Gesunde Pflanzen (2022) 74:583–593
https://doi.org/10.1007/s10343-022-00633-2

ORIGINAL ARTICLE / ORIGINALBEITRAG

Variation in Grain Mineral Contents of Oat Genotypes Grown at Six Locations

Zeki Mut[1] · Özge Doğanay Erbaş Köse[1] · Hasan Akay[2]

Received: 13 December 2021 / Accepted: 1 February 2022 / Published online: 4 March 2022

Abstract

Oat is an important widely grown crop and gained popularity as a functional food around the world. The study aimed to identify and interpret the variability of some mineral contents in oat genotypes at six locations over two years. Forty-nine different oat genotypes were grown for two years in six various locations. According to the combined analysis of variance over locations, genotype and location had highly significant effects on all minerals. Also, the effect of years was significant on other elements except for phosphorus, calcium and sodium. While potassium (K) contents of oat samples changed between 3937.18 and 4645.44 $mg\,kg^{-1}$, phosphorus (P) contents of oats ranged from 2342.40 to 3303.93 $mg\,kg^{-1}$. The magnesium (Mg), calcium (Ca) and sodium (Na) contents of grains were ranged from 1193.90 to 1352.88 $mg\,kg^{-1}$, 898.62 to 967.72 $mg\,kg^{-1}$, and 177.08 to 249.97 $mg\,kg^{-1}$, respectively. The iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) contents of grains were ranged from 45.58 to 63.84 $mg\,kg^{-1}$, 34.03 to 42.31 $mg\,kg^{-1}$, 22.22 to 28.44 $mg\,kg^{-1}$, and 4.75 to 5.75 $mg\,kg^{-1}$, respectively. The prominent C7, C9, L5, L6, L7, L9, L12, L23, L28, L29, L30, L31, L34 and L40 genotypes in terms of many minerals in the present investigation could serve as potential genetic resources which can be used in further breeding to improve the nutritional quality of oat grain.

Keywords Genotypes · Location · Mineral · Oat

✉ Özge Doğanay Erbaş Köse
ozgedoganay.erbas@bilecik.edu.tr

[1] Faculty of Agriculture and Natural Science, Department of Field Crops, Bilecik Şeyh Edebali University, Bilecik, Turkey

[2] Faculty of Agriculture, Fields Crops Department, Ondokuz Mayıs University, Samsun, Turkey

Variation der Mineralstoffgehalte von Hafergenotypen an sechs Standorten

Zusammenfassung

Hafer ist eine wichtige, weit verbreitete Kulturpflanze und hat als funktionelles Lebensmittel weltweit an Beliebtheit gewonnen. Ziel der Studie war es, die Variabilität einiger Mineralstoffgehalte in Hafergenotypen an sechs Standorten über zwei Jahre hinweg zu ermitteln und zu interpretieren. Neunundvierzig verschiedene Hafergenotypen wurden zwei Jahre lang an sechs verschiedenen Standorten angebaut. Nach der kombinierten Varianzanalyse über die Standorte hatten Genotyp und Standort hochsignifikante Auswirkungen auf alle Mineralien. Auch der Einfluss der Jahre war für andere Elemente mit Ausnahme von Phosphor, Kalzium und Natrium signifikant. Während der Kalium (K)-Gehalt der Haferproben zwischen 3937,18 und 4645,44 mg kg^{-1} schwankte, lag der Phosphor (P)-Gehalt des Hafers zwischen 2342,40 und 3303,93 mg kg^{-1}. Die Gehalte an Magnesium (Mg), Kalzium (Ca) und Natrium (Na) in den Körnern bewegten sich zwischen 1193,90 und 1352,88 mg kg^{-1}, 898,62 und 967,72 mg kg^{-1} bzw. 177,08 und 249,97 mg kg^{-1}. Die Gehalte an Eisen (Fe), Mangan (Mn), Zink (Zn) und Kupfer (Cu) in den Körnern lagen zwischen 45,58 und 63,84 mg kg^{-1}, 34,03 und 42,31 mg kg^{-1}, 22,22 und 28,44 mg kg^{-1} bzw. 4,75 und 5,75 mg kg^{-1}. Die Genotypen C7, C9, L5, L6, L7, L9, L12, L23, L28, L29, L30, L31, L34 und L40, die in der vorliegenden Untersuchung in Bezug auf viele Mineralstoffe hervorstachen, könnten als potenzielle genetische Ressourcen dienen, die in der weiteren Züchtung zur Verbesserung der ernährungsphysiologischen Qualität von Hafer genutzt werden können.

Schlüsselwörter Genotypen · Standort · Mineralstoff · Hafer

Introduction

Cereals are the main foods, meeting most of the daily caloric and mineral needs of humans in many cultures. Cereals, which are widely consumed in developing countries, are the main source of minerals such as Zn and Fe in these countries (Erba et al. 2011). When foods containing 200 g of wholemeal flour are consumed daily, more than 70% of the recommended daily intake of minerals (Cu, Fe, Mg, Zn, Mn, etc.) is satisfied (Ciolek et al. 2012). In addition, since grains are poor in some of these minerals, they cannot meet the daily needs of people if they are not eaten in a diverse diet. This situation causes the majority of people to suffer from micronutrient deficiencies (Çakmak 2002).

Oat (*Avena sativa* L.) is an important widely grown crop and has popularity as a functional food around the world. In the world, oats are grown on an area of 9.4 million hectares, and 23 million tons of grain are obtained from this area (FAO 2019). Oat has a unique nutritional composition as it contains significant amounts of lipids, unsaturated fatty acids, soluble fiber, proteins, essential amino acids, β-glucans, vitamins, antioxidants and minerals (Alemayehu et al. 2021). Oats, which have started to be used widely in the human diet because of their potential health benefits, are referred to as "Super grain" (Kaur et al. 2019).

Minerals, which are used as a basic food source for human health, are quite abundant in oat grains. A portion of the world's population is fed diets with low micronutrient content. This causes serious health problems. These health problems can be combated with methods such as diversifying the diet, fortification, supplementation, and biofortification. Except for biofortification, other methods require extra costs (de Oliveira Maximino et al. 2021). 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).

The phenotype arises not only from genetic factors and environmental conditions but also from their interaction. Contents of minerals in the grain are also influenced by multiple factors, including genotypes, environment, agriculture practice, soil properties, weather conditions, and interactions among nutrients (Wioeniowska-Kielian and Klima 2007). Determination of genotypes with stable content of minerals across target environments is as important as increasing the content of these minerals in the seeds. Peterson et al. (2005) reported that genetic characteristics and the environment in which oat is grown have an effect on nutritional characteristics. The current study was carried out to (i) evaluate a set of cultivars and pure lines for mineral concentration across variable locations and (ii) to compare genotypes (40 pure lines and 9 cultivars) according to mineral contents by using biplot techniques.

Materials and Methods

Plant Material and Locations

In the research, a total of 49 genotypes were used, together with nine registered cultivars (Faikbey-C1, Seydişehir-C2, Checota-C3, Sebat-C4, Yeniçeri-C5, Kahraman-C6, Kırklar-C7, Norline-C8 and Hifi-C9). The pure lines used in the study, eleven lines (between L1–L11) were selected from landraces collected from different parts of Turkey, and twenty-nine lines (L12–L40) were obtained from International Quaker Oat Nursery (Supplementary Table S1).

This research was carried out in six locations in Turkey, namely Sinop, Tokat, Çorum, Samsun-Center, Amasya, and Samsun-Bafra, during the 2014–2015 and 2015–2016 growing seasons. The location, climate and soil parameters of the experimental sites were presented in Table 1.

Experimental Design

The experiment was laid out as a 7×7 alpha lattice design with 4 replications across six locations for two years. In the trials, each plot was set up to be 6 m long, 20 cm row distance, and 6 rows. Each genotype was grown sowing density of 450 seeds per square meter. In all locations, sowing was done between October 1st and November 15th in both years. Fertilization was done considering the soil analysis results, and herbicides were used for weed control. Samples of all the plots were harvested close to the ground by hand using a sickle in July at all locations in both years. Then these samples were threshed by a plot threshing machine.

Mineral Analysis

Mineral analysis was performed by the modified methods of Miller (1998). Grains were ground with a hammer mill with a 0.5 mm sieve. Samples were stored at 4 °C until further analysis. Oat samples were dried at 65 °C until they reached constant weight before starting the 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 90 °C for 50 min on the hot plate. Then, these samples were placed in the ash furnace. The temperature of the furnace was gradually increased to 500 °C and the samples were burned for 8 h at this temperature until completely ashed. After, 1 N HCl was added to ash samples and left for 30 min. Then, the samples were filtered with filter paper and were diluted up to 50 mL with ultrapure water. The determination of potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) in grain were performed by inductively coupled plasma mass spectrometry (ICP-MS) using a Thermo Fisher Scientific-iCAPQc (Bremen, Germany). Statistical analysis was per-

Table 1 Location, soil and climate traits of testing environments

–	**Environment**	**Sinop**		**Tokat**		**Çorum**	
	Years	**2014–15**	**2015–16**	**2014–15**	**2015–16**	**2014–15**	**2015–16**
Location traits	Latitude (E)	41° 25′	41° 27′	40° 35′	40° 27′	39° 54′	39° 54′
	Longitude (N)	35° 07′	34° 46′	36° 58′	36° 50′	34° 04′	34° 04′
	Altitude (m)	324	417	320	365	801	801
Soil traits	Soil texture	*Clay*	*Clay loam*	*Loam*	*Clay loam*	*Clay loam*	*Clay loam*
	Organic matter (%)	2.11	3.11	3.55	2.89	1.93	1.87
	Salinity (dSm^{-1})	1.47	0.27	3.07	3.20	0.24	0.67
	pH	5.98	5.98	7.99	8.11	7.88	7.88
Climate traits	Mean temperature (°C)	11.8	13.1	13.0	7.7	10.6	11.8
	Total rainfall (mm)	532.9	661.3	556.7	439.2	527.0	529.1
	Relative humidity (%)	75.6	66.5	78.0	74.6	70.0	66.2
–	**Environment**	**Samsun**		**Amasya**		**Bafra**	
	Years	**2014–15**	**2015–16**	**2014–15**	**2015–16**	**2014–15**	**2015–16**
Location traits	Latitude (E)	41° 21′	41° 21′	40° 47′	40° 50′	41° 33′	41° 33′
	Longitude (N)	36° 11′	36° 11′	35° 32′	35° 27′	35° 52′	35° 52′
	Altitude (m)	194	194	523	610	22	22
Soil traits	Soil texture	*Clay*	*Clay*	*Clay loam*	*Sandy loam*	*Sandy loam*	*Sandy loam*
	Organic matter (%)	1.36	1.45	1.48	0.99	1.05	0.98
	Salinity (dSm^{-1})	2.80	2.93	2.67	2.67	1.87	0.53
	pH	7.12	7.22	7.78	7.82	8.10	8.11
Climate traits	Mean temperature (°C)	15.5	15.5	13.1	11.7	13.5	14.2
	Total rainfall (mm)	849.4	800.6	336.7	419.7	635.5	811.6
	Relative humidity (%)	67.6	66.1	59.9	65.6	83.6	82.0

formed by taking the average of the samples analyzed in duplicate.

Data Analysis

Statistical analysis with the Proc Mixed procedure in SAS was made to investigate mineral contents as a function of genotype and environment using ANOVA (SAS 1998). Genotype, year, location, and were the fixed effects whereas replications and their interactions were considered random effects. Before combined analysis of variance, a homogeneity of variance test was performed. Differences between genotype, location, and year means were compared using Tukey's HSD test. The means were shown in colors to separate the easy seeing of the differences among locations and genotypes. The average mineral concentration of a genotype was found by combining data from the years and locations. Biplot analyses were constructed using JUMP 13.0.0 software (2020 SAS Inst. Inc., Carey, NC).

Results and Discussion

Minerals that cannot be produced by living organisms are essential for our life. They are essential micronutrients for human health, as they are effective in essential metabolic functions, such as the skeleton and soft tissues, oxygen transport, blood clotting, enzymatic activity, and neuromuscular transmission. Minerals are divided into two groups as macro and micro minerals (Alemayehu et al. 2021). The average mineral contents of the genotypes were given in Fig. 1, and the average mineral contents of the locations and years were given in Fig. 2. The genotypes showed a wide range of variation for macro and micro element content, suggesting the existence of considerable genetic diversity. Both genotypes and locations contributed to this variation. Investigated minerals showed significant ($p < 0.01$) variation among the oat genotypes and testing locations. The element contents significantly ranged from the six locations due to the genetic made up as well as environmental factors as soil properties and climatic conditions. In addition, K, Mg, Fe, Mn, Zn and Cu contents of genotypes were significantly affected by the year. While the Y × G interaction was significant only for Ca and Cu, Y × L, L × G and Y × L × G interactions were highly significant for all the elements (Fig. 2).

Potassium Content

Potassium (K) is an essential nutrient for maintaining electrolyte balance, cellular function and total body fluid (Alemayehu et al. 2021). According to the average value in oat genotypes studied in 6 locations for two years, the K content ranged from 3937.18 (C1) to 4645.44 (L7) mg kg^{-1}. In general, averaged across locations and years, the advanced lines had better potassium content compared to the cultivars (Fig. 1). As seen Fig. 2, the six locations showed different responses for K content. The highest potassium content was found in the grains of the genotypes grown in Tokat location, while the lowest k content was found in the grains of the genotypes grown in the Amasya location (Fig. 2). This may be because the locations have different soil characteristics and climatic conditions. Kara et al. (2012) and Johansson et al. (2021) reported that have indicated growth environments as a major contributor to the minerals found in the cereal grain. The potassium content of the genotypes was higher in the first year (4514.14 mg kg^{-1}) than in the second year (4125.04 mg kg^{-1}) (Fig. 2). Erbaş Köse et al. (2021) reported that the potassium content of oat genotypes showed statistically significant differences according to years. World Health Organization suggested that adults take at least 3510 mg of potassium per day, reporting that most people can use sufficient potassium from their diet without the need for addition or specially formulated products (WHO 2012). With the consumption of 100 g of oats, which is a potential cereal potassium source, 7% of the potassium needed could meet. Ca, Fe, Zn, K, P, Mn and Mg concentrations of oat grains were more abundant compared with mineral contents of other cereals (Özcan et al. 2006). However, Jâkobsone et al. (2015), in their study on small grain cereals in Latvia, reported that the highest K concentration was found in triticale (5244.40 mg kg^{-1}) and the lowest in oats (3803.38 mg·kg^{-1}). The present results were similar to some previous studies, which reported a variation in K content in oat genotypes, from 3440 to 5470 mg kg^{-1} (Chappell et al. 2017; Erbaş Köse et al. 2021; Johansson et al. 2021). But, it was higher than the values (2417 to 2583 mg kg^{-1}) reported by Alemayehu et al. (2021).

Phosphorus Content

Oat grains have a high phosphorus content and most of the phosphorus contained in the grain of oat is concentrated in the outer bran of the oat groats. Most of the P occurs in the form of phytic acid (Peltonen-Sainio et al. 2006). Phosphorus (P) content of genotypes showed a wide variation over years and locations, and phosphorus content varied from 2342.40 (C1) to 3303.93 (C6) mg kg^{-1} with an average value of 2884.70 mg kg^{-1} (Fig. 1). These values show little differences with the previously reported literature data. P contents were previously reported between 2428.72 to 4557.25 mg kg^{-1} by Özcan et al. (2017), between 3441 to 4233 mg kg^{-1} by Chappell et al. (2017) and between 5144.0 to 5227.3 mg kg^{-1} by Metha and Jood (2018).

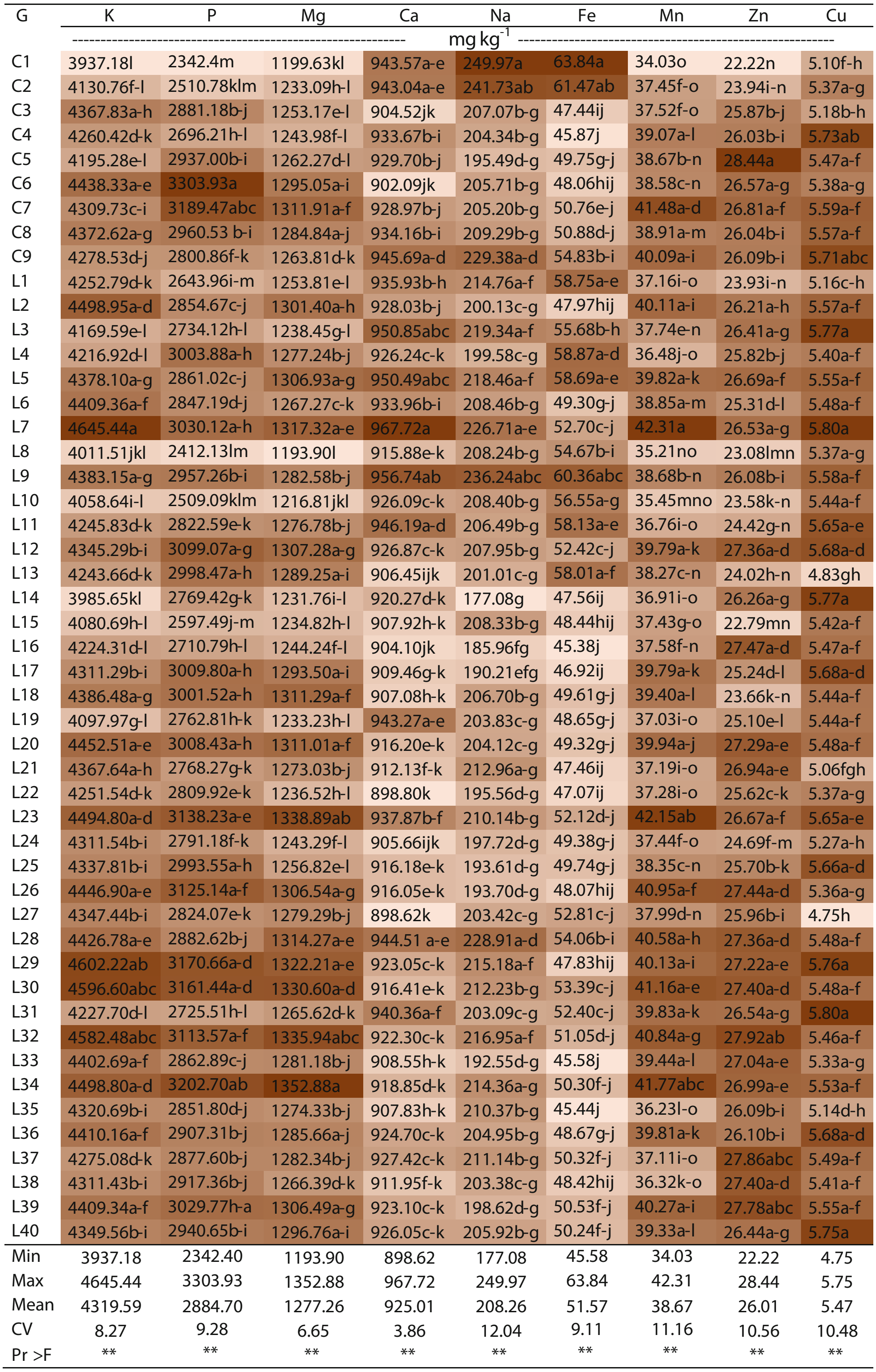


Fig. 1 Mean contents of elements in grains of 49 oat genotypes over six locations for two years. (The difference between the averages shown with the same letters is not significant at the 5% level, *Significant at $P \leq 0.05$, **Significant at $P \leq 0.01$, *ns* not significant)

G	K	P	Mg	Ca	Na	Fe	Mn	Zn	Cu
					mg kg^{-1}				
C1	3937.18l	2342.4m	1199.63kl	943.57a-e	249.97a	63.84a	34.03o	22.22n	5.10f-h
C2	4130.76f-l	2510.78klm	1233.09h-l	943.04a-e	241.73ab	61.47ab	37.45f-o	23.94i-n	5.37a-g
C3	4367.83a-h	2881.18b-j	1253.17e-l	904.52jk	207.07b-g	47.44ij	37.52f-o	25.87b-j	5.18b-h
C4	4260.42d-k	2696.21h-l	1243.98f-l	933.67b-i	204.34b-g	45.87j	39.07a-l	26.03b-i	5.73ab
C5	4195.28e-l	2937.00b-i	1262.27d-l	929.70b-j	195.49d-g	49.75g-j	38.67b-n	28.44a	5.47a-f
C6	4438.33a-e	3303.93a	1295.05a-i	902.09jk	205.71b-g	48.06hij	38.58c-n	26.57a-g	5.38a-g
C7	4309.73c-i	3189.47abc	1311.91a-f	928.97b-j	205.20b-g	50.76e-j	41.48a-d	26.81a-f	5.59a-f
C8	4372.62a-g	2960.53 b-i	1284.84a-j	934.16b-i	209.29b-g	50.88d-j	38.91a-m	26.04b-i	5.57a-f
C9	4278.53d-j	2800.86f-k	1263.81d-k	945.69a-d	229.38a-d	54.83b-i	40.09a-i	26.09b-i	5.71abc
L1	4252.79d-k	2643.96i-m	1253.81e-l	935.93b-h	214.76a-f	58.75a-e	37.16i-o	23.93i-n	5.16c-h
L2	4498.95a-d	2854.67c-j	1301.40a-h	928.03b-j	200.13c-g	47.97hij	40.11a-i	26.21a-h	5.57a-f
L3	4169.59e-l	2734.12h-l	1238.45g-l	950.85abc	219.34a-f	55.68b-h	37.74e-n	26.41a-g	5.77a
L4	4216.92d-l	3003.88a-h	1277.24b-j	926.24c-k	199.58c-g	58.87a-d	36.48j-o	25.82b-j	5.40a-f
L5	4378.10a-g	2861.02c-j	1306.93a-g	950.49abc	218.46a-f	58.69a-e	39.82a-k	26.69a-f	5.55a-f
L6	4409.36a-f	2847.19d-j	1267.27c-k	933.96b-i	208.46b-g	49.30g-j	38.85a-m	25.31d-l	5.48a-f
L7	4645.44a	3030.12a-h	1317.32a-e	967.72a	226.71a-e	52.70c-j	42.31a	26.53a-g	5.80a
L8	4011.51jkl	2412.13lm	1193.90l	915.88e-k	208.24b-g	54.67b-i	35.21no	23.08lmn	5.37a-g
L9	4383.15a-g	2957.26b-i	1282.58b-j	956.74ab	236.24abc	60.36abc	38.68b-n	26.08b-i	5.58a-f
L10	4058.64i-l	2509.09klm	1216.81jkl	926.09c-k	208.40b-g	56.55a-g	35.45mno	23.58k-n	5.44a-f
L11	4245.83d-k	2822.59e-k	1276.78b-j	946.19a-d	206.49b-g	58.13a-e	36.76i-o	24.42g-n	5.65a-e
L12	4345.29b-i	3099.07a-g	1307.28a-g	926.87c-k	207.95b-g	52.42c-j	39.79a-k	27.36a-d	5.68a-d
L13	4243.66d-k	2998.47a-h	1289.25a-i	906.45ijk	201.01c-g	58.01a-f	38.27c-n	24.02h-n	4.83gh
L14	3985.65kl	2769.42g-k	1231.76i-l	920.27d-k	177.08g	47.56ij	36.91i-o	26.26a-g	5.77a
L15	4080.69h-l	2597.49j-m	1234.82h-l	907.92h-k	208.33b-g	48.44hij	37.43g-o	22.79mn	5.42a-f
L16	4224.31d-l	2710.79h-l	1244.24f-l	904.10jk	185.96fg	45.38j	37.58f-n	27.47a-d	5.47a-f
L17	4311.29b-i	3009.80a-h	1293.50a-i	909.46g-k	190.21efg	46.92ij	39.79a-k	25.24d-l	5.68a-d
L18	4386.48a-g	3001.52a-h	1311.29a-f	907.08h-k	206.70b-g	49.61g-j	39.40a-l	23.66k-n	5.44a-f
L19	4097.97g-l	2762.81h-k	1233.23h-l	943.27a-e	203.83c-g	48.65g-j	37.03i-o	25.10e-l	5.44a-f
L20	4452.51a-e	3008.43a-h	1311.01a-f	916.20e-k	204.12c-g	49.32g-j	39.94a-j	27.29a-e	5.48a-f
L21	4367.64a-h	2768.27g-k	1273.03b-j	912.13f-k	212.96a-g	47.46ij	37.19i-o	26.94a-e	5.06fgh
L22	4251.54d-k	2809.92e-k	1236.52h-l	898.80k	195.56d-g	47.07ij	37.28i-o	25.62c-k	5.37a-g
L23	4494.80a-d	3138.23a-e	1338.89ab	937.87b-f	210.14b-g	52.12d-j	42.15ab	26.67a-f	5.65a-e
L24	4311.54b-i	2791.18f-k	1243.29f-l	905.66ijk	197.72d-g	49.38g-j	37.44f-o	24.69f-m	5.27a-h
L25	4337.81b-i	2993.55a-h	1256.82e-l	916.18e-k	193.61d-g	49.74g-j	38.35c-n	25.70b-k	5.66a-d
L26	4446.90a-e	3125.14a-f	1306.54a-g	916.05e-k	193.70d-g	48.07hij	40.95a-f	27.44a-d	5.36a-g
L27	4347.44b-i	2824.07e-k	1279.29b-j	898.62k	203.42c-g	52.81c-j	37.99d-n	25.96b-i	4.75h
L28	4426.78a-e	2882.62b-j	1314.27a-e	944.51 a-e	228.91a-d	54.06b-i	40.58a-h	27.36a-d	5.48a-f
L29	4602.22ab	3170.66a-d	1322.21a-e	923.05c-k	215.18a-f	47.83hij	40.13a-i	27.22a-e	5.76a
L30	4596.60abc	3161.44a-d	1330.60a-d	916.41e-k	212.23b-g	53.39c-j	41.16a-e	27.40a-d	5.48a-f
L31	4227.70d-l	2725.51h-l	1265.62d-k	940.36a-f	203.09c-g	52.40c-j	39.83a-k	26.54a-g	5.80a
L32	4582.48abc	3113.57a-f	1335.94abc	922.30c-k	216.95a-f	51.05d-j	40.84a-g	27.92ab	5.46a-f
L33	4402.69a-f	2862.89c-j	1281.18b-j	908.55h-k	192.55d-g	45.58j	39.44a-l	27.04a-e	5.33a-g
L34	4498.80a-d	3202.70ab	1352.88a	918.85d-k	214.36a-g	50.30f-j	41.77abc	26.99a-e	5.53a-f
L35	4320.69b-i	2851.80d-j	1274.33b-j	907.83h-k	210.37b-g	45.44j	36.23l-o	26.09b-i	5.14d-h
L36	4410.16a-f	2907.31b-j	1285.66a-j	924.70c-k	204.95b-g	48.67g-j	39.81a-k	26.10b-i	5.68a-d
L37	4275.08d-k	2877.60b-j	1282.34b-j	927.42c-k	211.14b-g	50.32f-j	37.11i-o	27.86abc	5.49a-f
L38	4311.43b-i	2917.36b-j	1266.39d-k	911.95f-k	203.38c-g	48.42hij	36.32k-o	27.40a-d	5.41a-f
L39	4409.34a-f	3029.77h-a	1306.49a-g	923.10c-k	198.62d-g	50.53f-j	40.27a-i	27.78abc	5.55a-f
L40	4349.56b-i	2940.65b-i	1296.76a-i	926.05c-k	205.92b-g	50.24f-j	39.33a-l	26.44a-g	5.75a
Min	3937.18	2342.40	1193.90	898.62	177.08	45.58	34.03	22.22	4.75
Max	4645.44	3303.93	1352.88	967.72	249.97	63.84	42.31	28.44	5.75
Mean	4319.59	2884.70	1277.26	925.01	208.26	51.57	38.67	26.01	5.47
CV	8.27	9.28	6.65	3.86	12.04	9.11	11.16	10.56	10.48
Pr >F	**	**	**	**	**	**	**	**	**

The highest P content was obtained from the Çorum location with 3177.15 mg kg^{-1}, while the lowest P content was acquired from the Amasya location with 2460.32 mg kg^{-1}. Bulyaba et al. (2020) reported that P uptake by plants was affected by factors such as heavy rainfall, soil texture, humidity and temperature. In our study, it was observed that the total precipitation was high and the soil structure was sandy in Samsun, Amasya and Bafra locations where the P content was partially lower. The P content was 2871.47 mg kg^{-1} in the first year and 2897.93 mg kg^{-1} in

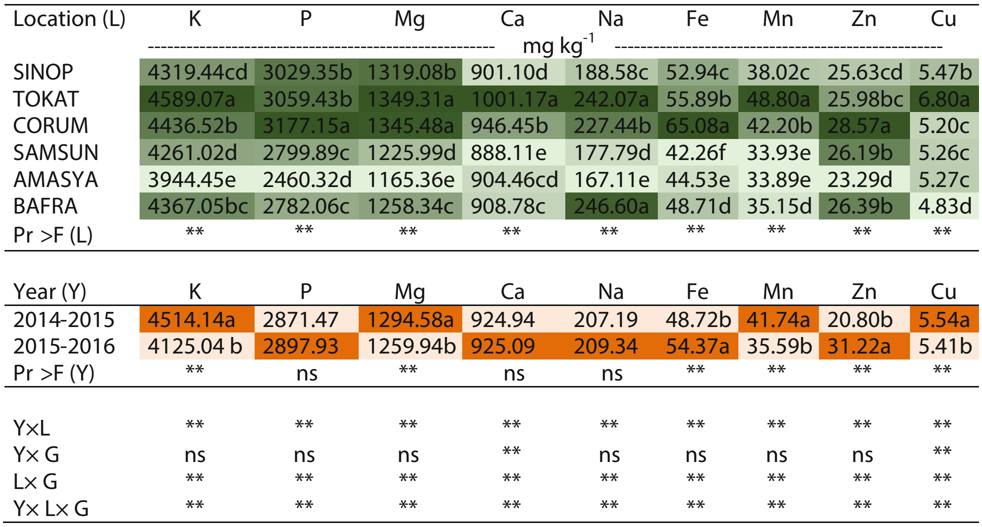


Fig. 2 Mean values of mineral element contents for locations and years. (The difference between the averages shown with the same letters is not significant at the 5% level, *Significant at $P \leq 0.05$,**Significant at $P \leq 0.01$, *ns* not significant)

Location (L)	K	P	Mg	Ca	Na	Fe	Mn	Zn	Cu
	----------	----------	----------	---------- mg kg^{-1}	----------	----------	----------	----------	----------
SINOP	4319.44cd	3029.35b	1319.08b	901.10d	188.58c	52.94c	38.02c	25.63cd	5.47b
TOKAT	4589.07a	3059.43b	1349.31a	1001.17a	242.07a	55.89b	48.80a	25.98bc	6.80a
CORUM	4436.52b	3177.15a	1345.48a	946.45b	227.44b	65.08a	42.20b	28.57a	5.20c
SAMSUN	4261.02d	2799.89c	1225.99d	888.11e	177.79d	42.26f	33.93e	26.19b	5.26c
AMASYA	3944.45e	2460.32d	1165.36e	904.46cd	167.11e	44.53e	33.89e	23.29d	5.27c
BAFRA	4367.05bc	2782.06c	1258.34c	908.78c	246.60a	48.71d	35.15d	26.39b	4.83d
Pr >F (L)	**	**	**	**	**	**	**	**	**

Year (Y)	K	P	Mg	Ca	Na	Fe	Mn	Zn	Cu
2014-2015	4514.14a	2871.47	1294.58a	924.94	207.19	48.72b	41.74a	20.80b	5.54a
2015-2016	4125.04 b	2897.93	1259.94b	925.09	209.34	54.37a	35.59b	31.22a	5.41b
Pr >F (Y)	**	ns	**	ns	ns	**	**	**	**

	K	P	Mg	Ca	Na	Fe	Mn	Zn	Cu
Y×L	**	**	**	**	**	**	**	**	**
Y× G	ns	ns	ns	**	ns	ns	ns	ns	**
L× G	**	**	**	**	**	**	**	**	**
Y× L× G	**	**	**	**	**	**	**	**	**

the second year, but no statistically significant difference was found between the years (Fig. 2). Other factors (cultivar, harvest year, growing location and climatic conditions), as well as the application of various analytical procedures for the detection of the content of P, might be accountable for varied results between previous studies (Doehlert et al. 2013; Chappell et al. 2017).

Magnesium Content

Magnesium (Mg), one of the most abundant elements in its intracellular concentration, is important for many cellular functions. These functions are DNA transcription, protein synthesis, fatty acid degradation, and glycolysis etc. (Alemayehu et al. 2021).

The comparison of 49 oat genotypes over the locations and years, exhibited clear differences in magnesium concentration among the genotypes (Fig. 1). As seen Fig. 1, the L8 genotype (1193.90 mg kg^{-1}) had the lowest magnesium content whereas the line L34 (1352.88 mg kg^{-1}) had the highest Mg content. The Tokat and Corum locations had the highest Mg content and were statistically in the same group. The Amasya location had the lowest Mg content with 1165.36 mg kg^{-1}. Bulyaba et al. (2020) determined that the Mg content was high in the lowa location where the organic matter content was high. This study, Mg content was higher in the first year than in the second year (Fig. 2). In previous studies, it was reported that magnesium content varies depending on genotypes (Erbaş Köse et al. 2021), years (Chappell et al. 2017) and environments (Doehlert et al. 2013). Jakobsone et al. (2019) reported that climate conditions such as temperature and rainfall changed the amounts of magnesium. Özcan et al. (2017), Metha and Jood (2018) and Erbaş Köse et al. (2021) also reported that the magnesium content of oat grains ranged from1252.4 to 2024.8 mg kg^{-1}, 1730 to 1772 mg kg^{-1} and 1160 to 1900 mg kg^{-1}, respectively.

Calcium Content

Calcium (Ca) is necessary for conducting cell functions. Calcium creates for 1–2% of adult human body weight and is used to build bones and teeth (Cashman 2002). According to the combined results of locations and years, the Ca content of oat genotypes varied from 898.62 (L7) to 967.72 (L27) mg kg^{-1} (Fig. 1). Ca content was significantly influenced by location, with the lowest Ca content was in Samsun location, while the highest Ca content was in Tokat location. There was no significant difference between years in terms of Ca content (firs year 924.94 mg kg^{-1}, second year 925.09 mg kg^{-1}) (Fig. 2). Previous studies have shown that Ca content is affected by growing area, genotype, year, and agronomic factors (Doehlert et al. 2013; Jakobsone et al. 2019; Alemayehu et al. 2021). It was consistent with the results of Özcan et al. (2017), who reported 568.5–1269.9 mg kg^{-1}, but higher than the values reported by Metha and Jood (2018) (428.0–491.6 mg kg^{-1}) and Chappell et al. (2017) (428.0–717.0 mg kg^{-1}). Since Ca is very important for bone metabolism and bone health, adequate dietary Ca intake is vital at every stage of life. According to our study, Ca content is quite high in oat genotypes.

Sodium Content

Sodium (Na) is a necessary element for humans and animals, and must be found in relatively major quantities in the diet. But there is insufficient Na available in the edible portions of most plants (Subbarao et al. 2003). In this study, the C1 genotype (249.97 mg kg^{-1}) had the greatest

Na content while the L14 oat line (177.08 mg kg^{-1}) had the lowest (Fig. 1). As seen in Fig. 2, Na contents in Bafra and Tokat locations were similar to each other and greater than in other locations. The contents of the Na significantly varied due to the variation in the genotypic make up as well as environmental factors. This situation probably resulted from the Bafra location being so close to the sea. The Na content no differed among years and it was found to be 207.19 mg kg^{-1} in the first year and 209.34 mg kg^{-1} in the second year (Fig. 2). Previous studies have shown that Na content can be affected by differences between species, genotypes, locations, years and agronomic factors (Chappell et al. 2017; Jakobsone et al. 2019; Bulyaba et al. 2020). Yli-Halla and Palko (1987) reported that the Na content of oat genotypes ranged from 14 to 777 mg kg^{-1} in acid sulfate soils and between 15 and 240 mg kg^{-1} in other soils in a study conducted in northern Finland. Similar to this study, in which significant differences were found between genotypes in terms of Na content, Rodehutscord et al. (2016) reported that Na content changed according to oat genotypes and varied between 81.1–184.0 mg kg^{-1}. The differences between studies could be thought to be due to different factors such as locations, genotypes, soil conditions, and analytical procedures used for determination.

Iron Content

Iron (Fe) is a critical micronutrient in all living organisms as it plays an important role in numerous metabolic processes such as respiration, oxygen storage in muscle tissue, cellular functions, photosynthesis and DNA synthesis. The daily requirement for Fe in adults ranges from 12 to 28 mg day^{-1}. In iron deficiency, people cannot produce adequate amounts of hemoglobin and impairment of the immune system. The primary cause of iron deficiency is insufficient Fe intake from a diet predominantly rich in starch but low in nutrients (Palanog et al. 2019).

Genotypes were also significantly different for Fe contents. Fe concentrations were changed between 45.38 and 63.84 mg kg^{-1}. Fe concentration was determined as the highest in the genotype C1 and followed by C2, L9, L4, L1, L5, L11, L13 and L10 genotypes, while L16 genotype had the lowest Fe concentration (Fig. 1). As seen in Fig. 1, the lines between L12 and L40 had lower Ca, Na and Fe contents. The highest Fe concentration was obtained from Çorum location with 65.08 mg kg^{-1}, followed by Tokat, Sinop, Bafra, Amasya, and Samsun locations, respectively (Fig. 2). Fe content was lower in the first year than in the second year (Fig. 2). In previous studies on the iron content of oat genotypes in different countries, it was reported that the iron content varied between 55.8 and 97.8 mg kg^{-1} in Germany (Rodehutscord et al. 2016), between 19 and 37 mg kg^{-1} in Russia (Bityutskii et al. 2017), between 29.7 and 48.9 mg kg^{-1} in Poland (Ciolek et al. 2007), and between 29.98 and 80.78 mg kg–^{1} in Turkey (Özcan et al. 2017). Also, some researchers reported that Fe content changed according to years, genotypes and agricultural practices (Chappell et al. 2017; Jakobsone et al. 2019; Alemayehu et al. 2021).

Manganese Content

Manganese (Mn) is a necessary element for plants, domestic animals, and humans. It is playing a role in many cellular processes such as carbohydrate metabolism and fatty acid synthesis. Mn insufficiency can influence the reproductive system, cause asthma and severe birth defects (de Oliveira Maximino et al. 2021).

In this study, the Mn content of oat genotypes had a mean content of 38.67 mg kg^{-1} with a range of 34.03–42.31 mg kg^{-1}. Mn content of genotypes over six locations for two years was determined as the highest in the genotype L7 and the lowest in the C1 genotype (Fig. 1). There was significant environmental variation for Mn, and Tokat location had the highest Mn content with 48.80 mg kg^{-1}, Amasya and Samsun locations had the lowest Mn content. Similar to the Bafra and Amasya locations in our study, Bulyaba et al. (2020) which a study about common bean genotypes in different locations, reported that Mn deficit may take place in sandy soils with pH ≥ 8. Mn content was higher in the first year (41.74 mg kg–1) than in the second year (35.59 mg kg–1) (Fig. 2). Parallel to our study, Kara et al. (2012) reported that Mn content in oat grains varied according to genotypes, years and locations. In previous studies with different oat genotypes in different environments, the Mn content of oat genotypes was reported that changed between 25.82 to 105.97 mg kg–1 (Chappell et al. 2017; Özcan et al. 2017; de Oliveira Maximino et al. 2021).

Zinc Content

Zinc performs essential roles in a wide variety of biochemical processes that affect growth, development, and reproduction and relates to many enzymes and proteins in the body. Lately, global awareness of the importance of Zn element to human health has risen rapidly. In this study, Zn content of genotypes over six locations for two years was determined between 22.22 (C1) to 28.44 mg kg^{-1} (C5) (Fig. 1). The highest Zn concentration was obtained from Çorum location with 28.57 mg kg^{-1}, followed by Bafra, Samsun, Tokat, Sinop and Amasya locations, respectively (Fig. 2). The Zn content was determined lower in the 2014–2015 growing season than in the 2015–2016 growing season (Fig. 2). Chappell et al. (2017) reported that Zn content in oat grains varied according to years and locations. The Zn content of oat genotypes was reported that ranged between 15.50–37.68 mg kg⁻¹ by Özcan et al. (2017), between 31.56–35.82 mg kg⁻¹ by Metha and Jood (2018), and between 16–21 mg kg⁻¹ by Alemayehu et al. (2021). Zn shortage causes a significant common risk to human health (Palanog et al. 2019). Zn deficiency is often a consequence of consuming a diet consisting mainly of cereals. The average need for Zn for human health is 14 mg day⁻¹. Since cereals do not contain high levels of Zn and only a part of Zn is used biologically due to the presence of phytate, only a part of the need can be met with a daily diet containing 300–400 g of cereals (de Oliveira Maximino et al. 2021). Therefore, this situation can be contributed by increasing the amount of zinc in the diet.

Copper Content

Copper (Cu) is necessary to all living organisms as a trace dietary mineral element. It stimulates the immune system, which aids in the fight against infections, healing and tissue repair. It also is an essential micro-nutrient that is necessary for the hematologic, neurologic systems, blood vessels, and nerves healthy (Alemayehu et al. 2021; de Oliveira Maximino et al. 2021).

Cu contents of oat genotypes were determined between 4.75 (L27) to 5.80 mg kg⁻¹ (L7 and L31) (Fig. 1). The highest Cu content was determined at the Tokat location with 6.80 mg kg⁻¹, while the lowest was determined at the Bafra location with 4.83 mg kg⁻¹. The Cu content was higher in the first year (5.54 mg kg⁻¹) than in the second year (5.41 mg kg⁻¹) (Fig. 2). Concerning Cu content, Özcan et al. (2017) reported mean values ranging from 1.77 to 8.67 mg/kg. Kara et al. (2012) reported that Cu content varied according to genotypes and locations. Chappell et al. (2017) reported that Cu content of genotypes was determined between 1.11 to 4.39 mg kg–1, and its varied according to genotypes and years. Jakopsone et al. (2019) also reported that the Cu content varied according to the fertilizer application.

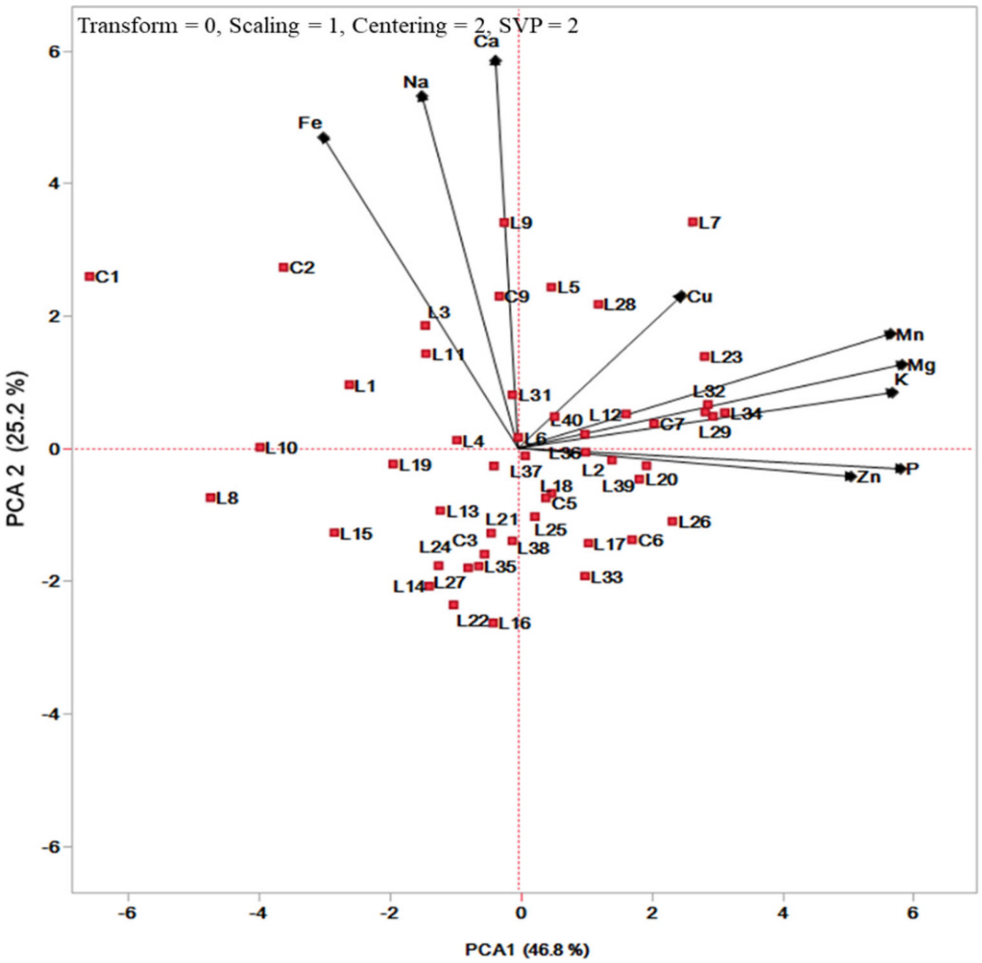
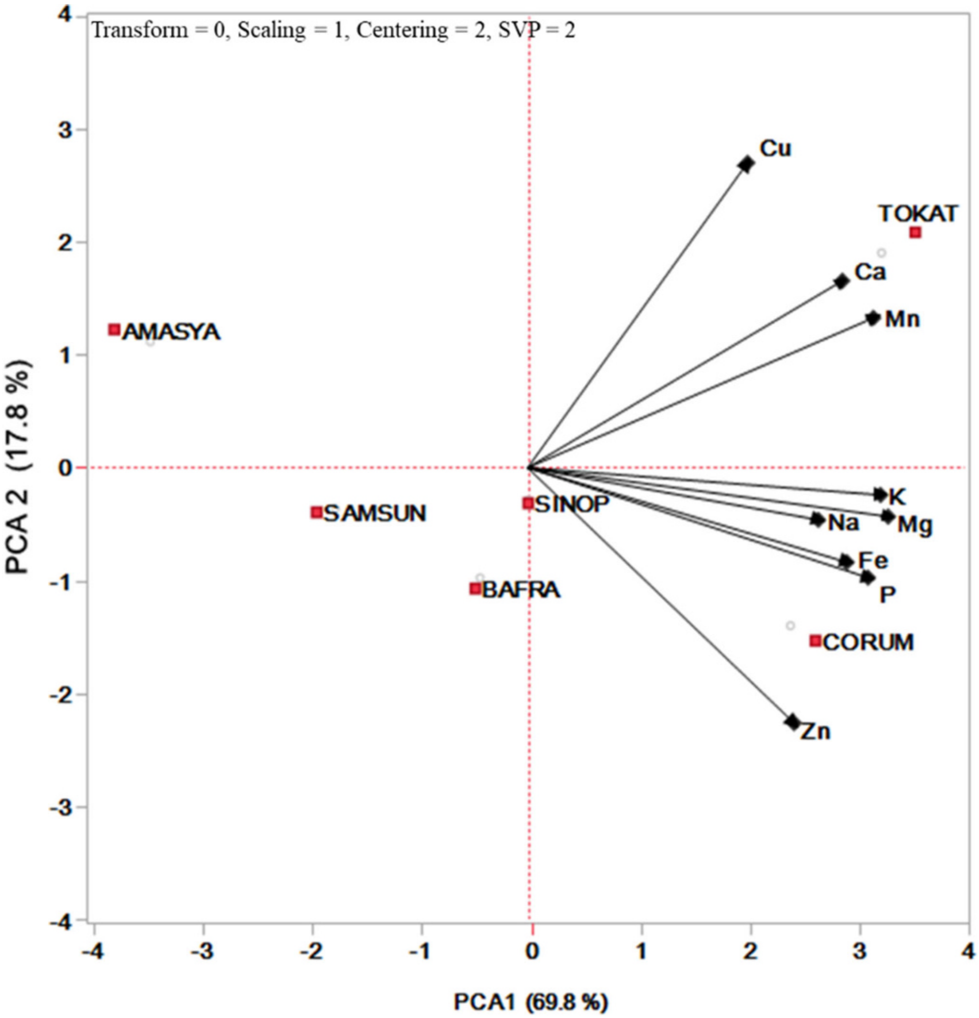


Fig. 3 Genotype × Trait biplot for investigated traits of oat genotypes

Fig. 4 Trait × Environment biplot for investigated traits of the environment



Biplot Analysis

Genotype × trait biplot allows visual comparison of different genotypes and traits, and aids in the identification of genotypes with superior characteristics (Yan and Kang 2003; Yan 2014). Trait values across 2 years in six locations of 49 oat genotypes are displayed in Fig. 1. These data were created for visual assessment of investigated traits over the locations (Fig. 3). The graph explained 72.0% of total variation (PC1 46.8% and PC2 25.2%). In the biplot graph, vector angles of less than 90° indicate that the traits are positively correlated, vector angles of greater than 90° indicate that the traits are negatively correlated, and finally, vector angles of equal to 90° indicate that the traits are not related. Positively correlated traits and the best genotypes for each trait were placed close to each other over the graph. The genotypes L7, L9 and C9 had greater than the general average in terms of all minerals. Also, genotypes C7, L5, L6, L12, L23, L28, L29, L30, L31, L34 and L40 had greater than the general average in terms of many minerals. The prominent genotypes showed acute angles with the minerals vectors since they were positively correlated with minerals. There was a high positive correlation between Fe, Na, Ca and Cu and also between Cu, Mn, Mg, K, P and Zn (Fig. 3).

The location × trait biplot was used for visual assessment of variations in elements based on environments and this graph is presented in Fig. 4. The graph explained 87.6% of the total variation (PC1 69.8% and PC2 17.8%). The length of an environmental vector is a forecast of the discriminating power of the environment (Yan et al. 2016). In this study, the Tokat and Corum locations largely contributed to the element × location interaction. Sinop, Bafra and Samsun locations were placed at the nearest distance from the origin and these locations provided little information about the mineral differences. There was a high positive correlation between Çorum, K, Mg, Na, Fe, P and Zn and also between Tokat, Cu, Ca and Mn. Amasya location had low values in terms of all elements (Fig. 4). Similar to the present findings, Erbaş Köse et al. (2021) reported positive relationships between P and Mg content. Gerrano et al. (2019) who conducted a study about cowpea genotypes, reported that a positive association of K content with P, Mn, Zn, Ma and Mg contents. Johansson et al. (2021) reported that a positive correlation was determined between all the minerals examined in their study.

Conclusion

The increase of nutrient contents in cereals, the important main food crop worldwide, is a hopeful attempt to improve human nutritional well-being. Increasing the amount of dietary nutrient intake by consuming oat genotypes with high mineral content developed through breeding programs is a sustainable approach. The present study on oat genotypes indicated large variability for the concentration of grain elements, also the presence of G × L and interaction for all elements indicating an influence of location on the expression of these elements. This suggested that there is genetic potential to improve the levels of these minerals in oat grains. Genotypes C7, C9, L5, L6, L7, L9, L12, L23, L28, L29, L30, L31, L34 and L40 were prominent in terms of many minerals over six locations for two years. In addition, the element contents of oat grains grown in Çorum and Tokat locations were found to be higher than the other locations, according to the two-year average.

Supplementary Information The online version of this article (https://doi.org/10.1007/s10343-022-00633-2) contains supplementary material, which is available to authorized users.

Acknowledgements The authors wish to thank the Scientific and Technological Research Council of Turkey (TUBITAK) for financial support of this project under Project Code: TOVAG-114O273.

Conflict of interest Z. Mut, Ö.D. Erbaş Köse and H. Akay declare that they have no competing interests.

References

Alemayehu GF, Forsido SF, Tola YB, Teshager MA, Assegie AA, Amare E (2021) Proximate, mineral and anti-nutrient compositions of oat grains (Avena sativa) cultivated in Ethiopia: implications for nutrition and mineral bioavailability. Heliyon 7(8):e7722. https://doi.org/10.1016/j.heliyon.2021.e07722

Barczak B, Nowak K (2013) Content of macroelements and their ionic ratios in oat grain depending on the sulphur form and dose. J Cent Eur Agric 14(1):114–123. https://doi.org/10.5513/JCEA01/14.1.1167

Bityutskii N, Yakkonen K, Loskutov I (2017) Content of iron, zinc and manganese in grains of Triticum aestivum, Secale cereale, Hordeum vulgare and Avena sativa cultivars registered in Russia. Genet Resour Crop Evol 64(8):1955–1961. https://doi.org/10.1007/s10722-016-0486-9

Bulyaba R, Winham DM, Lenssen AW, Moore KJ, Kelly JD, Brick MA, Ogg JB (2020) Genotype by location effects on yield and seed nutrient composition of common bean. Agronomy 10(3):347. https://doi.org/10.3390/agronomy10030347

Çakmak I (2002) Plant nutrition research: priorities to meet human needs for food in sustainable ways. Plant Soil 247(1):3–24

Cashman KD (2002) Calcium intake, calcium bioavailability and bone health. Br J Nutr 87(S2):169–S177. https://doi.org/10.1079/BJN/2002534

Chappell A, Scott KP, Griffiths IA, Cowan AA, Hawes C, Wishart J, Martin P (2017) The agronomic performance and nutritional content of oat and barley varieties grown in a northern maritime environment depends on variety and growing conditions. J Cereal Sci 74:1–10. https://doi.org/10.1016/j.jcs.2017.01.005

Ciolek A, Makarska E, Wesolowski M, Cierpiala R (2012) Content of selected nutrients in wheat, barley and oat grain from organic and conventional farming. J Elementol 17(2):181–189

Ciolek A, Makarski B, Makarska E, Zadura A (2007) Content of some nutrients in new black oat strains. J Elementol 12(4):251–259

Doehlert DC, Simsek S, Thavarajah D, Thavarajah P, Ohm JB (2013) Detailed composition analyses of diverse oat genotype kernels grown in different environments in North Dakota. Cereal Chem 90(6):572–578. https://doi.org/10.1094/CCHEM-09-12-0111-R

Erba D, Hidalgo A, Bresciani J, Brandolini A (2011) Environmental and genotypic influences on trace element and mineral concentrations in whole meal flour of einkorn (Triticum monococcum L. subsp. monococcum). J Cereal Sci 54(2):250–254. https://doi.org/10.1016/j.jcs.2011.06.011

Erbaş Köse ÖD, Mut Z, Akay H (2021) Assessment of grain yield and quality traits of diverse oat (Avena sativa L.) genotypes. Ann Bot. https://doi.org/10.13133/2239-3129/16777

FAO (2019) Statistical databases. https://www.fao.org/faostat/en/#home. Accessed 18 Feb 2022

Gerrano AS, Jansen van Rensburg WS, Venter SL, Shargie NG, Amelework BA, Shimelis HA, Labuschagne MT (2019) Selection of cowpea genotypes based on grain mineral and total protein content. Acta Agric Scand Sect B Soil Plant Sci 69(2):155–166. https://doi.org/10.1080/09064710.2018.1520290

Jakobsone I, Zute S, Bleidere M, Kantane I, Ece L, Bartkevics V (2019) Macro and trace elements in oat cultivars bred in Latvia. Zemdirb Agric 106(1):21–28. https://doi.org/10.1515/prolas-2015-0022

Johansson E, Prieto-Linde ML, Larsson H (2021) Locally adapted and organically grown landrace and ancient spring cereals—A unique source of minerals in the human diet. Foods 10(2):393. https://doi.org/10.3390/foods10020393

JUMP (2020) JMP users guide. Version 13.0.0. SAS Institute, Cary

Kara R, Dokuyucu T, Demirkiran AR, Dumlupinar Z, Akcura M, Akkaya A (2012) Groat element concentration at different spikelets of oat panicles (Avena sativa L.) evaluated at three Turkish locations. Turk J Field Crop 17(2):157–165

Kaur S, Bhardwaj RD, Kapoor R, Grewal SK (2019) Biochemical characterization of oat (Avena sativa L.) genotypes with high nutritional potential. LWT 110:32–39. https://doi.org/10.1016/j.lwt.2019.04.063

Metha B, Jood S (2018) Anti-nutritional factors and mineral content of different oat (Avena sativa L.) varieties. Food Sci Res J 9(1):117–120. https://doi.org/10.15740/HAS/FSRJ/9.1/117-120

Miller RO (1998) High temperature oxidation: dry ashing. In: Kalra YP (ed) Handbook of reference methods for plant analysis. CRC, Boca Raton, pp 53–56

Neeraja CN, Ravindra Babu V, Ram S, Hossain F, Hariprasanna K, Rajpurohit BS, Prabhakar, Longvah T, Prasad KS, Sandhu JS, Datta SK (2017) Biofortification in cereals: progress and prospects. Curr Sci 113:1050–1057. https://doi.org/10.18520/cs/v113/i06/1050-1057

de Oliveira Maximino JV, Barros LM, Pereira RM, de Santi II, Aranha BC, Busanello C, Pegoraro C (2021) Mineral and fatty acid content variation in white oat genotypes grown in Brazil. Biol Trace Elem Res 199(3):1194–1206. https://doi.org/10.1007/s12011-020-02229-1

Özcan M, Özkan G, Topal A (2006) Characteristics of grains and oils of four different oats (Avena sativa L.) cultivars growing in Turkey. Int J Food Sci Nutr 57(5/6):345–352. https://doi.org/10.1080/09637480600802363

Özcan MM, Bağcı A, Dursun N, Gezgin S, Hamurcu M, Dumlupınar Z, Uslu N (2017) Macro and micro element contents of several oat (Avena sativa L.) genotype and variety grains. Iran J Chem Chem Eng 36(3):73–79

Palanog AD, Calayugan MIC, Descalsota-Empleo GI, Amparado A, Inabangan-Asilo MA, Arocena EC, Swamy BP (2019) Zinc and iron nutrition status in the Philippines population and local soils. Front Nutr 6:81. https://doi.org/10.3389/fnut.2019.00081

Peltonen-Sainio P, Kontturi M, Peltonen J (2006) Phosphorus seed coating enhancement on early growth and yield components in oat. Agron J 98(1):206–211. https://doi.org/10.2134/agronj2005.0141

Peterson DM, Wesenberg DM, Burrup DE, Ericson CA (2005) Relationships among agronomic traits and grain composition in oat genotypes grown in different environments. Crop Sci 45:1249–1255

Rodehutscord M, Rückert C, Maurer HP, Schenkel H, Schipprack W, Bach Knudsen KE, Mosenthin R (2016) Variation in chemical composition and physical characteristics of cereal grains from different genotypes. Arch Tierernahr 70(2):87–107. https://doi.org/10.1080/1745039X.2015.1133111

SAS Institute (1998) INC SAS/STAT users' guide release 7.0. SAS, Cary

Subbarao GV, Ito O, Berry WL, Wheeler RM (2003) Sodium—a functional plant nutrient. CRC Crit Rev Plant Sci 22(5):391–416. https://doi.org/10.1080/07352680390243495

WHO (2012) Guideline: potassium intake for adults and children. https://www.who.int/publications/i/item/9789241504829. Accessed 25 Sep 2021

Wioeniowska-Kielian B, Klima K (2007) Comparison of microelement contents in the winter wheat grain from organic and conventional farms. J Res Appl Agric Engin 52(4):100–103 (in Polish)

Yan W (2014) Crop variety trials: data management and analysis. John Wiley & Sons, Hoboken, p 349

Yan W, Kang MS (2003) GGE Biplot analysis: a graphical tool for breeders, geneticists, and agronomists. CRC, Boca Raton

Yan W, Frégeau-Reid J, Pageau D, Martin R (2016) Genotype-by-environment interaction and trait associations in two genetic populations of oat. Crop Sci 56(3):1136–1145. https://doi.org/10.2135/cropsci2015.11.0678

Yli-Halla M, Palko J (1987) Mineral element content of oats in an acid sulphate soil area of Tupos village, northern Finland. J Agric Sci Finl 59:73–78

Özge Doğanay Erbaş Köse Dr., is Assistant professor in Department of Field Crops Faculty of Agriculture and Natural Science Bilecik Şeyh Edebali University, Bilecik, Turkey. She works in the field of cereals and pulses agronomy and breeding.