Turkey (3). Germplasm collections continue to play a vital role in providing the genetic resources needed for improving bread wheat. During the last 70 years of the 20th century, an individual study resulted in collecting and conserving these landraces in gene banks; their vernacular names and some of their characteristics have been documented (4). As distinct plant populations, landraces are named and maintained by traditional farmers to meet their social, economic, cultural, and environmental needs. Bread wheat landraces, in Turkey, also may be classified according to expected usage; different landraces are used for flour, bulgur, lavas, tandir, asure etc. (5). Wheat landraces, such as Kirik, is still grown in some areas of Eastern Anatolian Region, especially, in the least favorable areas. Advantages of Kirik landrace can be listed, in East Anatolia, as high quality and white grain for white unleavened lavash bread, a high value marketable product locally, short growing season, facultative wheat, low risk of production, good straw, no awns (6,7). Similarly, Asure is a landrace is grown in Elazig and Malatya provinces, its grains are sought for asure dessert (5).

The breeding of semi-dwarf, high-yielding wheat cultivars has markedly increased the grain yield since the mid-1960s and has contributed to alleviating global food shortages and famine that would have otherwise occurred at a much larger scale (8). Unfortunately, plant breeding has been historically oriented toward higher agronomic yield rather than the nutritional concentration of wheat grain (9, 10).

Wheat is an important source of minerals especially iron, zinc, copper and magnesium in the diet of Turkish people. Mineral deficiencies such as iron (Fe), iodine (I) and zinc (Zn) affect most of the people due to inadequate levels in their diet (9). There is an urgent need for development of wheat varieties with improved protein, Fe and Zn contents in Turkey (11).

In the present study, we used different both pure lines selected from Turkish bread wheat landraces and registered cultivars. The main objectives were (1) to determine the amount of genetic variation for some mineral contents [Iron (Fe), Zinc (Zn), boron (B), potassium (K), manganese (Mn), copper (Cu), magnesium (Mg) and Calcium (Ca)] (2) to compare genotypes (67 pure lines and two cultivars) according to mineral contents by using Genotype trait (GT) biplot techniques.

Material and methods

Plant materials

Totally 69 bread wheat genotypes (67 Turkish landraces pure lines and 2 registered bread wheat cultivars) were used as the experimental plant material. The pure lines were selected from bread wheat landraces by pure line selection method between 2002-2005 growing seasons at Central Anatolian Region of Turkey (12). Other experiment materials were registered 2 cultivars (Doğu-88 and Kirik) which were the most commonly grown in Eastern of Turkey. The field experiment was carried out under rain-fed conditions at Canakkale Onsekiz Mart University Dardanos Field Experiment Area in 2012-2013 growing season.

Before sowing, randomized soil samples (0-30 cm depth) were collected from the field; soil texture was loam. Soil pH recorded 7.9, measured in saturated soil. Organic matter was 1 g kg^{-1} of soil, free lime (calcium carbonate; $CaCO_3$) was 43 g kg^{-1} of soil. Plant-available K and phosphorus (P) in the soil were 2.4 kg da^{-1}, 41.30 kg da^{-1}, respectively. Plant-available Fe, Zn, Mn and Cu in the soil were 3.2, 4.8, 2.36 and 1.00 mg kg^{-1}, respectively. The plant materials (100 genotypes) were sown in 4 rows of 2 m long incomplete block design with two replications. Sowing was done on first week of October. Weeds were controlled manually. Fertilizer application was 27 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} at sowing, 43 kg ha^{-1} N was applied at the end of tillering stage at both growing seasons. Experiment was harvested at June 16 in 2013.

The total mean rainfall during the 2012-2013 growing season in Canakkale (Latitude: 40°7'N; Longitude: 26°23'E; Altitude: 6 m above sea level) was 505 mm. The long-term rainfall (means of 52 growing seasons) for Canakkale was 584 mm. Grain samples were dried and cleaned before measuring mineral concentrations.

Determination of mineral concentration of wheat grain

Samples of threshed grain and straw were dried at 70°C for 48 h in an air-forced oven, for the of mineral concentration analyses. Dried samples were ground with a mill. Later, about 0.3 g ground samples were digested in mixture 4: 1 (HNO_3:$HClO_4$) in a closed microwave system (13). Concentrations of Zn, Fe, Mn, B, Cu, Mg, K, Mo, and Ca were read by atomic absorption spectrophotometer according to Isaac and Kerber (14). Measurements of mineral concentrations were compared using the certified values of the related minerals in the reference grain samples (BCR-189 wheat whole meal flour) for each set of measurements.

Data analysis

Variance analyses were run on data obtained from 67 pure lines and 2 standard cultivars. In pooled analysis experiments, years were random, while genotypes were fixed. A linear correlation analyses was applied pairwise to all the parameters studied across the growing seasons. Analysis of variance and linear correlations were performed using SAS System (15).

The GGT biplot was constructed by plotting the first two principal components (PC1 and PC2) derived from subjecting the Genotype-mineral content matrix to singular value decomposition (16) of the trait-centered and standardized data. This methodology uses a biplot to show the factors (G and GT) that are important in genotype evaluation and that are also the sources of variation in multiple trait data (16). In the present study, genotype-focused scaling was used in visualizing for genotypic comparison, with mineral content-focused scaling for mineral content comparison. Furthermore, the symmetric scaling was preferred in visualizing the "which-won-what" pattern of the multiple traits data. The tester vectors that originated from biplot origin and reach markers of the mineral contents were used to visual among mineral contents (16). GGT biplot analyses were done using GenStat software (17).

Results and Discussion

Mineral concentrations

In this study, mineral concentrations in grain of 67 landraces and 2 cultivars of Turkish bread wheat were detected and the results are shown in Table 1. Fe and Zn concentrations of studied genotypes were between 32.54-51.25 mg kg^{-1} and 23.00-37.16 mg kg^{-1}, respectively. L2 genotype has the highest Fe and Zn concentrations. The lowest percentage of Fe and Zn were found in L65 and L28 landraces, respectively. Graham et al. (18) determined that bread wheat grain has highest level of Fe and Zn concentrations (56.5 and 53.3 mg kg^{-1}, respectively) and also Liu et al. (19) reported that the highest percentage of Fe and Zn among the one hundred and eighty-six ten wheat genotypes were54.8 mg kg^{-1}found in seed of Sichuan cultivar and 29.2 mg kg^{-1} found in Xinjiang wheat, respectively. In another study, whole wheat grains (43.1 mg kg^{-1} and 38.2 mg kg^{-1}) have Fe and Zn concentrations, respectively (20). The Fe and Zn concentrations of wheat obtained in our work agreed with that reported by Murphy et al. (21) 27.1-52.2 mg kg^{-1} and 24-43 mg kg^{-1}, Zhao et al. (22) 28,8-50,8 mg kg^{-1} and 13.5-34.5 mg kg^{-1} and Akcura and Kokten (23) 35.53-53.08 mg kg^{-1} and 22.66-38.57 mg kg^{-1}, respectively.

The mineral composition of studied seeds used as human food showed different concentrations of B. The B concentration in seeds of 69 genotypes of bread wheat ranged from 6.62 to 14.67 mg kg^{-1} (Table 1). From the data presented it could be seen that the highest B concentration was found in L36 landrace, while the lowest percentage was found in Kirik cultivar. The B concentration of wheat obtained in our work agreed with that reported by Akcura and Kokten (23), but was higher than that reported by Graham et al. (18).

The results in Table 1 also indicate that the content of Mn ranged from 30.17 to 50.00 mg kg^{-1}. While Mn concentration was the highest percentage in L10 landrace, the lowest percentage of Mn was found in L15 landrace. Cu concentration ranged from 4.04 to 6.88 mg kg^{-1}. The highest Cu concentration was found in L50 landrace, while the lowest percentage of Cu was found in L11 landrace. Mo concentrations of studied genotypes were between 0.88 and 1.23 mg kg^{-1} (Table 1). From the table presented it could be seen that the highest Mo was found in L3, L14, L22, L53 and L66 landraces, while the lowest percentage was found in L1, L11 and L13 landraces. The Mn, Cu and Mo concentrations of wheat genotypes obtained in our work agreed with that reported by Murphy et al. (21), Harmankaya et al. (20) and Akcura and Kokten (23).

K, Mg, and Ca contents of genotypes were determined between 2.19 g kg^{-1} (L7) and 5.62 g kg^{-1} (L40), 1.04 g kg^{-1} (L58) and 1.72 g kg^{-1} (L36), 0.37 g kg^{-1} (L11) and 0.55 g kg^{-1} (L10), respectively (Table 1). Graham et al. (18) determined that bread wheat grain has highest level of K, Mg and Ca concentrations (2.85-5.22 g kg^{-1}, 0.92-1.43 g kg^{-1} and 0.25-0.73 g kg^{-1}, respectively) and also Harmankaya et al. (20) reported that bread wheat varieties have highest K, Mg and Ca concentrations (3.03-5.57 g kg^{-1}, 0.97-1.53 g kg^{-1} and 0.27-0.53 g kg^{-1}, respectively). In another study, bread wheat genotypes (2.25-5.41 g kg^{-1}, 1.02-1.69 g kg^{-1} and 0.34-0.55 g kg^{-1}, respectively) have K, Mg and Ca concentrations (23).

Although the genotype-trait biplot methodology was originally proposed for analyzing multi-environment trials data for a given trait, it is equally applicable to all types of two-way data that assume an entry-by-tester structure, such as a genotype-by-trait two-way dataset (24). Further information about the discriminating power of mineral contents, together with a representation of their mutual relationships, can be obtained by the mineral content-vector view of the GGE-biplot (23). The mineral content vectors are the lines that originate from the biplot origin and reach markers of the traits (Figure 1). In this case, a long

Table 1. Mineral compositions (mg kg^{-1} and g kg^{-1}) in grain of Turkish bread wheat landraces and cultivars*

Pure lines and cultivars origin	NO	Fe	Zn	B	Mn	Cu	Mo	K	Mg	Ca
		mg kg^{-1}						g kg^{-1}		
Southeastern Anatolian landraces pure lines and cultivars										
ADIYAMAN TR 49034/2	**L1**	39.26	28.67	10.62	32.00	5.56	0.88	4.53	1.63	0.42
ADIYAMAN TR 50457/6	**L2**	51.25	37.16	9.83	36.33	5.51	0.92	3.74	1.53	0.38
ADIYAMAN TR 50476/1	**L3**	41.04	30.87	10.54	36.50	6.02	1.23	5.30	1.58	0.53
ADIYAMAN TR 50455/1	**L4**	47.80	33.50	13.42	49.00	5.72	1.12	3.52	1.51	0.44
ADIYAMAN TR 46810/6	**L5**	47.60	34.91	13.58	38.66	5.11	1.19	3.12	1.51	0.41
ADIYAMAN TR 49029/3	**L6**	45.60	30.17	10.62	35.67	6.83	1.05	4.55	1.53	0.39
ADIYAMAN TR 50465/6	**L7**	43.33	25.00	9.83	33.17	4.25	0.94	2.19	1.56	0.48
ADIYAMAN TR 49034/3	**L8**	43.33	26.00	11.21	32.66	4.22	0.90	3.54	1.56	0.42
ADIYAMAN TR 46822/3	**L9**	40.00	31.30	10.04	36.83	5.10	0.94	2.76	1.49	0.47
ADIYAMAN TR 50464/5	**L10**	42.37	32.75	9.83	50.00	5.12	0.94	4.90	1.62	0.55
ADIYAMAN TR 50465/1	**L11**	41.00	32.00	10.46	37.50	4.04	0.88	2.81	1.06	0.37
ADIYAMAN TR 49040/5	**L12**	40.00	31.25	13.87	36.83	5.49	1.08	3.00	1.50	0.41
ADIYAMAN TR 49040/4	**L13**	40.62	31.00	11.87	36.83	4.75	0.88	2.52	1.57	0.43
ADIYAMAN TR 49040/6	**L14**	45.00	29.92	13.37	35.50	5.11	1.23	2.32	1.30	0.42
ADIYAMAN TR 50465/4	**L15**	43.96	29.33	11.42	30.17	5.54	0.94	5.59	1.58	0.45
ADIYAMAN TR 50476/4	**L16**	38.00	24.33	13.08	34.83	4.46	1.05	3.05	1.47	0.42
ADIYAMAN TR 49029/5	**L17**	47.92	33.75	13.17	39.00	4.63	1.09	3.36	1.51	0.40
ADIYAMAN TR 49029/6	**L18**	38.54	28.00	13.37	32.16	4.72	1.03	3.17	1.50	0.42
ADIYAMAN TR 46822/5	**L19**	44.17	29.42	9.25	35.33	5.08	0.93	3.77	1.27	0.41
ADIYAMAN TR 49029/1	**L20**	43.33	32.16	9.62	37.67	5.10	0.92	3.75	1.36	0.46
ADIYAMAN TR 50476/5	**L21**	46.50	35.08	12.04	38.50	4.89	1.12	3.84	1.53	0.43
ERZURUM TR 32790/1	**L22**	37.50	25.92	12.96	32.67	5.61	1.23	2.90	1.54	0.45
ERZURUM TR 45370/5	**L23**	43.33	32.08	10.46	37.66	5.36	0.94	3.19	1.56	0.43
ERZURUM TR 45370/6	**L24**	39.96	31.33	9.83	37.00	5.90	1.00	2.67	1.28	0.45
ERZURUM TR 32893/1	**L25**	43.00	30.25	9.62	35.83	5.36	1.00	2.25	1.56	0.43
ERZURUM TR 45370/4	**L26**	42.50	32.67	9.62	38.17	5.75	1.05	4.97	1.61	0.46
ERZURUM TR 45370/6	**L27**	42.08	33.25	9.00	49.33	6.29	1.09	3.15	1.17	0.45
ERZURUM TR 32655/1	**L28**	43.44	23.00	9.62	35.00	6.09	1.05	5.00	1.62	0.47
ERZURUM TR 32780/3	**L29**	44.37	29.58	11.71	35.50	6.19	1.05	3.69	1.36	0.50
ERZURUM TR 32846/4	**L30**	45.40	30.33	10.96	35.83	6.42	0.94	3.57	1.09	0.44
HAKKARİ TR 47981/1	**L31**	39.17	26.50	13.12	32.33	5.75	1.22	4.08	1.49	0.42
HAKKARİ TR 46763/1	**L32**	36.42	25.33	14.66	33.50	6.40	1.17	4.69	1.57	0.47
HAKKARİ TR 47988/4	**L33**	42.08	33.25	9.83	49.33	4.50	0.94	2.46	1.16	0.45
HAKKARİ TR 47982/5	**L34**	42.29	32.91	8.96	49.83	5.93	1.05	3.61	1.25	0.40
HAKKARİ TR 47981/4	**L35**	38.50	27.83	14.21	32.33	4.97	1.12	3.13	1.53	0.47
HAKKARİ TR 47987/4	**L36**	43.54	24.60	14.67	33.83	4.97	1.05	3.56	1.72	0.40
K.MARAŞ M-396/6	**L37**	44.17	29.50	8.79	35.33	5.20	0.93	5.07	1.21	0.47
K.MARAŞ M-397/6	**L38**	41.00	30.00	12.92	31.50	5.05	1.05	4.95	1.20	0.42
K.MARAŞ TR 32009/1	**L39**	37.00	25.10	9.12	33.33	5.10	0.94	3.54	1.15	0.49
K.MARAŞ M-397/4	**L40**	41.35	31.91	13.54	37.33	5.59	1.00	5.62	1.42	0.45
K.MARAŞ M-388/4	**L41**	40.73	31.00	8.96	36.83	6.01	0.94	5.11	1.61	0.42
K.MARAŞ M-398/3	**L42**	45.52	30.17	9.83	35.83	6.17	0.94	5.11	1.51	0.49
K.MARAŞ M-394/6	**L43**	41.00	30.42	11.21	36.00	5.40	1.07	3.79	1.29	0.47
K.MARAŞ M-391/6	**L44**	39.17	26.50	10.46	32.66	5.42	0.94	4.02	1.57	0.47
KARS TR 48025/6	**L45**	36.67	25.60	8.92	33.16	5.64	1.12	4.58	1.06	0.49
KARS TR 46851/1	**L46**	45.42	30.17	13.12	31.17	5.07	1.17	4.17	1.44	0.42
KARS TR 45904/6	**L47**	43.75	29.08	10.96	31.83	5.10	0.94	3.76	1.36	0.42
MALATYA TR 31894/1	**L48**	42.29	33.08	9.83	49.50	5.36	0.94	4.52	1.25	0.41
VAN TR 45410/4	**L49**	41.87	31.92	10.46	37.33	4.92	0.94	2.61	1.50	0.47

(continued)

Table 1 *(continued)*. Mineral compositions (mg kg^{-1} and g kg^{-1}) in grain of Turkish bread wheat landraces and cultivars*

Pure lines and cultivars origin	NO	Fe	Zn	B	Mn	Cu	Mo	K	Mg	Ca
		mg kg^{-1}						**g kg^{-1}**		
VAN TR 47966/7	**L50**	39.00	26.50	9.67	32.33	6.88	1.05	5.31	1.49	0.42
VAN TR 45938/5	**L51**	39.87	31.33	8.96	37.00	5.23	1.00	3.28	1.35	0.50
VAN TR 45398/6	**L52**	43.33	28.00	9.67	32.17	5.10	1.09	2.51	1.55	0.44
VAN TR 45409/5	**L53**	38.12	27.25	13.42	32.33	5.12	1.23	2.88	1.61	0.48
VAN TR 45410/5	**L54**	39.17	28.58	10.04	32.00	4.81	0.92	3.34	1.31	0.43
VAN TR 45402/4	**L55**	50.83	37.00	9.83	36.33	4.58	0.94	3.18	1.54	0.38
VAN TR 47966/3	**L56**	36.50	29.00	10.50	31.83	5.86	1.00	5.08	1.58	0.47
VAN TR 47993/6	**L57**	39.17	28.67	9.67	32.00	5.04	0.93	2.69	1.60	0.45
VAN TR 32275/5	**L58**	44.17	29.33	13.37	35.16	5.63	1.19	2.33	1.04	0.44
VAN TR 48313/5	**L59**	47.92	33.92	11.21	38.83	5.48	0.94	2.64	1.36	0.41
VAN TR 47993/2	**L60**	36.00	24.50	10.75	33.83	4.84	1.03	3.15	1.59	0.47
VAN TR 47995/3	**L61**	36.67	25.60	10.96	33.00	6.27	1.09	2.43	1.24	0.48
VAN TR 47966/5	**L62**	47.71	33.42	10.04	49.16	4.65	1.05	2.67	1.55	0.45
VAN TR 45399/2	**L63**	37.00	24.33	10.96	34.83	6.14	1.05	4.87	1.29	0.45
VAN TR 47995/5	**L64**	36.00	24.73	10.46	33.83	6.19	1.23	4.02	1.36	0.44
VAN TR 45402/1	**L65**	32.54	24.33	9.62	34.00	6.35	0.94	3.60	1.36	0.49
VAN TR 47995/4	**L66**	35.29	24.33	12.46	34.50	5.71	1.23	4.97	1.06	0.40
VAN TR 39676/4	**L67**	46.30	33.91	13.12	39.00	5.88	1.18	5.07	1.08	0.43
Doğu-88	**C1**	38.00	31.67	12.33	37.17	5.50	1.12	2.79	1.08	0.46
Kirik	**C2**	42.00	32.00	6.62	37.50	6.45	1.19	5.55	1.63	0.48
Mean		**41.74**	**29.69**	**11.04**	**36.40**	**5.43**	**1.04**	**3.73**	**1.42**	**0.44**
Minimum		**32.54**	**23.00**	**6.62**	**30.17**	**4.04**	**0.88**	**2.19**	**1.04**	**0.37**
Maximum		**51.25**	**37.16**	**14.67**	**50.00**	**6.88**	**1.23**	**5.62**	**1.72**	**0.55**

mineral content vector reflects a high capacity to discriminate the genotypes. B, Zn and Fe concentrations were the most discriminating with the longest vectors from the origin. Cu, Mn, K, Ca and Cu concentrations were moderately discriminating while Mg was least discriminating with the smallest vector (Figure 1).

The correlation coefficients among the 9 test mineral contents were given in Table 2. Among the mineral contents, Fe content was positively correlated with Zn and Mn content. The association of Zn with Mn was positive and significant. B content positive and significant correlated with Mo content. Both Zn and Fe content was negative significant correlated with Ca (Table 2).

The vector view of the GGE-biplot (Figure 1) provides a succinct summary of the interrelationships among the mineral contents. Since the cosine of the angle between the vectors of any two traits approximates the correlation coefficient between them, this view of the biplot is best for visualizing the interrelationship among traits (24).

GGT-biplot, which was based on mineral content focused scaling, was portrayed to estimate the pattern of mineral contents (Figure 1). Considering the angles between mineral vectors, Fe and Zn and Mn concentrations were positive significantly strongly correlated (Figure 1). Addition, between Zn and Mn were significantly and positive relationship. However, between Fe and Zn relationship was higher than between Zn and Mn relationship. Similarly, between K, Cu and Ca were significantly positively associated with each other. Among traits, considering the angles between vectors, Fe between and Ca concentrations were significantly negative correlated. Another association between Mo and B was the positive and significant. Other associations between traits weren't significantly correlated. It is remarkable that the nine vector lines approximate well the whole correlation matrix (Table 2).

The biplot Figure 1, as polygon view, presents data of 67 landraces and 2 cultivars in nine minerals can be seen: the vertex landraces or cultivars in this research were Kirik, L10, L48, L2, L55, L17, L14, L36, L16,

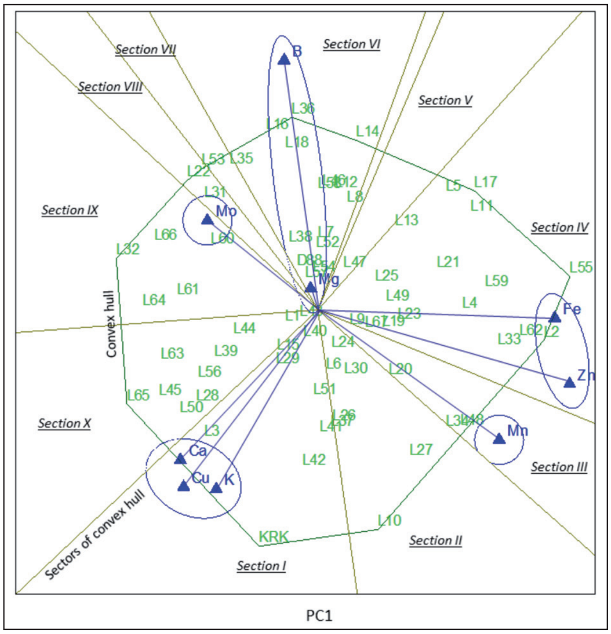

Figure 1. Polygon view of genotype × traits biplot of measured elements of 69 bread wheat landraces, showing which landrace(s) had the highest values for which elements. Details of landraces are presented in Tables 1

L53, L22, L32, L53 and L65. These landraces were the best or the poorest landraces in some or all of the traits since they had the longest distance from the origin of biplot. Therefore, it seems that L2 (ADIYAMAN TR 50457/6) and L55 (VAN TR 45402/4) had the highest values for Zn and Fe concentrations. The vertex landrace L36 (HAKKARİ TR 47987/4) and its related genotypes which fall in its sector were good for B concentration while the vertex landrace L65 (VAN TR 45402/19 and its related genotypes which fall in its sector were bad for Fe and Zn contents. Different trait was evaluated of other plants such as soybean (25), white lupin (26), and rapeseed (27).

The mean effects of the measured across genotypes were examined by defining an average tester coordinate (ATC) axis and an average or virtual genotype is indicated by a circle and shows the positive end of the ATC axis (28). In multi environment trials, ideal genotype is located in the first concentric circle in biplot (29). Desirable genotypes are those located close to the ideal genotype. Thus, starting from the middle concentric circle pointed with arrow concentric was drawn to help visualize the distance between genotypes and the ideal genotype (23). The ideal genotype can be used as a benchmark for selection. Genotypes that are far away from the ideal genotype can be rejected in early breeding cycles (Figure 2) while genotypes that are close to it can be considered in further tests (16). Located in to the first concentric circle landraces L10 can be thus used as benchmarks for evaluation of bread wheat genotypes and could be evaluated ideal genotypes. Landraces L27, L42, L34, L48, L37, L26 and Kirik cultivar, were located near the ideal genotype, thus desirable genotypes (Figure 2).

In GGE-biplot, the ideal environment is representative and has the highest decimating power (16). In GGE- biplot, the ideal test environment should have large PC1 scores and small (absolute) PC2 scores (29). Although such an ideal trait may not exist in reality, it can be used as a reference for genotype evaluation based on multiple traits. Similarly, to the ideal

Table 2. Correlation coefficients between grain mineral contents in bread wheat landraces

Mineral	Zn	B	K	Mn	Cu	Mg	Ca	Mo
Fe	0.700**	0.003	-0.067	0.347**	-0.188	0.124	-0.367**	-0.134
Zn		-0.114	-0.076	0.590**	-0.136	-0.034	-0.256*	-0.161
B			-0.135	-0.202	-0.154	0.055	-0.253*	0.472**
K				-0.086	0.497**	0.094	0.164	0.071
Mn					-0.019	-0.151	0.002	-0.062
Cu						-0.077	0.211	0.310
Mg							0.075	-0.069
Ca								0.065

*: P<0.05; **:P<0.01

genotype, we can evaluate ideal trait in GGT-biplot (23). Such an ideal trait is represented by an arrow pointing to it (Figure 3). A trait is more desirable if it is located closer to the ideal trait. On the other hand, more desirable trait strong positive correlated with ideal trait in biplot. Thus, using the ideal trait as the center, concentric circles were drawn to help visualize the distance between each trait and the ideal trait (16). In ideal trait evaluation, Figure 3 indicated that Mn which fell on the line of concentric circles, were ideal trait in terms of being the most representative of the overall traits and the most powerful to discriminate genotypes. Point of view this evaluation nearest to the first concentric circle, Fe, Zn, Ca, Cu and K were close to ideal trait.

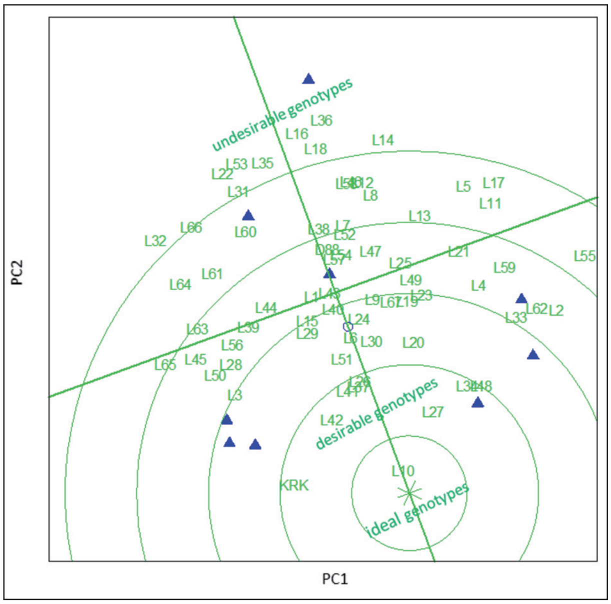

Figure 2. Genotype x trait biplot based on genotype-focused scaling for comparison the landraces with the ideal genotype. Details of landraces are presented in Tables 1

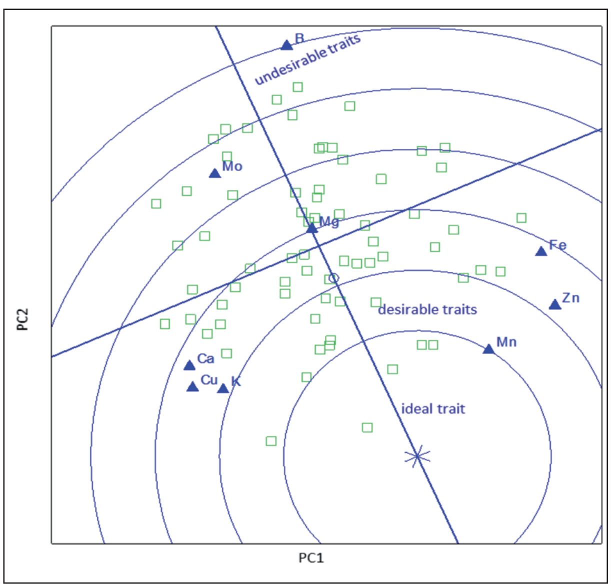

Figure 3. Genotype x trait biplot based on trait-focused scaling for comparison the traits (mineral contents) with the ideal traits

Conclusion

In this study, sixty-nine Turkish bread wheat landraces (67 landraces and 2 cultivars) were evaluated in respect to nine mineral concentrations. In conclusion, based on GT biplot, Mn, Zn and Fe concentrations were determined as ideal/desirable traits suitable for enhancing grain element concentration of bread wheat. When landraces and cultivars are compared, all of landraces revealed to have higher mineral concentrations than all proprietary cultivars. Some landraces including L27, L42, L34, L48, L37, and L26 are good genetic source for improving measured mineral contents due to existence of good genetic variability.

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