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Original scientific article

GENETIC DIVERSITY FOR MINERAL ELEMENT IN SEEDS OF TURKISH OAT LANDRACES

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Oat grain is an important cereal in the human diet and as an animal feed. It is cultivated in many regions of the world. This study was carried out to determine the variability in the element content of these oat gene sources collected from the West and Middle Black Sea Region of Turkey. Two hundred and fifty-six oat genotypes were examined under this study. The mean of mineral elements in landraces and commercial cultivars were 40.39 g kg^{-1} and 36.16 g kg^{-1} for K, 23.90 g kg^{-1} and 28.51 g kg^{-1} for P, 12.47 g kg^{-1} and 10.99 g kg^{-1} for Mg, 10.92 g kg^{-1} and 10.96 g kg^{-1} for Ca, 2.58 g kg^{-1} and 2.36 g kg^{-1} for Na, 54.70 mg kg^{-1} and 53.02 mg kg^{-1} for Fe, 32.08 mg kg^{-1} and 23.51 mg kg^{-1} for Mn, 25.39 mg kg^{-1} and 24.05 mg kg^{-1} for Zn and 8.26 mg kg^{-1} and 8.07 mg kg^{-1} for Cu, respectively. The ranges of mineral elements in the landraces were significantly higher than those in the commercial cultivars. The contributions of the first and second principal components (PC1 and PC2) to the total variation were 43.0% and 15.6%, respectively. These results indicate that examined oat landraces can provide a good source of diversity in mineral elements concentration and could be successfully used in biofortification programs.
Key words: Avena sativa L., macro-micro elements, genotypes, local cultivar

INTRODUCTION

Turkey is the center of origin, with great and genetic diversity of many wilds, transitional, and cultivated forms of annual and perennial plants such as the cultivated species of Allium, Amygdalus, Avena, Beta, Cicer, Hordeum, Lens, Linum, Pisum, Prunus, Secala, Triticum, and Vitis (TAN, 1998). Agricultural modernization, conventional breeding, and excessive inputs

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cause a reduction of genetic diversity and the stagnation of yields in cereals use (NEWTON *et al.*, 2010). Landraces are populations that have been formed by natural selection processes under the effects of climate, soil type and agronomic conditions of a particular region, and have suffered artificial selection pressures from the deliberate manipulation of farmers. In addition, landraces are important gene resources to increase genetic diversity and allow the development of new varieties with high-quality characteristics. Since oat acreage is much lower than that of most cereals, commercial effort in oat breeding is also lower (BUERSTMAYR *et al.*, 2007). Oat is usually grown by farmers with very small areas to supply feed for their limited number of cattle in the Black Sea Region in Turkey where field areas are small, traditional agriculture concept, geographical and ecological diversity. In the region, local oat varieties are generally grown for many years by farmers who produced their seed. Modern crop varieties were readily adopted by wealthy farmers, who had the capital, education, land, and others in time (TAN, 1998). There are many different local and wild oat varieties in Turkey. Therefore, Turkey is considered to be one of the important origin centers of the oat (DUMLUPINAR *et al*., 2011). For sustainable agriculture, collection, protection, characterization and identification of landraces are very important for future breeding studies. The landraces have enormous conservation value, both for the maintenance of the cultural heritage and to assist in crop breeding programs (CECCARELLI, 1994; BARDSLEY and THOMAS, 2005). A large number of modern oat cultivars have been derived from individual selections from landraces or crosses involving these selections (KATSIOTIS *et al.*, 2006). Oat is generally grown for both grain and forage for livestock feed in Turkey. It becomes very popular from the beginning of the XXI century, due to its great value: various forms of fibre, such as, ß-glucan and others, unique protein profile, high level of minerals, lipids, vitamins, antioxidants and phenolic compounds (AHMAD *et al*., 2014; SANG and CHU, 2017). Sustainable food systems widely include whole grain food, including oat in greater amounts, as well. The health benefits of oat can be attributed largely to their unique chemistry and nutrient profile.

In recent years, one of the aims of plant breeding programs is to increase mineral accumulation in cereal grains. This approach is a sustainable strategy to increase the use of micronutrients in diets as there are no further costs after the development of new cultivars (NEERAJA *et al*., 2017). Increasing its micronutrient ratio becomes an important breeding goal, as oats are increasingly included in diets due to their nutritional properties and being a low-cost food. In addition, minerals in plants, which are structure-forming (macro-nutrients) and participate in the regulation of biochemical processes (micro-nutrients), are also necessary for the proper growth and development of animals (BARCZAK and NOWAK, 2013).

This study, which was carried out to determine the variability in the element content of these oat gene sources collected from the West and Middle Black Sea Region of Turkey, will shed light on the future breeding and development possibilities of oats.

MATERIALS AND METHODS

Two hundred and fifty-two oat landraces collected from provinces in the West and Middle Black Sea Region of Turkey and 4 commercial cultivars (Seydişehir, Yeşilköy-330, Yeşilköy-1779, Faikbey) were examined under this study. Seeds of landraces were collected from farmers' fields, village threshing grounds and farmer stores of Düzce, Bolu, Zonguldak, Karabük, Kastamonu, Ordu, Sinop, Samsun, Amasya and Tokat provinces in previous years. All landraces, cultivars and their collection sites are given in Table 1 shows the collection sites of Turkish oat genotypes used in this study. Two hundred and fifty-six genotypes were evaluated using 16x16 alpha lattice design with three replications during the 2014-2015 growing seasons at the Ondokuz Mayıs University in Samsun, in the Middle Black Sea Region of Turkey (41º 21'N, 36º 15' E, elevation: 195 m). Each genotype was sown in four rows of 2 meters length with row spacing of 20 cm. Sowing dates were 25 October 2014. Plots were fertilized with 60 kg ha^{-1} N and 60 kg ha^{-1} P at sowing. Also, top-dressing was applied as 4 kg ha^{-1} N at tillering stage. Herbicide (Tribenuran-metil (DF) %75) was used in the tillering stage for weed control. Harvesting dates were 11 July 2015.

Soil samples were taken to determine some of the soil properties from 0-30 cm depth. The soil structure and pH were clay and 7.1, respectively. Organic matter ratio, Ca and Mg contents were 2.98, 0.64 and 0.11%, respectively. K content was 362.1 g kg^{-1}, P content was 71.0 g kg^{-1}, Fe, Zn and Mn contents were 32.40, 3.60 and 52.11 mg kg^{-1}, respectively. Throughout the vegetation period (from October to July) of 2014-15 total rainfall was 743.2 mm, the mean temperature was 14.5, and average relative humidity was 67.6 %.

Mineral element analysis

Grains for the mineral element analysis were transported to the laboratory in cloth bags. The grains were cleaned in an air screen cleaner to remove all foreign matter such as dust, dirt, stones and chaff, and then immature and broken grains were discarded. These grains were dried in an oven for 48 h at 65 ºC and at the end of all these processes, their moisture content was measured. Samples were ground for analysis. The ground samples were weighed as 1 g in porcelain crucibles. The weighed samples were added 5% H_2SO_4 and pre-digested was carried out at 90ºC for 50 minutes on the hot plate. Then, these samples were placed in the ash furnace. The temperature of the furnace was gradually increased to 500ºC and the samples were burned for 8 hours at this temperature until completely ashed. After, 1 N HCl was added to ash samples and left for 30 minutes. Then, the samples were filtered with filter paper and were diluted up to 50 mL with ultrapure water.

Minerals were quantified using inductively coupled plasma mass spectrometry (ICP-MS) using a Thermo Scientific - iCAPQc (Bremen, Germany) (GULUMSER *et al*., 2021) in Science and Technology Application and Research Center at the Bozok University. All samples were analyzed in duplicate and the mean was used for the statistical analysis. The following minerals were quantified: Potassium (K), Magnesium (Mg), Calcium (Ca), Sodium (Na), Iron (Fe), Manganese (Mn), Zinc (Zn) and Copper (Cu). Phosphorus (P) content was determined by the "Olsen" method (OLSEN and SOMMERS, 1982).

Statistical Analysis

Analysis of variance was performed for 9 minerals by using the PROC GLM method of the SAS computer program (SAS, 1998). Significant variation ($P<0.01$) was identified between the accessions for all examined minerals. For the investigated minerals standard deviation (SD) was also calculated. The principal component analysis (PCA) was performed based on all the investigated traits and the relationship between the provinces where the genotypes were collected and the elements. Pearson's linear correlation coefficients among all the traits were obtained by PROC CORR. To group the landraces and cultivars based on studied traits PCA was performed based on the Euclidean distances and the unweighted pair group method with arithmetic mean (UPGMA) was applied (ROHLF, 2004; RAZA *et al*., 2017).

RESULTS

The means of mineral element concentrations in grain of the 256 genotypes were presented in Table 1. And the mean, maximum, minimum and standard deviations (SD) values in which these genotypes were shown in Table 2. The variation in the K, P, Ca, Mg, Na, Fe, Mn, Zn and Cu concentrations of oat genotypes collected from different locations was 48.7 g kg^{-1}, 25.0 g kg^{-1}, 54.5 g kg^{-1}, 57.0 g kg^{-1}, 31.2 g kg^{-1}, 35.6 mg kg^{-1}, 32.8 mg kg^{-1}, 39.6 mg kg^{-1} and 39.9 mg kg^{-1}, respectively (Table 1).

While K contents in grains of landraces were ranged between 28.36 g kg^{-1} (G189) and 58.29 g kg^{-1}(G80) with an average of 40.39 g kg^{-1}, K contents in cultivars were ranged between 32.11 g kg^{-1} (Faikbey) and 38.30 g kg^{-1} (Seydişehir) with an average of 36.16 g kg^{-1}. G80, G86, G84, G24, G38, G32, G5, G79, G21, G29, G55, G52 and G89 genotypes had the highest K content. The present research revealed that P was the second most abundant element. The P content in grains of landraces was 23.90 g kg^{-1} with a range from 11.09 (G75) to 44.30 (G83) g kg^{-1}. P content in commercial genotypes was found in the range of 21.93 (Faikbey) to 28.51 (Y-1779) g kg^{-1} with an average of 24.97 g kg^{-1}. The highest P content was determined in G83, G24, G84, G110, G86, G80, G137, G63 and G21 genotypes (Table 1 and 2).

The Mg amount in the grains of the studied landraces varied from 9.02 g kg^{-1} (G4) to 16.56 g kg^{-1} (G80), and the mean value was 12.47 g kg^{-1}. Mg content in cultivars was ranged between 10.70 g kg^{-1} (Y-1779) to 11.21 g kg^{-1} (Faikbey), the mean value was 10.99 g kg^{-1}. Among all the genotypes examined, the Mg content of G24, G66, G79, G80, G86, G110 and G135 genotypes were obtained to be higher than the other genotypes (Table 1 and 2).

The overall average value of Ca contents among all landraces was 10.92 g kg^{-1}, ranging from 8.38 g kg^{-1} (G9) and 14.70 g kg^{-1} (G80). Ca content of cultivars varied between 10.96 g kg^{-1} (Y-1779) and 11.83 g kg^{-1} (Faikbey) with an average value of 11.44 g kg^{-1}. G39, G58, G66, G79, G80, G148 and G226 had higher Ca content than the other genotypes (Table 1 and 2).

The maximum value for Na content was determined as 4.01 g kg^{-1} (G6) and 1.25 g kg^{-1} (G189) as the minimum value. The average Na content of landraces was higher than cultivars (2.58 and 2.36 g kg^{-1}, respectively). Grains in genotypes G1, G3, G5, G6, G7, G66, G69, G79, G89, G146 and G241 were characterized by high Na concentration, whereas grains of genotypes G113, G184, G186, G189 and G230 were characterized by low Ca concentration (Table 1 and 2).

The Fe contents of the studied landraces varied between 32.01 mg kg^{-1} (G87) and 89.85 mg kg^{-1} (G4) with an average value of 57.70 mg kg^{-1}. The mean Fe content of cultivars ranged from 42.14 mg kg^{-1} (Y-1779) to 63.43 mg kg^{-1} (Faikbey) and with an average value of 53.02 mg kg^{-1}. The average Fe content of landraces was higher than cultivars. While the highest Fe content was recorded in G4, G204, G5, G105, G189, G13 and G8 genotypes, the lowest Fe content was recorded in G87, G187, G141, G32, G147, G243, G54, G240 and G126 genotypes, respectively (Table 1 and 2).

Table 1. Passport data of 252 landrace and 4 commercial cultivars of Turkish oat for different mineral elements

No	L/C	CS	K	P	Mg	Ca	Na	Fe	Mn	Zn	Cu
1	Düzce1	Center	49.46	28.19	14.10	10.88	3.50	63.72	32.47	25.09	5.46
2	Düzce2	Center	38.13	26.12	10.74	11.68	3.49	71.56	27.36	23.70	7.87
3	Düzce3	Center	49.30	30.52	14.52	10.83	3.56	61.21	35.49	23.68	5.54
4	Düzce4	Center	44.19	31.99	9.02	11.83	3.08	89.85	27.91	17.80	8.33
5	Düzce5	Center	50.97	30.78	13.87	10.91	3.76	86.44	31.66	26.40	5.31
6	Düzce6	Kaynaşlı	48.20	32.37	13.65	11.51	4.01	49.40	30.96	26.74	7.30
7	Düzce7	Kaynaşlı	43.44	26.52	12.31	10.90	3.55	58.97	24.81	25.89	6.52
8	Düzce8	Çilimli	36.27	19.07	10.63	10.53	2.90	80.02	20.35	25.38	5.69
9	Düzce9	Çilimli	34.15	13.70	9.13	8.38	2.04	70.40	23.84	23.40	4.39
10	Düzce10	Gümüşova	40.20	26.49	13.21	10.91	3.26	63.36	27.89	19.54	6.35
11	Düzce11	Gölyaka	41.06	20.48	11.28	11.10	3.28	55.03	24.17	23.30	7.45
12	Bolu1	Center	37.95	20.24	12.12	10.93	2.61	66.57	30.44	25.55	7.64
13	Bolu2	Center	47.81	28.30	14.56	11.81	3.26	81.04	46.61	26.77	8.00
14	Bolu3	Center	49.19	29.33	14.28	10.90	2.43	39.46	46.82	27.01	8.97
15	Bolu4	Center	42.59	18.98	11.86	11.07	2.16	48.30	38.08	29.24	8.50
16	Bolu5	Center	37.64	14.60	11.17	10.61	2.43	55.38	28.68	25.40	7.07
17	Bolu6	Center	33.33	13.76	10.85	10.03	2.00	60.91	24.65	20.27	5.58
18	Bolu7	Center	42.01	23.22	12.51	10.60	2.56	49.60	29.67	24.68	7.21
19	Bolu8	Center	49.61	31.35	14.09	11.33	3.27	50.47	47.56	29.65	8.75
20	Bolu9	Mudurnu	39.97	22.20	11.60	11.18	2.64	54.03	32.89	27.45	8.64
21	Bolu10	Mudurnu	50.72	34.09	14.92	10.67	2.63	40.39	47.07	28.03	8.12
22	Bolu11	Mudurnu	45.16	30.98	13.37	11.01	2.56	65.48	44.04	28.96	8.04
23	Bolu12	Mudurnu	47.01	31.01	13.78	10.76	2.51	37.28	40.89	29.45	8.33
24	Bolu13	Mudurnu	51.76	40.08	15.38	10.79	3.08	72.15	50.79	30.53	7.48
25	Bolu14	Mudurnu	42.78	27.63	12.67	10.87	2.38	35.43	37.57	30.77	8.61
26	Bolu15	Mudurnu	48.28	33.06	14.72	10.57	2.52	59.98	45.53	30.65	7.43
27	Bolu16	Mudurnu	46.66	30.48	13.71	10.99	2.48	41.44	46.74	30.81	8.62
28	Bolu17	Mudurnu	44.95	28.70	13.47	10.60	2.19	49.82	39.31	33.21	8.24
29	Bolu18	Göynük	50.59	31.68	14.56	10.97	2.51	40.86	51.41	31.63	8.82
30	Bolu19	Göynük	42.12	25.47	12.49	10.71	1.83	47.51	36.64	32.60	8.94
31	Bolu20	Göynük	43.11	21.52	13.33	11.55	2.94	65.09	43.27	28.01	8.30
32	Bolu21	Göynük	51.05	32.36	14.61	10.53	2.33	33.00	48.57	30.04	9.77
33	Bolu22	Göynük	38.65	20.10	11.27	10.31	2.39	64.70	24.84	27.13	8.95
34	Bolu23	Göynük	39.69	23.23	12.65	10.72	2.08	54.74	32.80	30.82	9.28
35	Bolu24	Göynük	40.51	22.42	12.07	10.45	2.40	52.75	32.77	28.26	8.49
36	Bolu25	Göynük	31.53	17.73	11.05	10.69	1.60	72.21	28.21	29.29	8.80
37	Bolu26	Göynük	42.81	24.38	12.82	10.61	2.48	38.69	36.61	28.90	8.13
38	Bolu27	Göynük	51.11	30.40	14.62	11.06	2.54	45.13	50.06	29.35	9.05
39	Bolu28	Göynük	31.81	25.04	12.38	12.89	3.08	72.00	43.29	19.70	8.63
40	Bolu29	Mengen	38.74	25.35	12.36	10.88	2.31	77.52	33.30	24.93	7.23

Table 1. continued

41	Bolu30	Mengen	48.92	32.55	14.53	10.95	2.89	74.02	48.21	31.29	8.00
42	Bolu31	Mengen	43.30	28.34	13.05	10.56	2.08	66.06	39.19	30.69	7.18
43	Bolu32	Mengen	38.31	22.44	11.52	11.21	2.55	69.79	28.25	28.62	7.82
44	Bolu33	Seben	42.47	23.71	13.35	11.45	2.82	54.71	41.15	26.11	8.73
45	Bolu34	Seben	46.39	26.13	14.37	11.94	2.98	62.28	45.38	25.39	8.94
46	Bolu35	Seben	46.44	27.22	13.29	10.54	2.12	58.66	42.96	32.00	7.63
47	Bolu36	Seben	39.87	18.75	12.24	10.45	1.88	38.24	38.55	29.01	7.61
48	Bolu37	Gerede	37.16	16.39	10.61	9.38	2.36	35.74	26.48	24.52	5.72
49	Bolu38	Gerede	43.12	28.12	13.65	11.14	2.89	66.03	42.52	26.79	7.62
50	Bolu39	Dörtdivan	36.81	17.61	11.60	10.44	1.68	59.93	32.32	26.61	7.38
51	Bolu40	Yeniçağa	38.33	19.08	12.31	10.70	2.97	63.21	34.32	20.76	6.51
52	Bolu41	Yeniçağa	50.38	30.62	14.22	11.25	3.24	55.83	46.54	27.70	7.86
53	Zonguldak1	Center	45.57	27.38	13.00	11.43	3.31	68.03	29.48	24.36	7.15
54	Zonguldak2	Center	41.26	17.82	11.65	10.58	2.44	33.64	31.09	21.43	8.45
55	Zonguldak3	Center	50.59	30.23	13.97	9.89	3.10	50.57	32.13	26.13	5.48
56	Zonguldak4	Center	33.01	13.28	11.62	10.34	3.49	53.38	18.66	23.25	6.28
57	Zonguldak5	Center	41.14	17.77	12.58	10.73	3.48	60.18	30.24	21.46	6.24
58	Zonguldak6	Center	40.48	19.07	12.90	12.64	3.46	62.11	38.98	34.02	6.74
59	Zonguldak7	Center	40.08	23.64	12.95	10.64	2.88	76.97	28.08	26.45	5.76
60	Zonguldak8	Center	34.58	20.24	11.60	10.84	3.21	68.68	22.64	24.61	6.05
61	Zonguldak9	Center	43.80	30.25	13.82	10.58	2.86	67.05	35.11	25.97	6.60
62	Zonguldak10	Ereğli	37.37	19.97	11.92	10.62	2.53	67.57	32.79	27.02	6.80
63	Zonguldak11	Ereğli	46.40	34.22	14.27	10.62	2.91	63.87	37.31	26.93	7.13
64	Zonguldak12	Ereğli	40.53	17.82	12.14	10.61	1.98	50.90	38.41	29.03	7.57
65	Zonguldak13	Ereğli	37.21	14.99	10.68	10.27	2.43	46.49	21.79	21.39	7.57
66	Zonguldak14	Ereğli	47.68	26.82	15.53	12.48	3.59	77.60	38.97	26.72	6.61
67	Zonguldak15	Ereğli	45.99	17.25	11.26	11.19	2.17	64.97	31.50	24.24	6.38
68	Zonguldak16	Ereğli	45.43	16.30	12.70	9.90	2.10	77.40	26.90	25.05	6.43
69	Zonguldak17	Ereğli	39.61	23.80	13.32	10.48	3.60	53.31	25.16	25.47	6.59
70	Zonguldak18	Ereğli	42.26	18.94	11.56	9.85	2.40	48.14	27.25	20.34	6.59
71	Zonguldak19	Ereğli	34.91	13.93	10.18	11.09	1.73	46.44	28.80	28.60	9.15
72	Zonguldak20	Ereğli	42.40	22.86	11.46	10.63	3.10	39.37	21.34	25.09	6.73
73	Zonguldak21	Ereğli	41.69	16.63	12.13	9.98	1.82	36.79	37.35	25.24	6.41
74	Zonguldak22	Ereğli	43.58	22.47	12.32	9.71	3.31	35.93	19.07	21.55	4.77
75	Zonguldak23	Ereğli	34.53	11.09	10.23	10.08	1.71	35.37	24.39	25.96	6.82
76	Zonguldak24	Ereğli	43.48	23.88	12.60	10.16	3.06	39.23	28.89	21.80	5.82
77	Zonguldak25	Çaycuma	40.24	19.50	11.94	10.74	2.58	71.60	33.96	32.07	6.68
78	Zonguldak26	Çaycuma	41.86	27.60	12.44	10.37	3.46	50.71	22.31	26.61	5.52
79	Zonguldak27	Çaycuma	50.78	32.04	15.97	12.89	3.69	65.00	45.21	33.48	8.81
80	Zonguldak28	Çaycuma	58.29	35.33	16.56	14.70	3.28	71.00	56.90	32.05	9.46
81	Zonguldak29	Çaycuma	36.02	16.26	10.93	10.23	2.53	47.68	24.88	19.92	6.65
82	Zonguldak30	Çaycuma	44.46	22.39	12.43	10.83	2.76	37.61	34.63	21.20	8.82

Table 1. continued

83	Zonguldak31	Çaycuma	46.49	44.30	12.69	10.26	2.63	60.74	39.36	32.83	6.68
84	Zonguldak32	Çaycuma	53.36	38.25	13.99	9.99	2.82	72.29	49.14	40.33	5.95
85	Zonguldak33	Devrek	42.59	28.97	12.89	10.70	3.42	56.36	32.10	31.93	7.21
86	Zonguldak34	Devrek	57.44	36.23	15.72	10.94	3.34	40.32	53.99	20.43	8.41
87	Zonguldak35	Devrek	39.37	19.06	11.40	9.77	1.64	32.01	29.63	27.21	7.03
88	Zonguldak36	Devrek	44.21	25.62	13.05	10.82	2.35	44.57	35.89	29.89	7.08
89	Zonguldak37	Devrek	50.22	32.13	14.83	11.57	3.87	50.44	39.95	32.99	6.91
90	Zonguldak38	Devrek	49.91	30.93	14.73	11.50	3.21	52.82	46.01	30.55	7.93
91	Zonguldak39	Devrek	44.62	26.95	13.77	11.41	2.54	63.97	44.74	27.68	8.98
92	Zonguldak40	Devrek	43.62	20.68	13.44	10.06	2.63	55.52	37.00	26.24	8.54
93	Zonguldak41	Gökçebey	48.10	30.76	13.90	10.25	2.53	42.21	38.09	25.27	8.28
94	Zonguldak42	Gökçebey	33.72	14.61	10.28	9.97	2.14	44.19	18.98	19.93	7.42
95	Zonguldak43	Gökçebey	34.44	13.69	10.43	9.76	2.12	36.15	21.35	21.10	6.92
96	Zonguldak44	Alaplı	35.18	13.37	10.48	9.74	2.00	35.61	21.94	21.55	6.87
97	Zonguldak45	Alaplı	36.21	11.96	10.52	9.84	1.91	35.74	23.20	22.21	6.64
98	Zonguldak46	Alaplı	36.61	18.75	11.81	10.70	3.34	40.65	29.64	22.31	8.93
99	Zonguldak47	Alaplı	35.81	16.15	11.12	10.24	2.20	44.20	24.82	21.96	7.85
100	Karabük1	Center	38.09	27.09	13.85	11.69	3.34	43.53	35.23	24.67	11.01
101	Karabük2	Safranbolu	33.07	21.76	12.13	10.53	2.20	48.64	25.49	24.25	9.20
102	Karabük3	Safranbolu	34.67	25.00	12.59	11.49	3.27	76.66	27.21	26.45	8.86
103	Karabük4	Safranbolu	31.60	22.86	12.19	11.34	2.77	73.97	25.68	26.11	9.14
104	Karabük5	Safranbolu	33.67	21.21	11.74	11.10	2.14	75.19	24.18	24.20	9.38
105	Karabük6	Eskipazar	34.69	28.04	12.31	10.71	2.08	83.57	22.15	24.87	8.74
106	Karabük7	Eskipazar	36.97	28.98	13.56	10.99	2.49	55.91	35.13	26.78	9.77
107	Karabük8	Eskipazar	33.78	21.26	11.72	10.57	2.05	60.73	22.51	25.89	9.14
108	Karabük9	Eskipazar	37.26	28.13	13.33	11.32	2.97	60.22	30.17	23.89	9.43
109	Karabük10	Ovacık	42.38	27.20	14.57	11.28	2.94	64.41	41.84	27.07	9.00
110	Karabük11	Ovacık	46.17	38.10	15.61	11.32	3.23	70.68	47.63	30.17	8.72
111	Karabük12	Ovacık	37.76	28.25	13.77	11.31	2.78	45.34	36.13	24.71	9.82
112	Kastamonu1	Center	37.59	24.91	12.93	10.74	2.32	39.11	31.14	21.86	9.54
113	Kastamonu2	Center	32.99	21.94	12.41	10.48	1.43	68.81	31.14	26.72	8.68
114	Kastamonu3	Center	34.34	25.77	13.03	11.10	2.46	64.60	30.48	24.21	9.68
115	Kastamonu4	Center	30.88	24.15	12.31	10.37	1.64	44.68	26.25	25.13	9.67
116	Kastamonu5	Center	29.67	23.50	12.28	10.86	1.84	67.07	26.76	26.28	9.68
117	Kastamonu6	Center	34.22	22.15	12.43	10.54	1.79	56.38	28.44	22.51	9.15
118	Kastamonu7	Devrekani	33.76	25.90	13.10	10.64	1.99	62.33	30.36	25.31	9.17
119	Kastamonu8	Devrekani	37.30	19.41	11.94	10.49	1.82	53.25	27.77	24.84	8.54
120	Kastamonu9	Devrekani	39.39	22.34	12.70	10.96	2.50	55.43	35.13	23.74	8.35
121	Kastamonu10	Araç	39.73	24.28	12.82	10.88	2.50	44.49	33.66	23.82	8.76
122	Kastamonu11	Araç	45.40	30.09	14.35	10.95	3.01	54.16	41.28	23.38	8.67
123	Kastamonu12	Araç	45.21	25.83	13.46	11.22	2.82	47.00	40.63	25.77	9.04
124	Kastamonu13	Araç	44.22	26.03	13.62	11.04	2.75	55.40	38.61	24.29	8.49

Table 1. continued

125	Kastamonu14	Taşköprü	38.13	23.70	12.66	10.58	2.65	43.59	29.33	24.90	8.10
126	Kastamonu15	Taşköprü	43.90	33.10	14.72	10.90	2.84	34.29	38.00	24.68	10.19
127	Kastamonu16	Taşköprü	38.08	24.29	12.81	10.61	2.24	47.53	32.57	21.26	8.73
128	Kastamonu17	Taşköprü	37.87	29.38	13.45	10.79	2.15	35.72	33.19	26.06	10.21
129	Kastamonu18	Taşköprü	37.21	27.58	12.88	10.91	2.49	59.37	27.49	26.99	9.32
130	Kastamonu19	Daday	38.65	26.17	12.69	10.42	1.96	41.05	28.85	25.71	9.23
131	Kastamonu20	Daday	39.42	30.58	14.04	10.98	2.74	48.79	35.44	23.85	9.25
132	Kastamonu21	Hanönü	35.71	27.64	13.30	10.96	2.65	58.73	29.25	23.87	9.06
133	Kastamonu22	Hanönü	36.42	26.56	12.96	11.05	2.51	53.80	30.11	24.24	9.20
134	Kastamonu23	Hanönü	41.49	28.53	13.50	10.57	2.19	39.13	34.70	25.43	9.49
135	Kastamonu24	Seydiler	48.75	33.78	15.24	11.27	3.12	52.14	47.21	23.30	9.15
136	Kastamonu25	Küre	35.35	22.83	12.28	10.95	2.37	45.38	32.12	25.41	9.16
137	Kastamonu26	İhsangazi	39.01	34.49	13.97	11.42	3.14	68.17	30.19	27.30	8.30
138	Kastamonu27	İhsangazi	36.06	24.02	12.47	10.78	2.34	42.21	28.36	24.23	9.20
139	Kastamonu28	İnebolu	36.79	19.11	11.16	10.50	2.09	44.06	23.20	24.06	8.49
140	Kastamonu29	İnebolu	39.95	17.21	10.95	11.37	3.11	54.53	26.32	24.22	8.27
141	Kastamonu30	Çatalzeytin	43.74	21.04	12.35	10.77	2.48	32.62	34.92	25.51	9.06
142	Ordu1	Akkuş	49.99	31.29	14.36	11.17	3.24	48.56	40.84	23.65	8.54
143	Ordu2	Akkuş	37.72	23.90	12.69	11.02	2.95	52.64	31.14	24.47	8.10
144	Ordu3	Kumru	30.59	17.27	10.97	10.46	2.44	65.00	22.38	17.92	8.35
145	Ordu4	Çaybaşı	39.25	24.59	12.74	11.31	2.40	61.42	38.79	20.30	9.54
146	Ordu5	Aybastı	46.38	24.54	12.88	11.76	3.54	35.01	33.79	26.14	9.44
147	Ordu6	Korgan	39.18	15.15	10.66	11.07	2.71	33.02	26.11	23.41	8.41
148	Sinop1	Center	43.61	32.08	14.74	12.09	3.27	52.01	42.89	23.68	10.94
149	Sinop2	Center	42.06	27.41	13.38	11.70	3.30	53.95	35.68	25.54	9.84
150	Sinop3	Center	40.16	22.97	13.49	10.74	2.85	37.82	35.80	16.49	9.37
151	Sinop4	Erfelek	44.29	26.15	13.76	11.30	3.00	40.89	40.66	20.13	9.36
152	Sinop5	Erfelek	46.59	31.73	14.66	10.34	2.65	44.82	40.22	24.69	7.76
153	Sinop6	Erfelek	38.34	19.56	12.83	11.23	3.12	54.12	33.98	15.99	9.24
154	Sinop7	Erfelek	38.38	27.86	13.00	11.85	2.59	57.00	32.19	25.26	9.65
155	Sinop8	Erfelek	47.56	20.22	13.10	10.97	3.27	36.09	40.56	18.31	8.81
156	Sinop9	Durağan	31.05	25.17	11.99	11.49	1.91	70.00	23.36	24.15	9.48
157	Sinop10	Durağan	35.53	21.31	11.70	11.55	1.94	71.00	27.14	27.67	9.23
158	Sinop11	Durağan	36.66	29.11	13.16	11.33	2.73	55.88	27.28	23.81	8.70
159	Sinop12	Durağan	40.53	30.46	13.54	11.71	3.05	64.08	32.74	27.39	9.30
160	Sinop13	Gerze	35.60	27.46	13.40	11.08	2.33	58.34	31.06	22.73	9.90
161	Sinop14	Gerze	34.29	23.37	12.65	10.58	1.78	51.07	29.34	22.49	9.05
162	Sinop15	Gerze	37.37	22.96	12.93	10.78	2.65	38.95	29.83	17.03	9.18
163	Sinop16	Gerze	42.93	26.51	13.35	11.04	2.50	46.98	36.73	24.39	9.36
164	Sinop17	Ayancık	35.10	17.11	12.08	10.80	2.36	58.50	30.84	17.64	8.71
165	Sinop18	Saraydüzü	35.20	15.60	10.97	10.68	1.79	54.97	23.89	24.31	8.69
166	Sinop19	Saraydüzü	34.00	18.43	11.33	10.36	1.71	47.24	23.12	23.87	8.47

Table 1. continued

167	Sinop20	Dikmen	38.18	23.65	12.17	10.97	2.21	39.99	27.93	25.97	9.25
168	Sinop21	Dikmen	42.38	26.62	13.06	11.13	2.81	42.29	32.97	25.23	9.11
169	Samsun1	Center	37.18	25.52	12.13	11.10	2.41	68.72	24.78	27.82	8.72
170	Samsun2	Center	37.96	22.23	11.08	10.77	1.88	71.74	26.61	29.08	8.23
171	Samsun3	Center	37.24	27.15	12.13	10.81	2.03	54.20	24.26	25.47	8.99
172	Samsun4	Center	41.24	28.12	12.64	11.59	2.92	71.06	31.99	29.33	8.49
173	Samsun5	Center	36.07	15.73	10.80	10.70	2.54	45.53	23.52	19.20	7.99
174	Samsun6	Asarcık	37.83	25.06	11.43	10.82	2.52	70.38	24.65	26.60	7.99
175	Samsun7	Asarcık	40.38	26.58	12.03	10.43	2.34	40.65	28.04	26.28	8.45
176	Samsun8	Asarcık	39.38	27.74	12.58	11.09	2.57	71.92	35.98	28.07	8.67
177	Samsun9	Asarcık	34.76	24.00	11.32	10.38	1.78	46.19	24.26	26.19	8.65
178	Samsun10	Vezirköprü	34.48	26.77	12.09	11.00	2.70	72.24	24.37	26.43	8.43
179	Samsun11	Vezirköprü	30.97	21.39	11.21	11.36	2.56	56.50	25.63	24.72	8.37
180	Samsun12	Vezirköprü	37.28	25.31	12.59	11.20	2.28	63.26	28.24	26.60	9.47
181	Samsun13	Vezirköprü	38.25	29.38	13.59	10.66	2.20	40.82	33.53	24.06	9.14
182	Samsun14	Vezirköprü	31.11	23.12	11.83	10.72	2.58	73.67	23.42	18.65	8.26
183	Samsun15	Vezirköprü	38.50	27.21	12.87	11.51	2.21	71.04	35.52	23.87	9.58
184	Samsun16	Ladik	33.99	27.66	12.62	10.52	1.30	76.77	30.66	25.06	9.79
185	Samsun17	Ladik	40.29	21.72	11.25	10.74	1.70	65.22	31.37	27.82	8.75
186	Samsun18	Ladik	32.38	22.21	11.44	10.37	1.36	54.42	20.54	27.14	8.89
187	Samsun19	Ladik	40.80	29.48	13.09	10.46	2.36	32.56	25.48	25.22	9.00
188	Samsun20	Ladik	40.38	23.63	11.77	10.60	1.68	50.57	32.01	26.35	9.05
189	Samsun21	Tekkeköy	28.36	14.07	9.72	10.51	1.25	82.13	24.28	22.99	8.25
190	Samsun22	Tekkeköy	34.37	20.13	10.71	11.06	2.61	79.22	25.86	24.37	8.20
191	Samsun23	Tekkeköy	42.27	26.67	12.71	11.36	3.02	62.28	33.41	27.48	8.98
192	Samsun24	Tekkeköy	38.08	18.85	11.21	11.01	2.35	72.77	29.58	21.60	8.64
193	Samsun25	Tekkeköy	43.31	24.39	12.51	10.74	2.82	38.71	34.05	26.24	8.52
194	Samsun26	Ayvacık	44.67	32.54	14.39	11.74	2.87	78.84	36.68	25.71	9.92
195	Samsun27	Ayvacık	37.40	23.93	11.36	10.41	2.20	60.30	26.50	26.00	8.02
196	Samsun28	Ayvacık	47.92	26.92	13.12	11.63	2.80	36.41	37.76	27.09	9.38
197	Samsun29	Çarşamba	38.53	26.66	12.08	10.63	2.41	61.87	25.14	24.67	8.46
198	Samsun30	Çarşamba	40.92	24.23	12.02	11.05	2.19	60.04	31.40	27.59	9.06
199	Samsun31	Çarşamba	40.52	30.65	12.70	11.29	3.27	57.75	29.77	28.72	7.58
200	Samsun32	Alaçam	44.54	24.24	11.61	11.09	2.65	65.40	29.69	28.25	8.28
201	Samsun33	Alaçam	33.27	20.86	11.23	11.19	2.17	64.63	26.01	27.66	9.07
202	Samsun34	Alaçam	42.94	21.11	12.25	11.30	3.17	55.22	32.46	26.42	7.68
203	Samsun35	Bafra	37.59	19.60	10.77	10.79	1.77	59.26	28.09	28.05	8.90
204	Samsun36	Bafra	41.11	24.35	11.92	11.55	1.83	86.50	36.08	27.06	8.89
205	Samsun37	Havza	37.20	23.35	11.72	11.39	2.51	64.81	26.39	28.09	8.85
206	Samsun38	Havza	34.99	26.02	11.84	10.85	2.07	70.29	28.40	27.64	8.68
207	Samsun39	Havza	36.20	21.34	10.80	10.84	2.14	73.25	26.85	29.51	8.14
208	Samsun40	Kavak	40.24	24.24	12.11	11.04	2.32	59.46	31.72	27.25	8.63

Table 1. continued

209	Samsun41	Kavak	38.51	24.61	12.08	11.22	2.15	64.80	31.37	27.01	8.74
210	Samsun42	Kavak	37.27	21.61	11.66	11.66	2.87	46.00	29.77	24.21	8.51
211	Samsun43	Kavak	44.34	26.48	12.47	10.94	2.35	57.02	37.57	26.04	8.50
212	Samsun44	Kavak	38.16	22.10	11.71	11.18	2.42	63.74	31.47	28.81	8.62
213	Samsun45	Kavak	35.24	19.73	11.05	11.09	2.08	62.30	26.42	27.24	8.77
214	Samsun46	Kavak	41.70	23.08	12.36	11.18	2.88	48.62	31.23	24.76	8.32
215	Samsun47	Kavak	41.11	25.24	11.96	10.66	2.79	54.54	28.98	24.62	7.21
216	Samsun48	Salıpazarı	41.24	19.47	12.08	11.12	2.40	45.35	33.20	21.31	9.03
217	Amasya1	Center	37.16	19.98	11.04	10.33	2.07	44.77	28.63	19.98	7.91
218	Amasya2	Taşova	42.94	22.56	12.10	11.37	2.63	45.77	33.46	25.14	9.10
219	Amasya3	Taşova	45.51	24.42	12.56	10.94	3.13	39.33	32.70	24.82	7.60
220	Amasya4	Taşova	39.98	22.92	12.35	10.75	2.41	46.25	31.73	24.08	8.93
221	Amasya5	Taşova	49.47	28.58	13.58	10.96	3.26	37.75	35.94	23.88	8.07
222	Amasya6	Gümüşhacıköy	44.09	19.05	11.58	10.93	2.79	42.26	30.68	22.69	7.72
223	Amasya7	Gümüşhacıköy	39.86	18.91	12.14	11.56	3.01	64.61	28.99	22.52	8.78
224	Amasya8	Suluova	43.43	23.83	12.67	11.62	3.08	62.23	35.50	24.33	8.70
225	Amasya9	Suluova	43.71	25.63	13.17	11.73	3.26	49.53	35.79	22.75	8.86
226	Amasya10	Suluova	43.82	23.90	13.27	12.08	3.12	62.66	35.73	21.99	8.74
227	Amasya11	Merzifon	41.65	21.25	11.91	11.13	2.62	53.38	31.37	23.68	8.44
228	Amasya12	Merzifon	38.85	24.90	12.44	10.92	2.60	41.44	28.99	22.70	9.22
229	Amasya13	Merzifon	34.57	27.24	12.16	10.68	2.24	59.71	23.85	22.28	8.55
230	Amasya14	Hamamözü	33.15	15.23	10.75	11.17	1.57	70.25	29.89	26.89	8.74
231	Tokat1	Center	42.66	21.73	12.43	10.80	2.45	39.82	33.41	23.80	8.45
232	Tokat2	Center	36.14	14.15	10.38	10.23	1.74	37.80	28.28	23.39	7.46
233	Tokat3	Center	36.64	17.42	11.14	10.52	1.86	45.38	27.24	22.79	8.63
234	Tokat4	Center	47.61	27.16	12.87	11.24	3.23	52.56	34.98	21.98	8.02
235	Tokat5	Center	46.47	23.58	12.25	11.22	2.82	46.42	32.45	23.61	8.14
236	Tokat6	Center	43.07	25.73	12.66	10.71	2.53	41.67	31.12	24.02	8.42
237	Tokat7	Erbaa	42.37	18.74	11.12	11.05	3.07	36.04	27.07	24.53	8.40
238	Tokat8	Erbaa	36.08	15.45	10.50	11.04	2.73	54.56	23.20	23.77	8.32
239	Tokat9	Niksar	36.89	14.25	10.27	11.28	2.63	49.96	24.70	25.85	8.61
240	Tokat10	Niksar	37.49	14.90	10.58	10.65	2.16	33.96	25.73	22.78	8.73
241	Tokat11	Niksar	41.40	19.91	11.63	11.44	3.63	60.55	26.17	23.42	7.66
242	Tokat12	Artova	38.14	13.47	10.85	10.93	2.44	50.47	23.27	22.20	7.49
243	Tokat13	Artova	37.96	17.32	10.78	10.64	2.42	33.38	26.61	24.54	8.58
244	Tokat14	Artova	38.38	16.27	10.62	10.82	2.56	36.23	25.64	25.61	8.32
245	Tokat15	Artova	39.20	19.48	11.84	11.22	2.75	48.33	30.11	23.21	8.69
246	Tokat16	Yeşilyurt	37.02	14.96	10.46	10.89	2.56	38.10	26.71	27.28	8.19
247	Tokat17	Yeşilyurt	37.37	15.61	10.60	10.77	2.39	36.29	24.94	25.62	8.40
248	Tokat18	Almus	35.52	18.37	10.87	10.78	2.24	48.03	25.88	24.67	9.19
249	Tokat19	Almus	34.40	13.77	10.35	10.68	2.13	43.63	22.51	22.88	8.49
250	Tokat20	Zile	36.75	16.04	10.53	10.80	2.57	43.78	24.54	24.84	8.14

Table 1. continued

251	Tokat21	Reşadiye	40.28	17.76	11.38	11.16	2.90	52.46	27.77	23.75	8.01
252	Tokat22	Reşadiye	38.30	24.08	12.92	11.79	2.92	61.02	33.68	24.58	9.40
253	Seydişehir	Cultivar	38.30	24.52	11.01	11.48	3.12	55.42	26.59	22.88	8.62
254	Y-330	Cultivar	36.17	24.91	11.05	11.50	1.97	51.10	23.89	24.02	8.16
255	Y-1779	Cultivar	38.08	28.51	10.70	10.96	2.15	42.14	24.72	24.27	7.46
256	Faikbey	Cultivar	32.11	21.93	11.21	11.83	2.19	63.43	18.85	25.04	8.05
Overall mean			39.42	21.83	11.71	11.05	2.50	53.40	29.18	24.90	8.48

K: Potassium (g kg^{-1}), P: Phosphorus (g kg^{-1}), Mg: Magnesium (g kg^{-1}), Ca: Calcium (g kg^{-1}), Na: Sodium (g kg^{-1}), Fe: Iron (mg kg^{-1}), Zn: Zinc (mg kg^{-1}), Mn: Manganese (mg kg^{-1}), Cu: Copper (mg kg^{-1}), L: Landraces, C: Cultivar

Table 2. Average, SD and range values of mineral substance contents of landraces and commercial oat cultivars

Minerals	Landraces				Cultivars			
			Range				Range	
	Mean	SD	Min	Max	Mean	SD	Min	Max
K (g kg^{-1})	40.39	5.29	28.36	58.29	36.16	2.87	32.11	38.30
P (g kg^{-1})	23.90	5.71	11.09	44.30	24.97	2.71	21.93	28.51
Mg (g kg^{-1})	12.47	1.31	9.02	16.56	10.99	0.21	10.70	11.21
Ca (g kg^{-1})	10.92	0.59	8.38	14.70	11.44	0.36	10.96	11.83
Na (g kg^{-1})	2.58	0.53	1.25	4.01	2.36	0.52	1.97	3.12
Fe (mg kg^{-1})	54.70	13.1	32.01	89.85	53.02	8.87	42.14	63.43
Mn (mg kg^{-1})	32.08	7.28	18.66	56.90	23.51	3.31	18.85	26.59
Zn (mg kg^{-1})	25.39	3.53	15.99	40.33	24.05	0.89	22.88	25.04
Cu (mg kg^{-1})	8.26	1.11	4.39	11.01	8.07	0.48	7.46	8.62

While Mn content of landraces samples changed between 18.66 mg kg^{-1} and 56.90 mg kg^{-1}, cultivars ranged from 18.85 mg kg^{-1} to 23.89 mg kg^{-1}. The average Mn content of local genotypes was higher than commercial cultivars. The highest Mn content was found in G80 (56.90 mg kg^{-1}), G86 (53.99 mg kg^{-1}), G29 (51.41 mg kg^{-1}), G24 (50.79 mg kg^{-1}) and G38 (50.06 mg kg^{-1}) (Table 1 and 2).

The highest and lowest Zn contents were determined in G84 (40.33 mg kg^{-1}) and G153 (15.99 mg kg^{-1}) landraces. Zn content of cultivars ranged from 22.88 mg kg^{-1} (Seydişehir) to 25.04 mg kg^{-1} (Faikbey). Zn content of landraces with an average of 25.39 mg kg^{-1} was higher than cultivars with an average of 24.05 mg kg^{-1}. The highest Zn content was found in G84, G58,G79, G28, G89, G83, G30, G77, G80, G46, G85, G29 and G41 genotypes (Table 1 and 2).

The overall average value of Cu contents among all landraces was 8.48 mg kg^{-1}, ranging from 4.39 mg kg^{-1} to 11.01 mg kg^{-1}. The average Cu content of landraces was higher than commercial cultivars (8.26 and8.07 mg kg^{-1}, respectively). The highest Cu contents were found G100 (11.01 mg kg^{-1}), G148 (10.94 mg kg^{-1}), G128 (10.21 mg kg^{-1}) and G126 (10.19 mg kg^{-1}) genotypes (Table 1 and 2).

Accordingly, to the variability in mineral content, landraces and cultivars were pointed out differently. Average values of all studied elements (except for P and Ca) were found to be greater in landraces as per commercial cultivars. The maximum and minimum mineral contents were within a wide range for landraces as compared to commercial cultivars that expressed a narrow range for all studied mineral elements (Table 2).

Associations among 9 mineral element concentrations in 256 oat genotypes (252 landraces and 4 cultivars) were presented in Table 3. Correlation analysis indicated numerous significant positive and negative correlations. Grain K content was positively correlated with P, Mg, Ca, Na, Mn and Zn ($P<0.01$). P content was positively correlated with the content of Mg ($P<0.01$), Ca ($P<0.01$), Na ($P<0.01$), Mn ($P<0.01$), Zn ($P<0.01$), Fe ($P<0.05$) and content of Cu ($P<0.05$). While Mg content had positive and significant correlations with the contents of Ca, Na, Mn and Zn ($P<0.01$), Ca content had positive and significant correlations with content of Na, Fe and Cu ($P<0.01$ for all). Na content was negatively correlated with the content of Cu ($P<0.01$). A significant and positive correlation was obtained between content of Fe and Zn, at a level of significance 0.05. Mn content had positive and significant correlations with the contents of Zn ($P<0.01$) and Cu ($P<0.05$). Cu content was positively correlated with the content of P ($P<0.05$), Ca ($P<0.01$), Mn ($P<0.05$) but negatively correlated with content of Na ($P < 0.01$).

Table 3. Correlation coefficient among different mineral elements for Turkish oat genotypes

	K	P	Mg	Ca	Na	Fe	Mn	Zn
P	0.606**							
Mg	0.698**	0.804**						
Ca	0.243**	0.325**	0.369**					
Na	0.546**	0.389**	0.474**	0.454**				
Fe	-0.121	0.176*	0.037	0.301**	0.060			
Mn	0.765**	0.634**	0.796**	0.372**	0.301**	-0.005		
Zn	0.346**	0.397**	0.307**	0.144	-0.024	0.193*	0.411**	
Cu	-0.163	0.182*	0.174	0.423**	-0.221**	-0.110	0.182*	-0.033

Also, we used PCA to detect the structure in the relationships between elements simultaneously. The cumulative percentages of the eigenvalues, variations percentage and load coefficient of the first six components for all nine minerals through the application of PCA based on the correlation matrix were also shown in Table 4. The first six principal components accounted for 95.5 % of the total variance (Table 4). PC1 accounted for 43.00 % of the total variation. Mg played a lead role in PC1 followed by the Mn, P and K, respectively. PC2 explained 15.6% of the total variation, and Cu and Ca contents had the highest positive coefficients. PC3 accounted for 13.5 % of the total variation, PC4 explained 12.7% of the variation, PC5 and PC6 explained 6.4% and 4.30% of the variation, respectively. PC1 and PC2 were very important and explained more than half of the total variations. Hence, they were investigated by drawing a graph to demonstrate the relationship among genotypes. The Biplot graph indicates the relationships of 256 oat genotypes for nine elements (Figure 1).

Table 4. Eigenvectors, eigenvalues, individual and cumulative percentages of variation explained by the first six principal components (PC) after assessing mineral element concentrations in Turkish oat genotypes

	PC1	PC2	PC3	PC4	PC5	PC6
K	0.422	-0.344	0.115	-0.033	-0.148	0.261
P	0.429	0.050	0.005	0.129	0.466	-0.490
Mg	0.461	-0.008	0.130	-0.013	0.333	-0.024
Ca	0.277	0.488	-0.248	-0.337	-0.460	0.098
Na	0.298	-0.238	-0.270	-0.580	-0.164	-0.349
Fe	0.062	0.248	-0.784	0.196	0.340	0.272
Mn	0.441	-0.004	0.204	0.135	-0.021	0.594
Zn	0.237	-0.008	-0.131	0.688	-0.542	-0.345
Cu	0.072	0.723	0.403	-0.048	0.034	-0.118
Eigenvalue	3.869	1.408	1.216	1.140	0.576	0.388
Percent	43.00	15.60	13.50	12.70	6.40	4.30
Cumulative percentages	43.00	58.60	72.10	84.80	91.20	95.50

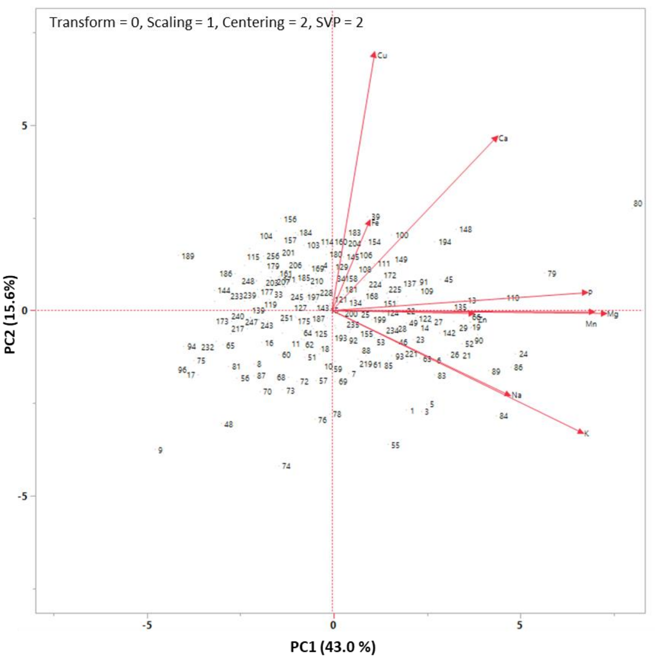

Figure 1. Biplot graphs showing the relationship between 256 oat genotypes and examined elements

The Biplot graph showing the relationship between the genotypes origin and the elements was collected and the elements were given in Figure 2. The contributions of the first and second principal components (PC1 and PC2) to the total variation were 32.1% and 30.2%, respectively.

P, Zn, F and K vectors were acute angles and were associated with Bolu and Zonguldak provinces where landraces were collected. Düzce province where landraces were collected found at the right bottom quadrant contains high values for Na. Landraces collected from Kastamonu, Karabük and Sinop provinces had higher values in terms of Mn, Mg and Cu values and were located in the top left part of the quadrate. Amasya and Ordu provinces where genotypes were collected found at the left bottom quadrant contain high values for Ca. Among the genotypes, 79, 80, 110, 148 and 194 numbered genotypes were prominent in terms of all the minerals. In addition, 13, 14, 19, 21, 23, 24, 26, 27, 29, 45, 52, 66, 83, 84, 86, 89, 90, 91, 100, 109, 122, 135, 142, 149 and 154 numbered genotypes had high values for many investigated elements.

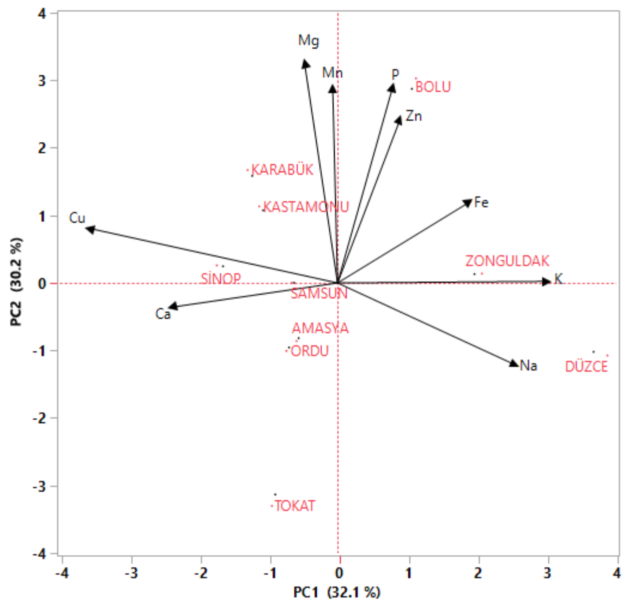

Figure 2. The Biplot graph showing the relationship between the landraces origin and the examined elements

DISCUSSION

Achievement in crop improvement through plant breeding strategies was based on the existence of genetic variation for the aims in the gene pool available (ZHANG *et al.*, 2010). Landraces have long been known as an important source of genetic diversity for crop species, and these may be used as genetic resources to develop new cultivars having superior traits. Although Turkey is an important origin center of oat, information about genetic diversity in mineral elements of Turkish oat landraces is very little. These results indicated that there is a noticeable variation in grain mineral nutrient content of oat landraces and this material might be used in breeding programs for biofortification. Mineral deficiencies influence billions of people around the world. Therefore, mineral elements like Cu, Ca, Mn, Zn and Fe are important from the viewpoint of malnutrition (WELCH and GRAHAM, 2004). Mineral compounds in plants serve a variety of functions. For example, while macronutrients are structure-forming elements, micronutrients participate in the regulation of biochemical processes (BARCZAK *et al*., 2006). Insufficiency of minerals resulting in low working efficiency, cardio-vascular diseases, cancer, auto-immune diseases, high healthcare costs and increased rates of premature death is affecting more than three billion population of the world (WELCH and GRAHAM, 2004).

Increasing element content in cereals through breeding requires the existence of substantial genetic variation including high elements in grains. Considering the great value of plant genetic resources with great diversity, it is very important to characterize the populations concerning their mineral status. Therefore, the present study elucidates the genetic diversity in the mineral contents of the grains of landraces oat grown in Turkey. All landraces and four cultivars were grown under the same conditions to eliminate the role of variations from the environment. For the different mineral element contents, landraces and cultivars indicated very important variations. In this study, the maximum values of investigated all elements were found greater in landraces as compared to commercial cultivars. The reason for this great difference between the element concentrations is thought to be due to the very different genetic structures of the landraces in the study. This suggests that genotypic variation in oat landraces supplies good opportunities for improvement of cultivated oat.

In previous studies on the element content of oat grains in different varieties and locations, CHAPPELL *et al*. (2017) determined that oat grain had K (44.8 g kg^{-1}), P (42.33 g kg^{-1}), Mg (12.74 g kg^{-1}), Ca (7.17 g kg^{-1}), Na (1.46 g kg^{-1}), Fe (43.8 mg kg^{-1}), Mn (49.6 mg kg^{-1}), Zn (33.5 mg kg^{-1}) and Cu (45.6 mg kg^{-1}). In other studies, MARMOUZI *et al*., (2016) reported that oat grain contained 39.56 g kg^{-1} K, 25.41 g kg^{-1} P, 7.54 g kg^{-1} Mg, 8.60 g kg^{-1} Ca, 25.2 mg kg^{-1} Fe, 18.9 mg kg^{-1} Mn, 8.3 mg kg^{-1} Zn. LIU and MAHMOOD (2015) reported that oat grain contained 0.82 mg g^{-1} Ca, 1.65 mg g^{-1} Mg, 5.05 mg g^{-1} P, 4.90 mg g^{-1} K, 0.2 mg g^{-1} Na, 2.10 mg g^{-1} S, 2.0 µg g^{-1} Al, 1 µg g^{-1} Ba, 6 µg g^{-1} Cu, 10 µg g^{-1} Fe, 51 µg g^{-1}Mn, and 39 µgg^{-1} Zn.

The K, P, Mg and Ca contents of all varieties were close with results reported by DOEHLERT *et al*. (2013), CIOLEK *et al.* (2007; 2012), LIU and MAHMOOD (2015), OZCAN *et al.* (2017), CHAPPELL *et al*. (2017) and MEHTA and JOOD (2018). But some of our results of mineral contents showed differences when compared with the literature. These differences may have resulted from the use of many landraces with different genetic structures in this study. Also, these differences might be due to climate, growing area, type of soil, agricultural practice.

We examined the relationships of element concentrations of grain by correlation analysis and PCA. Some positive or negative correlations indicate that the plants can absorb some in higher amounts. Because some elements compete with each other for assimilation, while others support each other. K showed a highly significant and positive correlation with P, Mg, Ca, Na, Mn and Zn. In addition, Correlations were also strong for P, Mg, Ca, Na, Mn and Zn indicating that selection for landraces with high concentrations of these elements would be particularly effective. So, the selection of correlated traits directly influences each other letting the breeder for simultaneous selection in the breeding programs (RUKUNDO *et al*., 2013). The data indicate the possibility of breeding for nutritional improvement in minerals of the oat grain. The relationship between the elements achieved in this study was similar to the results obtained by DOEHLERT *et al*. (2013). The genetic structure of plants has an important effect on the intake, transport and accumulation of elements from the soil. Such positive correlations point out potential enhancement for one or more elements (ASHOK-KUMAR *et al*., 2010). PETERSON *et al*. (1975) pointed out that the many positive correlations obtained between pairs of elements indicate that possibly a breeding objective could be an overall increase in the concentration of all elements, rather than endeavouring separately for increased amounts of individual elements.

Genotype by trait biplot may be appropriate to select genotypes with more than one trait desired in breeding programs. In the present study, this analysis expressed the movement of some landraces away from the center of the axis, so describing considerable diversity from the other landraces. These genotypes showed a high amount of genetic variation for the determined minerals and could be used as a direct source in oat breeding. Within the first six principal components of the PCA 95.5% of the shape variations were covered. The PC1 and PC2 were the most important, constituting 56% of the total variation in genotypes, and the traits responsible for this high variation were K, P, Mg, Ca, Mn and Cu among genotypes. However, K also contributed significantly to the PC2 with negative loading.

MWADZINGENI *et al*., (2016) notified the presence of a high association of traits in discriminating genotypes that have small angles between dimensions vectors in the same direction. In this study, a very close association was observed between Na and K, between P, Mg and Mn, Zn and between Ca and Cu indicating their positive interaction in the plant system. High P content in oat grain is just as harmful as low P content. Since P majority is present in anti-nutrient phytate, blocking the absorption of metal ions from the digestive organs. In addition, excess P causes a deficiency of micronutrients such as Zn, Fe or Co. The landraces located at the top right quadrant were described and associated with a high concentration of P, Ca, Cu, and Fe content. These groups of landraces could present potential candidates for improvements in the breeding programs. The landraces found at the right bottom quadrant contain high values for K, Na, Mg, Mn and Zn. These minerals have similar chemical properties and they compete for the site of absorption, transport, and function in plant tissues (Robson and Pitman 1983). Therefore, the selection of any one of these elements will arrive at a raised concentration of the other elements, thereby improving nutritional values in oat.

CONCLUSION

The present study found a wide range of genetic diversity among the 256 landraces oat that was evaluated for the concentration of studied mineral elements. This study supplies the basic knowledge about the variation of different mineral element amounts. Landraces were significantly different for all element concentrations. Among the genotypes, 79, 80, 110, 148 and 194 numbered genotypes were prominent in terms of all the minerals. Recognition of genetic variation is essential for achieving improvements in the mineral content of plants. This variation of different mineral element contents present in the Turkish oat genetic resources can be used as a source to improve the nutritional content of oats in breeding programs. On the other hand, there is required to conduct such experiments under various environments for several years.

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GENETIČKI DIVERZITET ZA MINERALNE ELEMENTE U ZRNU TURSKIH POPULACIJA OVSA

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Izvod

Zrno ovsa je važna žitarica u ljudskoj ishrani i kao hrana za životinje. Uzgaja se u mnogim regionima sveta. Ova studija je sprovedena da bi se utvrdila varijabilnost u sadržaju elemenata ovih izvora gena ovsa prikupljenih iz zapadnog i srednjeg crnomorskog regiona Turske. U okviru ove studije ispitano je dvesta pedeset i šest genotipova ovsa. Srednja vrednost mineralnih elemenata kod lokalnih populacija i komercijalnih sorti bila je 40,39 g kg^{-1} i 36,16 g kg^{-1} za K, 23,90 g kg^{-1} i 28,51 g kg^{-1} za P, 12,47 g kg^{-1} i 10,99 g kg^{-1}. za Mg, 10,92 g kg^{-1} i 10,96 g kg^{-1} za Ca, 2,58 g kg^{-1} i 2,36 g kg^{-1} za Na, 54,70 mg kg^{-1} i 53,02 mg kg^{-1} za Fe, 32,08 mg kg^{-1} i 23,51 mg kg^{-1} za Mn, 25,39 mg kg^{-1} i 24,05 mg kg^{-1} za Zn i 8,26 mg kg^{-1} i 8,07 mg kg^{-1} za Cu, respektivno. Rasponi mineralnih elemenata u lokalnim populacijama bili su znatno veći od onih u komercijalnim sortama. Doprinos prve i druge glavne komponente (PC1 i PC2) ukupnoj varijaciji iznosio je 43,0%, odnosno 15,6%. Ovi rezultati ukazuju da ispitane lokalne populacije ovsa mogu da obezbede dobar izvor diverziteta u koncentraciji mineralnih elemenata i da se mogu uspešno koristiti u programima biofortifikacije.

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