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Changes in the Mineral Contents of Bread Wheat Genotypes during the Development Periods of Wheat

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ABSRACT

The purpose of the presented study is to investigate mineral content and their distribution and changes during growth periods of wheat. Twelve bread wheat genotypes were used (Es-26, Bezostaja-1, Müfitbey, Altay-2000, Sönmez-01, Soyer-02, Çetinel-2000, Harmankaya-99, Sultan-95, and Alpu-01, Atay-85 and Gerek-79). Samples for determining minerals were taken at tillering period (Zadoks 20-29), flowering period (Zadoks 60-69), maturity period (Zadoks 90-99) and seed. Considerable differences occured between genotypes and growth stages for minerals. Trends of mineral levels in genotypes are polynomial, it increased and reached at highest level in flowering then decreased. Principal analysis explained that concentrations of ten minerals are homogenous at W_{11} Atay-85 and W_1 Es-26 genotypes. W_7 Çetinel-2000 and W_9 Sultan-95 genotypes also have homogenous content of all ten minerals. It was concluded that W_{10} Alpu-01, W_2 Bezostaja-1 genotypes have the highest content of K, Mg, Na and Mn; W_5 Sönmez-01 genotype has the lowest Zn level and the highest N level. The other genotypes had homogenous mineral concentration. The large variation among genotypes showed that the genetic potential with higher mineral levels could be used in further breeding programs that involve genotypes with large variations, crossing and selection processes, selecting better genotypes for yield, quality, minerals for different environmental conditions.

1. Introduction

Wheat (*Triticum* spp.) is a major food source in the world and it is commonly grown in most of the countries. It has wide adaptability to various environments including irrigated and dry land conditions, this explains why it prevails in food production of the world literature. Wheat is also considered a good source of protein, minerals, B-group vitamins and dietary fiber (Shewry 2007). The nutritional value of wheat is represented by nutritional value of seed and it is grounded for flour, semolina, etc. forming ingredients such as bread, pasta etc. (Lindsay 2002, Welch and Graham 2002, Bouis 2003). Roughly 50% of the cereal production is met by wheat and it is vital role in supplying about 60% of carbohydrates, proteins and minerals (Schulthess et al. 2000). Moreover, wheat serving as seed, green parts of plant and straw is used for animal feed. Straw especially in developing countries fill the gap of fodder crop (Ashraf and Harris 2004). Minerals in plants act basic and important roles in physiological and biochemical processes. Hussain et al. (2010) found that minerals supply more than half of daily intake of Cu, Se, Fe, Mg, Zn, Mn, Mo and P. Existence and availability of them are necessary for every periods of plant growth. Concentrations of minerals in wheat are determined by the choice of genotypes, environmental factors such as soil, climate and management practices and nutritional value of vegetation for minerals significantly depends upon level and availability of minerals in plants and soil, development period of plant. Besides, functionality of plant nutrients is termed as availability of nutrients in right form, quantity, and ratios at a suitable environmental conditions and growth stages (Dikeman and Pomeranz 1982, Akman and Kara 2003, Welch and Graham 2004,

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Murphy et al. 2007, Cakmak 2008, Kirchmann et al. 2009, Kouakou et al. 2008, Roberts 2010). Therefore nutritional value of wheat is so vital for human and animal feeding. Also, determining nutritional values of green parts in different growing periods and in seeds plays important role for development of novel genotypes in breeding programs, agronomic studies (Turnlund 1982, Welch and Graham 2004). One of the targets in agricultural activities is to increase the production of major staple food crops that are rich in macro and micronutrients (Welch and Graham 2004, Stewart et al. 2001, Martinez-Ballesta et al. 2009). The purpose of the presented study is to investigate mineral content and their distribution and changes in wheat during growth periods of wheat. Correlation and factor based principle component analysis (PCA) was made to discriminate minerals and genotypes in wheat.

2. Materials and methods

In this study, twelve bread wheat genotypes (Es-26, Bezostaja-1, Müfitbey, Altay-2000, Sönmez-01, Soyer-02, Çetinel-2000, Harmankaya-99, Sultan-95, and Alpu-01, Atay-85 and Gerek-79) were planted in greenhouse and transferred to grow in outside. This study were carried out in growing periods during 2012-2013. Initially, seeds were sterilized and transferred into pots (0.75 m width, 1 m length, and 0.75 m height) containing 75 kg of loamy textured soil (36,3 % sand, 27,8 % silt, and 39,2 % clay). Soil also had 0,32 % $CaCO_3$, 342,4 mmol/kg P_2O_5, 421,6 mmol/kg K_2O, and 2,13 % organic matter, 6,31 pH, and 2,23 dS/m electrical conductivity. Plants were grown in greenhouse conditions with a day/night temperature regime of 25-28/15-17 °C. Relative humidity was 70/80 % and photoperiod was 17/7 h at a photon flux density about 300 µmol $m^{-2}s^{-1}$ provided by natural light supplement with fluorescent lamps. Experiments were carried out in randomized complete block design with three replications. Wheat was sown during the first two weeks of September. Sixty kg N ha^{-1} (½ at sowing period and ½ at tillering period) and 60 kg ha^{-1} P_2O_5 (at sowing) were applied. Ammonium sulfate (21% N) and triple superphosphate (46% P_2O_5) were used as fertilizers in the study. Normal quality water (EC=1.0–2.5 dS m^{-1}) was selected in the study. Plants were allowed to grow until tillering period (Zadoks 21) under greenhouse then they were transferred outside and they overwintered under ambient conditions. Transferred pots in the experiment were protected from bird damage by netting. Normal irrigations at sowing, at stem elongation (Zadoks 24), and at flowering (Zadoks 65) were applied. Outside study was carried out on experimental station of Osmangazi University, Agricultural College Eskişehir during crop growing season of 2012-2013 (36° 56° North, 30° 32° East, 788 m altitude). Precipitations in 2012-2013 and long term years were 316,9 mm and 311,5 mm, respectively. Moreover, minimum, maximum and average temperatures were -2,6°C, 24,9°C and 7,2°C in 2012-2013; -10,8°C, 29.0°C and 9,0°C in long term years. Total rainfall in 2012-2013 was higher than long term periods. Besides, monthly rainfalls in 2012-2013 were higher in March and May, and lower in October, November, April and June (Table 1).

Samples for determining minerals were taken at tillering period, flowering period, maturity period and seed. The Kjeldahl method and a Vapodest 10 Rapid Kjeldahl Distillation Unit (Gerhardt, Konigswinter, Germany) were used to determine the total N content (Doğan 2002, Varga et al. 2002). The Ca, Mg, Na, K, P, Fe, Cu, Mn, Zn contents in genotypes were determined by using an Inductively Coupled Plasma spectrometer (Perkin-Elmer, Optima 2100 DV, ICP/OES, Shelton, CT 06484-4794, USA (Mertens 2005). Descriptive analysis of the data, Principle Component and Correlation Analyses were performed by using the soft-ware package STATISTICA 10.0 (Rees 1995, Jambu 1991, Otto 2007, Hiltbrunner et al. 2007).

3. Results and Discussions

3.1. Tillering Period (Zadoks 20-29)

The levels of minerals in tillering period are shown in Table 2. Differences occurred in differed levels for genotypes. The highest mineral levels were obtained from $\mathbf{W_5}$ (2,27%), $\mathbf{W_4}$ (2651 mg/kg) and $\mathbf{W_{11}}$ (12021 mg/kg), whereas $\mathbf{W_7}$ (1,98%), $\mathbf{W_7}$ (2218 mg/kg) and $\mathbf{W_4}$ (10268 mg/kg) had the lowest mineral level in N, P and K, respectively. In Ca, Mg and Na, the highest mineral levels belonged to $\mathbf{W_6}$ (4951 mg/kg), $\mathbf{W_4}$ (1955 mg/kg) and $\mathbf{W_9}$ (469 mg/kg). The lowest ones were $\mathbf{W_8}$ (3811 mg/kg), $\mathbf{W_{12}}$ (1612 mg/kg) and $\mathbf{W_1}$ (402 mg/kg), respectively. $\mathbf{W_8}$ gave interesting results, it had the highest level in Fe (89,45 mg/kg) and lowest level in Cu (35,41 mg/kg); lowest value in Fe was 75,69 mg/kg in $\mathbf{W_5}$ and the highest value in Cu was 46,41 mg/kg in $\mathbf{W_{10}}$. Moreover, $\mathbf{W_7}$ with 29,51 mg/kg in Mn and $\mathbf{W_{10}}$ with 36,49 mg/kg in Zn gave the highest levels. The lowest values were 20,10 mg/kg in $\mathbf{W_{12}}$ for Mn and 24,15 mg/kg in $\mathbf{W_6}$ for Zn (Table 2).

3.2. Flowering Period (Zadoks 60-69)

The levels of minerals in flowering period are shown in Table 3. The highest mineral levels were taken from $\mathbf{W_5}$ (2,59%), $\mathbf{W_4}$ (2943 mg/kg) and $\mathbf{W_1}$ (11505 mg/kg); moreover the lowest ones belonged to $\mathbf{W_9}$ (2,31%), $\mathbf{W_1}$ (2454 mg/kg) and $\mathbf{W_4}$ (9755 mg/kg) in N, P and K, respectively. The highest and lowest values in Ca, Mg and Na were 6040 mg/kg in $\mathbf{W_1}$ and 4698 mg/kg in $\mathbf{W_5}$; 2111mg/kg in $\mathbf{W_4}$ and 1741 mg/kg in $\mathbf{W_{12}}$; 516 mg/kg in $\mathbf{W_9}$ and 442 mg/kg in $\mathbf{W_1}$; Fe and Cu had the highest values in $\mathbf{W_5}$ and $\mathbf{W_4}$ with 111,81 mg/kg and 40,01 mg/kg; $\mathbf{W_5}$ and $\mathbf{W_8}$ with 94,61 mg/kg and 30,45 mg/kg had the lowest mineral levels. The highest mineral levels for Mn and Zn were in $\mathbf{W_7}$ (34,82 mg/kg); and in $\mathbf{W_{10}}$ (33,94 mg/kg) and minimum values were taken in $\mathbf{W_{12}}$ 28,65 mg/kg) and in $\mathbf{W_4}$ (22,46 mg/kg).

3.3. Maturity Period (Zadoks 90-99)

The levels of minerals in maturity period are shown in Table 4. **W_5** (2,17%) and **W_7** (1,90%) in N, **W_4** (2707 mg/kg) and **W_1** (2258 mg/kg) in P, **W_1** (13000 mg/kg) and **W_4** (11023 mg/kg) in K, **W_6** (5376 mg/kg) and **W_8** (4181 mg/kg) in Ca, **W_4** (2280 mg/kg) and **W_{12}** (1880 mg/kg) in Mg, **W_9** (475 mg/kg) and **W_1** (407 mg/kg) in Na, **W_8** (124,11 mg/kg) and **W_{10}** (108 mg/kg) in Fe, **W_5** (35,21 mg/kg) and **W_8** (26,80 mg/kg) in Cu, **W_7** (42,13 mg/kg) and **W_{12}** (28,70 mg/kg) in Mn, **W_{10}** (42,76 mg/kg) and **W_6** (28,30 mg/kg) in Zn gave the highest and lowest values, respectively. The levels of minerals in grain are shown in Table 5. In N, P, K, Ca and Mg, The highest mineral levels were taken from **W_5** (2,00%), **W_4** (3059 mg/kg), **W_1** (4550 mg/kg), **W_6** (6075 mg/kg) and **W_4** (707 mg/kg); besides the lowest values belonged to **W_7** (1,74%), **W_1** (2551 mg/kg), **W_4** (3858 mg/kg), **W_9** (4596 mg/kg) and **W_{12}** (583 mg/kg).

Table 1
Average, minimum and maximum temperatures, precipitations in 2012-2013 and long term years in Eskişehir

Climatic Param.	Years	October	Novem-ber	Decem-ber	January	Febru-ary	March	April	May	June	July	Tot./Av.
Max. Temp. (ºC)	2012-2013	24,2	21,8	19,1	14,3	17,8	24,6	24,4	29,2	34,3	38,9	24,9
	Long	33,0	25,4	21,4	20,2	20,5	28,1	31,1	33,3	36,8	40,6	29,0
Min. Temp. (ºC)	2012-2013	-3,3	-6,7	-9,1	-7,4	-12.9	-8,1	-2,8	1,5	5,6	6,6	-2,6
	Long	-6,8	-12,2	-19,2	-27,8	-22,4	-12,0	-10,4	-2,2	0,5	5,0	-10,8
Av. Temp. (ºC)	2012-2013	8,5	0,8	0,9	-3,6	-5,5	1,5	12,0	14,4	20,1	22,8	7,2
	Long	11,7	5,6	1,7	-0,2	0,9	4,9	9,6	14,9	19,1	22,1	9,0
Total Ra. (mm)	2012-2013	5,8	0,0	46,1	58,0	42,1	56,4	22,1	80,9	0,0	5,5	316,9
	Long	32,8	34,0	40,5	30,6	26,1	27,6	43,1	40,0	23,7	13,1	311,5

* Data of regional meteorology station, Eskisehir
**Long years include years of 1970-2013

Table 2
The levels of minerals on tillering period in wheat genotypes

Tillering Period	%	mg/kg								
Genotypes	N	P	K	Ca	Mg	Na	Fe	Cu	Mn	Zn
W_1Es-26	2,1	2211	12110	4023	1912	402	80,72	42,12	22,31	26,59
W_2Bezostaja-1	2,24	2341	11542	4255	1756	425	82,36	43,15	25,62	25,87
W_3Müfitbey	2,03	2458	11365	4168	1823	416	88,62	40,21	24,15	31,24
W_4Altay-2000	2,15	2651	10268	4474	1955	447	84,15	44,58	23,15	30,78
W_5Sönmez-01	2,27	2501	10845	4512	1748	431	75,69	46,52	22,37	26,58
W_6Soyer-02	2,12	2419	10524	4951	1792	451	76,57	38,59	25,61	24,15
W_7Çetinel-2000	1,98	2218	11362	4632	1856	448	82,31	37,62	29,51	34,51
W_8Harmankaya-99	2,11	2347	11320	3851	1842	424	89,45	35,41	24,13	32,06
W_9Sultan-95	2,03	2516	10574	3746	1799	469	80,11	39,58	28,62	30,74
W_{10}Alpu-01	2,21	2498	12021	3911	1813	457	78,2	46,41	20,35	36,49
W_{11}Atay-85	2,16	2245	11635	4026	1765	420	83,56	40,13	25,48	29,51
W_{12}Gerek-79	2,26	2330	11598	4475	1612	410	79,48	42,31	20,10	32,00
Mean	2,14	2394,58	11263,67	4252,00	1806,08	433,33	81,77	41,39	24,28	30,04
S_d	0,10	136,08	590,03	362,23	86,86	20,70	4,28	3,44	2,91	3,67

.... lowest level, ______ highest level

Table 3

The levels of minerals on flowering period in wheat genotypes

Tillering Period	%	mg/kg								
Genotypes	N	P	K	Ca	Mg	Na	Fe	Cu	Mn	Zn
W_1Es-26	2,39	2454	11505	4908	2065	442	100,90	36,22	26,33	24,73
W_2Bezostaja-1	2,55	2599	10965	5191	1896	468	102,95	37,11	30,23	24,06
W_3Müfitbey	2,31	2728	10797	5085	1969	458	110,78	34,58	28,50	29,05
W_4Altay-2000	2,45	2943	9755	5458	2111	492	105,19	38,34	27,32	28,63
W_5Sönmez-01	2,59	2776	10303	5505	1888	474	94,61	40,01	26,40	24,72
W_6Soyer-02	2,42	2685	9998	6040	1935	496	95,71	33,19	30,22	22,46
W_7Çetinel-2000	2,26	2462	10794	5651	2004	493	102,89	32,35	34,82	32,09
W_8Harmankaya-99	2,41	2605	10754	4698	1989	466	111,81	30,45	28,47	29,82
W_9Sultan-95	2,31	2793	10045	4570	1943	516	100,14	34,04	33,77	28,59
W_{10}Alpu-01	2,52	2773	11420	4771	1958	503	97,75	39,91	24,01	33,94
W_{11}Atay-85	2,46	2492	11053	4912	1906	462	104,45	34,51	30,07	27,44
W_{12}Gerek-79	2,58	2586	11018	5460	1741	451	99,35	36,39	23,72	29,76
Mean	2,44	2657,99	10700,48	5187,44	1950,57	476,67	102,21	35,59	28,65	27,94
S_d	0,11	151,14	560,52	441,97	93,74	22,84	5,35	2,96	3,43	3,41

.... lowest level, _______ highest level

Table 4

The levels of minerals on maturity period in wheat genotypes

Tillering Period	%	mg/kg								
Genotypes	N	P	K	Ca	Mg	Na	Fe	Cu	Mn	Zn
W_1Es-26	2,01	2258	13000	4368	2230	407	112,00	31,88	31,85	31,16
W_2Bezostaja-1	2,15	2391	12390	4620	2048	430	114,27	32,66	36,58	30,31
W_3Müfitbey	1,94	2510	12200	4526	2126	421	122,96	30,43	34,48	36,61
W_4Altay-2000	2,06	2707	11023	4858	2280	452	116,76	33,74	33,05	36,07
W_5Sönmez-01	2,17	2554	11642	4899	2039	436	105,02	35,21	31,94	31,15
W_6Soyer-02	2,03	2470	11298	5376	2090	456	106,24	29,20	36,57	28,30
W_7Çetinel-2000	1,90	2265	12197	5029	2165	453	114,21	28,47	42,13	40,44
W_8Harmankaya-99	2,02	2397	12152	4181	2149	429	124,11	26,80	34,45	37,57
W_9Sultan-95	1,94	2569	11351	4067	2098	475	111,15	29,95	40,86	36,02
W_{10}Alpu-01	2,12	2551	12905	4247	2115	462	108,50	35,12	29,06	42,76
W_{11}Atay-85	2,07	2293	12490	4371	2059	425	115,94	30,37	36,38	34,58
W_{12}Gerek-79	2,16	2379	12450	4859	1880	415	110,28	32,02	28,70	37,50
Mean	2,05	2445,35	12091,55	4616,82	2106,62	438,53	113,45	31,32	34,67	35,20
S_d	0,09	138,84	633,31	393,39	101,32	20,86	5,94	2,61	4,15	4,30

.... lowest level, _______ highest level

3.4. Grain

The highest and lowest values in Na, Fe, Cu, Mn and Zn were **W_9** (195mg/kg) and **W_1** (167 mg/kg), **W_8** (22,34 mg/kg) and **W_5** (18,90 mg/kg), **W_5** (8,10 mg/kg) and **W_8** (6,16 mg/kg), **W_7** (10,95 mg/kg) and **W_{12}** (9,01 mg/kg), **W_7** (23,45 mg/kg) and **W_6** (16,41 mg/kg), respectively.

3.5. Correlation and Principal Component Analyses

Correlation coefficients in all minerals are given in Table 6. Relationship between Mn and N, K and P, Na and K, Cu and Fe, Mn and Cu were found at negative and significant at 5%; whereas only relationship between Mg and N, N and Cu, Na and P were positive and significant at 5%.

Similarities/dissimilarities are revealed by eigenvalues and total variances in wheat genotypes are shown in Table 7. The first factor showing the largest eigenvalue (6,84) accounts for approximately 68,50% of the total variance. The second factor giving the second eigenvalue (1,46) accounts for almost 14,60% of the total variance. Having 83,10% of total variance, Factor I and II assign variances in minerals and genotypes.

Table 5
The levels of minerals in grain of wheat genotypes

Grain	%	mg/kg								
Genotypes	N	P	K	Ca	Mg	Na	Fe	Cu	Mn	Zn
W_1Es-26	1,85	2551	4550	4936	691	167	20,16	7,33	8,28	18,07
W_2Bezostaja-1	1,97	2701	4337	5221	635	176	20,57	7,51	9,51	17,58
W_3Müfitbey	1,79	2836	4270	5114	659	173	22,13	7,00	8,97	21,23
W_4Altay-2000	1,89	3059	3858	5489	707	185	21,02	7,76	8,59	20,92
W_5Sönmez-01	2,00	2886	4075	5536	632	179	18,90	8,10	8,30	18,06
W_6Soyer-02	1,87	2791	3954	6075	648	187	19,12	6,72	9,51	16,41
W_7Çetinel-2000	1,74	2559	4269	5683	671	186	20,56	6,55	10,95	23,45
W_8Harmankaya-99	1,86	2708	4253	4725	666	176	22,34	6,16	8,96	21,79
W_9Sultan-95	1,79	2903	3973	4596	650	195	20,01	6,89	10,62	20,89
W_{10}Alpu-01	1,95	2883	4517	4799	656	190	19,53	8,08	7,55	24,80
W_{11}Atay-85	1,90	2591	4372	4940	638	174	20,87	6,99	9,46	20,06
W_{12}Gerek-79	1,99	2689	4358	5491	583	170	19,85	7,36	7,46	21,75
Mean	1,88	2763,24	4232,04	5217,01	653,05	179,80	20,42	7,20	9,01	20,42
S_d	0,08	157,06	221,77	444,45	31,37	8,64	1,07	0,60	1,08	2,50

.... lowest level, _______ highest level

Table 6
Correlation matrix for characters of wheat genotypes

	N	P	K	Ca	Mg	Na	Fe	Cu	Mn
P	0,167ns								
K	0,150ns	-0,662*							
Ca	0,121ns	0,024bs	-0,405ns						
Mg	0,537*	0,184ns	-0,176ns	-0,133ns					
Na	-0,258ns	0,546*	-0,557*	0,053ns	0,208ns				
Fe	-0,433ns	-0,112ns	0,101ns	-0,396ns	0,347ns	-0,322ns			
Cu	0,681*	0,460ns	0,086ns	0,050ns	-0,090ns	0,019ns	-0,519*		
Mn	-0,698*	-0,203ns	-0,359ns	0,055ns	0,218ns	0,433ns	0,177ns	-0,616*	
Zn	-0,238ns	0,078ns	0,274ns	-0,361ns	0,067ns	0,265ns	0,296ns	-0,040ns	-0,077ns

*: Significant at 5%
**: Significant at 5%, ns: No significant

Table 7
Eigenvalues and total variances in wheat genotypes

	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6	PC_7	PC_8	PC_9	PC_{10}
Eigenvalue	6,8481	1,4611	0,6749	0,5733	0,2234	0,1370	0,0542	0,0153	0,0074	0,0054
Proportion	0,685	0,146	0,067	0,057	0,022	0,014	0,005	0,002	0,001	0,001
Cumulative	0,685	0,831	0,898	0,956	0,978	0,992	0,997	0,999	0,999	1,000

Correlation based factor coordinates of minerals in wheat genotypes are seen in Table 8 and Rotated principal component loadings in minerals of wheat genotypes are given in Figure 1. K (-0,988), Mg (-0,979), Na (-0,956) and Mn (-0,901) in the first PC, N (0,710) and Ca

(0,687) in the second PC have highest contribution (Table 8 and Figure 1)

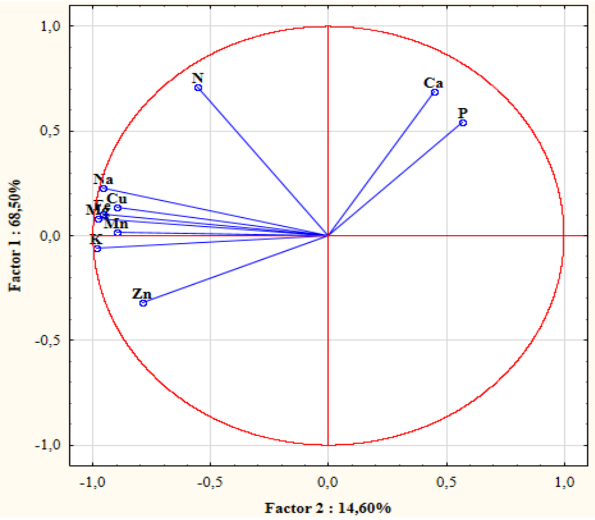

Figure 1

Rotated principal component loadings in minerals of wheat genotypes

Moreover, rotated principal component scores for genotypes in wheat are given in Figure 2. W_{10} Alpu-01, W_2 Bezostaja-1 affect total variability of the first component. Figure 2 also showed that total variability of the second component was influenced mostly by W_5 Sönmez-01. W_{10} Alpu-01, W_2 Bezostaja-1 genotypes denote the first PC (K, Mg, Na and Mn); W_5 Sönmez-01 almost denotes the second PC (N and Ca). Two PC explain that concentrations of ten minerals are homogenous at W_{11} Atay-85 and W_1 Es-26 genotypes. W_7 Çetinel-2000 and W_9 Sultan-95 genotypes also have homogenous content of all ten minerals (Figure 2). It was concluded that W_{10} Alpu-01, W_2 Bezostaja-1 genotypes have the highest content of K, Mg, Na and Mn; W_5 Sönmez-01 genotype has the lowest Zn level and the highest N level. The other genotypes have homogenous mineral concentration.

4. Discussions

Plants take inorganic minerals from environments mostly from soil to accomplish enough plant growth and development of both vegetative and reproductive tissues. Minerals taken act important roles such as structural, enzymatic and osmotic processes (Lopez et al. 2003). Depending upon roles and efficiencies, levels of

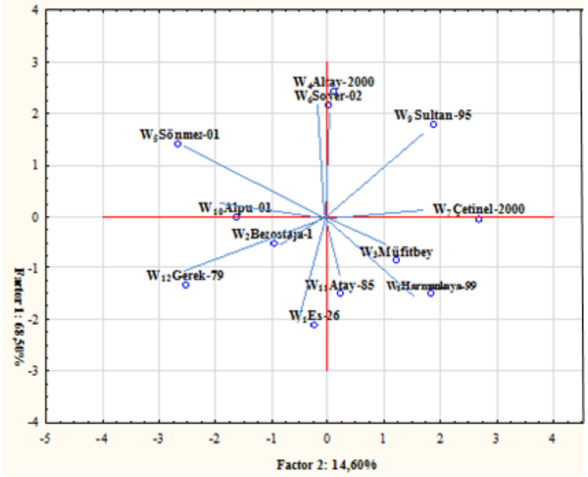

Figure 2

Rotated principal component scores for wheat genotypes

minerals expose changes, they increase and draw polynominal range during the development of plants (Branca and Ferrari 2002). Higher grain and biomass productions in wheat are significantly related to amount and availability of minerals in soil (Bonfil and Kafkafi, 2000). Changes on mineral levels in crop growth development periods of wheat genotypes are shown in Figure 3. Trend of mineral differently occurred. Excluding Cu, changes in all minerals draw exponential trends in genotypes; it increased and reached at highest level in flowering then decreased. Changes in mineral concentrations in tillering, flowering, maturity periods and grain of wheat genotypes are evaluated. Tillering period is early development period and shows rapid development. Besides biochemical products and mineral levels are lower than later periods (Cakmak 2008, Kirchmann et al. 2009). Similar to studies, level of minerals was at lowest level in this period. Flowering initiates almost four days after heading. This period is known as transition period of vegetation and grain filling periods; generative development takes place to determine yield potential of crop (Varga et al. 2002, Gomez-Becerra et al. 2010).

Table 8

Factor coordinates of minerals, based on correlations in wheat genotypes

Characters	PC_1	PC_2	Characters	PC_1	PC_2
N	-0,554	0,710	Na	-0,956	0,228
P	0,569	0,542	Fe	-0,960	0,103
K	-0,988	-0,058	Cu	-0,900	0,133
Ca	0,447	0,687	Mn	-0,901	0,014
Mg	-0,979	0,082	Zn	-0,791	-0,317

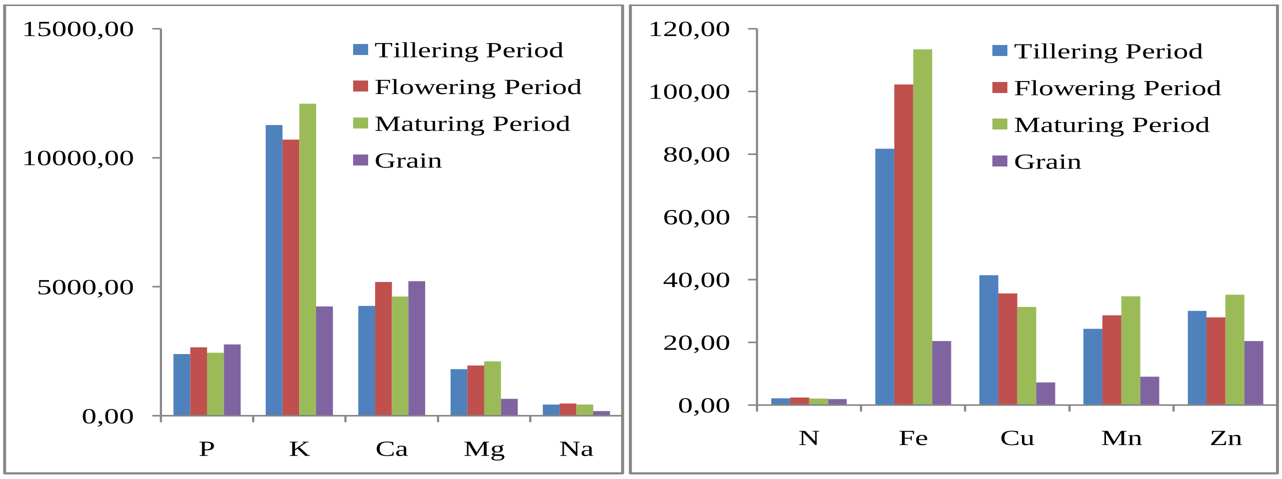

Figure 3
Changes on mineral levels in crop growth development periods of wheat genotypes

Tillering period is also determinator of grain filling period that final yield is monitored (Doğan 2002). Big differences were found in genotypes for minerals. Mineral levels increased with growing of genotypes and they reached the highest levels in this period. Maturity period assigns the period from flowering to grain maturity. During this period endosperm starts to form and assimilates, starches, proteins, compounds and minerals from leaves, stems, and roots to grains are transported. This period that grain size and weight are formed in is also under the effect of genotype x environment interactions. The usage and levels in minerals are closely related to increase/ decrease in photosynthetic activity and hence plant growth; mineral levels increase toward flowering then decline and follow polynominal relationship (Stewart et al. 2001, Martinez-Ballesta et al. 2009). In our study mineral levels were determined lower than flowering stage.

As a main source of nutrients to the most of the world population, the nutritional value of wheat grain carries great importance. Main strategies of breeding programs are to develop wheat genotypes, enriched for proteins, vitamins, minerals etc. We found that trends of mineral levels in genotypes are polynomial, it increased and reached at highest level in flowering then decreased. Our results are similar to findings of Akman and Kara (2003), they found that concentrations of minerals draw polynomial line. Davis et al. (1977) examined mineral concentrations in wheat and found large variations in genotypes grown different locations. Being essential for growth and health, or non-essential contributing to physiological functions, they are potentially necessary for plant growth, yield and quality (Ashraf and Harris 2004). Wheat growth are mainly under effect of genetic factors in interaction with environment depending upon genetic potential and suitability of environmental factors and agronomic practices, the amount of minerals in plant parts and grain is related to biologic activities. Photosynthetic activities of vegetative tissues play vital role on determining mineral concentration in plant parts and therefore in grain (Schelmmer et al. 2005, Yuncai et al. 2007). There are great variations in photosynthetic activities and chlorophyll concentrations in wheat genotypes (Yuncai et al. 2007, Roberts 2010). Similarly variations between genotypes and growing periods and grain are determined in the present study. Correlation between the chlorophyll content and N and Fe concentration is positive, increase in chlorophyll content causes increase in amount of Fe in the leaves and in the grain (Haugstad et al. 1983, Bouis 2007, Peleg et al. 2008, Jambu 1991, Roberts 2010). Moreover, increasing mineral uptake by plants result in an increases in dry matter and mineral accumulations in the stem and leaves, then dry matter and mineral accumulation in reproductive period, so the more dry matter and mineral accumulate the more yield occurs (Schelmmer et al. 2005). Similar results were found by Haugstad et al. (1983) and Peleg et al. (2008) that chlorophyll content, leaf surface and dry matter weight could be used as a potential indicator for nutrients deficiency in the soil. N and P increase dry matter synthesis and cause more dry matter weight.

Bread wheat and barley having economic importance are splendid crops for genetically, morphological and physiological studies (Varga et al. 2002, Murphy et al. 2008, Hussain et al. 2010). Assessment of plants in terms of morphological characteristics is main breeding objective and could be successfully defined by principal component analysis and classifications are performed by principal component analysis that could be used to identify and to map into dimensions among characters, to determine clusters of variables with similar characteristics. Besides the aim of principal component and classification analysis is to determine certain factors, and to explain correlations in variable data. It could be said that the higher value of the factor is loaded of a variable on a particular factor, the more significantly is the variable related to that factor. (Mohammadi and Prasanna 2003). Moreover, correlation analysis is widely used in statistical evaluations and it shows efficiency of relationship between two variables (Rees 1995, Ozdamar 1999). If correlation close to zero, two characters are independent from each other (Acevedo et al. 1989, Rees 1995, Ozdamar 1999, Hiltbrunner et al. 2007). Obtained data from correlation analysis show similarities with literatures. Positive correlation between N and yield, N and chlorophyll content and N and dry matter; negative correlation between yield and Cu, Fe and Mg (Hussain et al. 2010). Meanwhile, correlation between the chlorophyll content and N and Fe concentration is positive (Roberts 2010).

In conclusion, this study reports that, considerable differences occur between genotypes and growth stages for minerals. The large variation among genotypes shows that the genetic potential with higher mineral levels could be used in further breeding programs that involve genotypes with large variations, crossing and selection processes, selecting better genotypes for yield, quality, minerals for different environmental conditions.

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