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Mineral Composition of Bread Wheat Cultivars as Influenced by Different Fertilizer Sources and Weed Management Practices

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Abstract

Mineral and vitamin deficiencies are one of the important threats especially in developing and under-developed countries. Wheat grain also contains a number of elements vital to our biological functions, but hazardous to our health in high concentrations. This research was carried out to determine the effects of agronomic practices on the mineral composition of organically grown bread wheat (*Triticum aestivum* L.) varieties. In terms of all nutrients evaluated, the mineral content of wheat showed significant differences according to crop years, varieties, weed management methods and fertilizer sources. As the average of all factors, the Cu, Fe, Mn, Se, Zn, Cd, Co, Cr, Ni and Pb contents of the ground wheat grain were 3.93, 42.8, 79.6, 0.549, 11.34, 0.012, 0.140, 0.194, 3.71 and 0.269 mg/kg, respectively. According to the wheat varieties, the Kirik was superior in terms of Cu (7.6%), Fe (3.8%), Se (57%), Zn (40.5%), Co (31.1%) and Cr (36.1%), and the Dogu-88 was superior in terms of Mn (5.5%), Cd (1.9%), and Ni (17.0%). The effect of weed management methods on mineral content was variable. According to fertilizer sources, the highest mineral content was obtained from the control plots without fertilizer treatments. The lowest mineral contents were obtained from chemical fertilization, cattle manure and organic fertilizer applications. There was no significant increase in the mineral content of wheat with organic fertilization, however, organic agriculture still preserves its place in terms of healthy food. As a result, it has been determined that the values obtained for all mineral elements were not at a level that pose a risk on the environment, human and animal health according to WHO. In order to identify wheat varieties with higher mineral content, which are beneficial for human health, new research should be done with different organic fertilizer sources with more varieties.

Keywords Organic wheat · Genotypes · Seeding rate · Fertilization · Mineral content

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Mineralstoffzusammensetzung von Brotweizensorten unter dem Einfluss verschiedener Düngerquellen und Unkrautbekämpfungsmethoden

Zusammenfassung

Mineralstoff- und Vitaminmangel sind vor allem in Entwicklungsländern und unterentwickelten Ländern eine große Bedrohung. Auch Weizenkörner enthalten eine Reihe von Elementen, die für unsere biologischen Funktionen lebenswichtig, in hohen Konzentrationen jedoch gesundheitsschädlich sind. In dieser Studie wurden die Auswirkungen der agronomischen Praktiken auf die Mineralstoffzusammensetzung von ökologisch angebauten Brotweizensorten (*Triticum aestivum* L.) untersucht. Bei allen bewerteten Nährstoffen wies der Mineralstoffgehalt von Weizen je nach Anbaujahr, Sorte, Unkrautbekämpfungsmethode und Düngerquelle signifikante Unterschiede auf. Im Durchschnitt aller Faktoren betrugen die Gehalte an Cu, Fe, Mn, Se, Zn, Cd, Co, Cr, Ni und Pb im gemahlenen Weizenkorn 3,93, 42,8, 79,6, 0,549, 11,34, 0,012, 0,140, 0,194, 3,71 bzw. 0,269 mg/kg. Bei den Weizensorten war Kirik in Bezug auf Cu (7,6 %), Fe (3,8 %), Se (57 %), Zn (40,5 %), Co (31,1 %) und Cr (36,1 %) überlegen, während Dogu-88 in Bezug auf Mn (5,5 %), Cd (1,9 %) und Ni (17,0 %) überlegen war. Die Auswirkungen der Unkrautbekämpfungsmethoden auf den Mineralstoffgehalt waren unterschiedlich. Je nach Düngerquelle wurde der höchste Mineralstoffgehalt in den Kontrollen ohne Düngerbehandlung erzielt. Die niedrigsten Mineralstoffgehalte wurden durch chemische Düngung, Kuhmist und organische Düngung erzielt. Die organische Düngung führte nicht zu einer signifikanten Erhöhung des Mineralstoffgehalts des Weizens, dennoch behält die ökologische Landwirtschaft ihren Platz in Bezug auf gesunde Lebensmittel. Als Ergebnis wurde festgestellt, dass die für alle Mineralelemente ermittelten Werte nicht auf einem Niveau lagen, das laut WHO ein Risiko für die Umwelt sowie die Gesundheit von Mensch und Tier darstellt. Um Weizensorten mit höherem Mineralstoffgehalt zu identifizieren, die für die menschliche Gesundheit vorteilhaft sind, sollten neue Forschungen mit verschiedenen organischen Düngemitteln und weiteren Sorten durchgeführt werden.

Schlüsselwörter Bio-Weizen · Genotypen · Aussaatmenge · Düngung · Mineralstoffgehalt

Introduction

High nutritional and quality traits are desired in wheat grains for human and animal health. It appears that about half of all diseases were caused by nutritional disorders. However, the consequences of many disorders remain hidden because of the complexity of the relationship between food quality and health and because of the time lag between cause and effect (Mie et al. 2017). Agriculture that produces healthy food contributes to the prevention of diseases and this aspect is often underestimated (WHO 2021). Effects of food quality on health can be assessed by determining the value of the ingredients in food products or by medical indices of health status where nutritional disorders are not directly observed. Nutritional disorders result from latent deficiencies rather than acute (visible) deficiencies (Anglani 1998; WHO 2021).

Wheat grain contains a number of elements (Cu, Zn, Fe, Ni, Mn) vital to our biological functions, but hazardous to human health in high concentrations (Conti et al. 2000; Skrbic and Onjia 2007; Shewry and Hey 2015). It also contains some toxic elements (As, Pb, Hg, Cd). There are three groups of minerals of interest in the food industry, science and nutrition specialists (Stefanovic et al. 2008): (a) essential to human (Cu, Ca, Fe, K and Mg) (b) essential to plants and one or more animal species however not for humans (As, Cd, Ni, and others) and (c) toxic or used in therapeutic dosages (Al, Ba, Hg).

In agronomic studies related to wheat, the parts related to mineral content are generally not taken into account. Literature reviews have shown that there were not enough studies on the effects of fertilizer sources and other agronomic practices (like sowing densities) or weed management treatments on mineral content of wheat plants in agricultural systems. According to Ugulu et al. (2021), the heavy metal/metalloid concentrations in the wheat grains ranged from 12.95 to 25.83, 1.03 to 1.11, 16.83 to 20.26, 0.92 to 0.98, 0.504 to 1.997, 2.24 to 5.98 and 0.493 to 1.154 mg/kg for Zn, Co, Fe, Cd, Pb, Cu, and Cr, respectively. In fact, as a result of agronomic practices, mineral content of the wheat grain may exceed the acceptable limits for the environment, human and animal health. For this reason, health problems can occur insidiously.

Mineral content of wheat not only relies on agronomic practices, but also on soil and climate conditions of the region and the varieties. Mineral composition of wheat is determined by factors such as growing seasons, genotype, soil conditions and fertilizing practices (Anglani 1998; Zhao et al. 2009; Zhang et al. 2014; Johansson et al. 2021). Some minerals reach the toxic level in the soil as a result of fertilizer applications (especially phosphorus). Fertilization has a great effect on the mineral content of wheat. It has been reported that 54–58% of the Cd reaching the soil by human activities comes from phosphorus fertilizers and 2–5% from waste sludge and farm manure applications (Wang et al. 2015). The results of other study showed that the mineral content of bread wheat genotypes varied depending on the year, variety, seeding rates and fertilizer sources were important for mineral content differences in wheat (Bulut 2022a, b; Bulut et al. 2022).

Mineral content of wheat is not evaluated much in agronomic studies. Therefore, this research was conducted to determine the effect of agronomic factors on the mineral content of the wheat grain. In the present study, effects of different fertilizer sources and weed management methods on mineral contents of two bread wheat varieties were investigated for three years.

Material and Methods

Wheat seeds evaluated in the current study were obtained from a previous research carried out in Ataturk University, Agricultural Research and Extension Center, during the cropping seasons of 2006–07, 2007–08 and 2008–09. The experiment was carried out using a completely randomized design in 2 × 3 × 7 factorial scheme, with 3 replicates. In previous study, the factors were 2 wheat varieties (Kirik and Doğu-88), 3 weed management practices (weedy control [475 seeds m^{-2}], hand weeding [475 seeds m^{-2} + HW], and dense sowing [625 seeds m^{-2}]), and seven fertilizer sources (Control, standard inorganic [NP], Bio Organic [Bio], Bio Organic SR [Bio SR], Leonardit, Organic Fertilizer [OF], Cattle Manure [CM]) and 2 × 3 × 7 = 42 treatment combinations randomly distributed in blocks.

Kirik is an old local cultivar (awnless, white-grain, facultative) and the most common cultivar, which occupies about 60% of the total wheat-sown area in the region. Dogu 88 is a modern cultivar (awny, red-grain, winter), and the highest-yielding cultivar under rain-fed conditions of the region.

The climate is semi-arid with an average annual precipitation of 395 mm and an average annual air temperature of 4.9 °C. Some physical and chemical properties of the experimental soils (0–20 cm) were determined in the fall prior to the cropping years (Table 1). Optimum seeding rate for winter wheat in the region is 475 seeds m^{-2} under dryland conditions. The experiment comprised three non-chemical weed control methods: an unweeded control (475 seeds m^{-2}), a hand weeding-once at the beginning of stem elongation (475 seeds m^{-2} + HW), and a high seeding rate (625 seeds m^{-2}). Cattle manure from the Research Farm of Ataturk University was prepared after cattle dung and bedding material had been composted about 90 days. The composted cattle manure and four commercial organic amendments (Bio Organic, Bio Organic SR, Leonardit, Organic Manure) were manually applied to field plots and incorporated into the soil just before sowing in recommended doses. Application rates and important characteristics of organic manures used in the experiment are shown in Table 2. In mineral fertilized plots, N as ammonium sulphate was applied of 60 kg ha^{-1} and P as triple superphosphate of 50 kg ha^{-1}. Half of N and all P were applied at sowing; second half of N was applied at the beginning of stem elongation, according to the common practice in the region.

Table 1 Soil properties, environmental data, sowing and harvesting dates for field experiments

Cropping seasons	2006–07	2007–08	2008–09
Soil texture	Clay-loam	Clay-loam	Clay-loam
Organic matter (%)	1.49–1.56	1.71–1.77	1.38–1.50
Total N (g kg^{-1})	0.6–0.7	0.7–0.8	0.5–0.7
Available P (mg kg^{-1})	11.2–14.8	9.8–12.2	9.1–12.9
Available K (mg kg^{-1})	699–748	602–721	762–776
pH	7.6–7.8	7.1–7.5	6.6–6.8
Precipitation (mm)			
Total (1 September–31 August)	467.0	336.7	386.7
1 September–30 November	144.6	101.9	76.9
1 December–30 April	130.0	108.0	138.4
1 May–31 August	192.4	126.8	171.4
Air temperature (°C)			
Average annual	5.3	5.0	5.2
Average of 1 September–30 November	7.5	7.4	8.4
Average of 1 December–30 April	–4.6	–5.6	–4.5
Average of 1 May–31 August	16.0	16.4	14.8
Maximum	31.0 (in July)	32.9 (in July)	32.0 (in July)
Minimum	–31.6 (in Dec.)	–32.6 (in Jan.)	–36.0 (in Jan.)
Sowing date	1 September	30 August	29 August
Harvesting date	9 August	15 August	18 August
Number of weeds in hand weeding plots m^{-2}	26–57 (42)	41–67 (55)	17–34 (26)
Weed biomas in hand weeding plots (g m^{-2})	14–177 (63)	74–413 (179)	122–297 (103)

The yield, quality, economic analysis and weed density components of the study have been published in four previous manuscripts. In this part of the study, the mineral element contents of the bread wheat grains were determined from the seed samples obtained previously and stored at –20 degrees. After harvesting, the spikes were threshed and grains were stored at –20 °C. Dried seed samples were grinded and etched in microwave (Berghof Speedwave, Germany) using 2 ml of 35% H_2O_2 and 5 ml of 65% HNO_3. Following the digestions, seed mineral contents Copper (Cu), Iron (Fe), Manganese (Mn), Selenium (Se) Zinc

Table 2 Important characteristics and application rates of fertiliser resources

Organic manures		Total N (g kg^{-1})	Available P (g kg^{-1})	Organic matter (%)	Application rate (kg ha^{-1})	Producer company
Bio-Organic (Bio)		14.8	0.52–0.83	50–55	750	Biyotar
Bio-Organic SR (Bio SR)		14.8	0.52–0.83	70–75	750	Biyotar
Leonardit		10.3	3.06	25–45	650	Bereket Organik
Organic Manure		35.0	13.10	70	1500	BioFarm
Cattle manure	(2006–07)	7.7	2.62	17	10,000	–
	(2007–08)	8.0	2.84	20	10,000	–
	(2008–09)	8.3	2.71	21	10,000	–

(Zn), Cadmium (Cd), Cobalt (Co), Chrome (Cr), Nickel (Ni) and Lead (Pb) were analyzed in an Inductively Coupled Plasma Mass Spectrometry (ICP-MS; Agilent 7500a) in laboratories of Technological Research and Extention Center of Erciyes University (TAUM). To check related elemental measurements, reference leaf samples from National Institute of Standards and Technology (Gaithersburg, MD, USA) were used in present study.

Statistical Analysis Experimental results were subjected to analysis of variance (ANOVA) and significant means were compared with the use of Duncan's multiple range test at 0.05 significance level. Statistical analyses were performed with the use of SAS software.

Results and Discussion

In the previous studies of ours, indicate that wheat grain yields and grain quality in organic production can be raised by modifying agronomic practices. High yield potential, ability to competition with weeds and use nitrogen input may be important traits adapted to environments managed organically, if grain yield is a selection criterion. Dogu 88 produced grain yields that were 44.7, 135.0 and 63.6% higher than the Kirik in 2006–07, 2007–08 and 2008–09 cropping seasons, respectively (Table 3). Overall, these data suggest that response to weed control management and manure source may depend on choice of cultivar. On average of years, hand weeding and dense sowing increased grain yield by 9.2 and 7.7% compared to weedy control. Increased seeding rates appear to be a useful method providing the wheat a competitive advantage against weeds in organic production under rain-fed conditions. Controlling the weeds by increasing seeding rate by 30% could be more suitable, particularly in large areas and where labour is expensive (Table 3). Mineral NP treatment was superior in terms of yield components and grain yield. Among the organic manures, cattle manure was found to be better, followed by Organic Manure. Cattle manure and Organic Manure increased grain yield of wheat by 25.6 and 23.2%, respectively, compared to unfertilized treatment (Oztürk et al. 2012). The economic evaluation of increasing in both grain and stubble yield was determined according to local cost and organic product prices. "Dogu 88 + 625 seeds m^{-2} + cattle manure" treatment combination had the highest gross production value and gross profit (Birinci et al. 2010). In our previous study, weed control practices significantly affected wheat quality parameters. The highest Zeleny sedimentation value and wet gluten content were obtained from hand weeding, while the highest crude protein ratio was obtained from weedy control. Organic manure sources increased the quality parameter compared to the control and cattle manure should be applied as an organic fertilizer due to high quality values in organic wheat farming under the dry farming conditions (Bulut et al. 2013). As in grain yield end quality parameters, significant differences were observed among cultivars with regard to weed dry weights; dry weights were determined as 139.5 kg da^{-1} for Kirik and 90.3 kg da^{-1} for Doğu-88. Doğu-88 variety was found to be more competitive in weed biomass than Kirik genotype. The effect of weed biomass of fertilizer sources was found to be statistically significant. However, although NP, Bio, Bio SR and OG fertilizer sources were statistically in the same group in terms of weed biomass, OG fertilizer source was the fertilizer source with the least weed biomass. On the other hand, one of the important fertilizer sources in organic wheat farming is cattle manure. However, as in our research, cattle manure (SG) application increases weed density, incidence and dry weight in the field may have been associated with the potential introduction of seeds in the cattle manure (Bulut et al. 2012). In the other hand, in the study investigating the effects of weed control methods on grain yield in chickpea, it was determined that with an increase of 1.5 times in seeding rate, total weed density and total weed weight decreased by 30 and 32%, respectively, and increased seed yield by 24% (Kanatas and Gazoulis 2022). In another study of the same researchers on spinach, it was determined that the commercial biomass of spinach increased with decreasing in-row spacing [$R2 = 0.881$] and increasing the number of mechanical treatments [$R2 = 0.911$] (Gazoulis et al. 2021).

Table 3 Effects of experimental variables on grain yield and weed dry weights[a] (published data)

Variable	Grain yield (kg da^{-1})				Weed biomass (kg da^{-1})			
	2006–07	2007–08	2008–09	Mean	2006–07	2007–08	2008–09	Mean
Cultivars (C)								
Kirik	294.9 b	171.8 b	244.9 b	237.2 A	64.8	160.9 a	192.7 a	139.5 A
Dogu 88	426.8 a	403.8 a	400.7 a	410.4 B	60.9	44.9 b	165.1 b	90.3 B
Mean	360.9 A	287.8 C	322.8 B	323.8	62.8 C	102.9 B	178.9 A	114.9
Weed management (W)								
Unwedded	342.2 b	269.7 b	308.2 b	192.6	–	–	–	–
Hand weeding	373.0 a	300.1 a	329.8 a	209.9	–	–	–	–
High seeding rate	367.3 a	293.7 a	330.3 a	208.0	–	–	–	–
Manures (M)								
Unfertilized	303.6 e	234.1 d	280.4 d	272.7	66.3 b	121.5 abc	239.6 a	142.5 a
Mineral NP	427.5 a	361.2 a	375.8 a	388.2	41.1 c	78.8 bcd	161.1 bc	93.7 b
Bio	335.6 d	260.5 cd	305.4 c	300.5	38.9 c	52.6 d	150.8 bc	80.7 b
Bio SR	352.4 cd	259.0 cd	305.8 c	305.7	41.3 c	71.6 cd	178.9 ab	97.3 b
Leonardit	359.8 bcd	279.1 c	313.6 c	317.5	111.2 a	129.3 ab	210.4 ab	150.3 a
Organic manure	368.0 bc	307.8 b	337.7 b	337.8	28.5 c	100.2 bcd	95.9 c	74.9 b
Cattle manure	379.0 b	313.0 b	340.6 b	344.2	112.4 a	166.3 a	215.6 ab	164.8 a
Mean	*360.8*	*287.8*	*322.8*	*323.8*	*62.8*	*102.9*	*178.9*	*114.9*
F-values								
Years (Y)	–	–	–	–	–	–	–	128.12**
Cultivars (C)	681.25**	1796.11**	1040.94**	–	0.68	132.14**	4.59*	66.92**
Weed management (W)	14.03**	11.35**	9.13**	–	–	–	–	–
Manures (M)	32.81**	34.81**	23.76**	–	31.75**	8.57**	8.02**	21.15**
Y × C	–	–	–	–	–	–	–	32.19**
Y × M	–	–	–	–	–	–	–	2.89**
C × W	2.22	1.29	4.95**	–	–	–	–	–
C × M	4.69**	21.40**	2.58**	–	0.84	2.85*	2.23	2.83*
W × M	1.2	1.32	2.40**	–	–	–	–	–
Y × C × M	–	–	–	–	–	–	–	1.72
C × W × M	0.62	0.79	1.23	–	–	–	–	–
CV (%)	*9.08*	*12.33*	*9.7*	–	13.23	10.71	11.99	13.93

[a]Means followed by the same letter in the same column are not significantly different at $P \leq 0.05$ as determined by the Duncan's test (*$P < 0.05$, **$P < 0.01$)

In the current study, the effect of different fertilizer sources (organic matter, organic fertilizer and mineral fertilizer) and weed management treatments (high seeding rates and hand weeding) on the mineral content (Cu, Fe, Mn, Se, Zn, Cd, Co, Cr, Ni and Pb) of wheat (Dogu-88 and Kirik genotypes) samples were investigated. The effects of production years, wheat varieties, weed management methods and fertilizer sources on mineral content were significant ($P < 0.05$), (Tables 4 and 5).

The differences between the production years have been significant in terms of all investigated mineral elements. For all elements, the highest values were obtained in the second crop year when the climatic conditions were favorable for wheat growth. The lowest values were obtained in the first production year when rainfall was less than the other years (Table 4).

Copper (Cu) Average cupper content of entire treatments was found to be 3.93 ppm. Kirik and Doğu-88 varieties had 4.08 and 3.79 ppm Cu concentrations, respectively and copper concentrations of weedy control, hand weeding, and dense sowing were 3.75, 3.67 and 4.38 ppm, respectively. Copper concentrations of control, NP, Bio, Bio SR, Leonardit, OF and CM fertilizer sources were 6.74, 1.75, 5.47, 4.79, 2.80, 3.03 and 2.99 ppm, respectively (Table 4). Copper is an essential trace element present in plants and animals (Dogan et al. 2010). The deficiency of Cu causes bone disorders, higher risks for infection, abnormalities in glucose metabolism (Chen et al. 2020; Grzeszczak et al. 2020) and adverse effects on heart health (Klevay 2000). Average of entire treatments Cu content was 3.93 ppm. The Cu content obtained in the study conducted by Stefanovic et al. (2008) is in agreement with our results. The results

Table 4 Copper (*Cu*), Iron (*Fe*), Manganese (*Mn*), Selenium (*Se*) and Zinc (*Zn*) concentrations of organic wheat under some treatments[a]

	Cu (ppm)	Fe (ppm)	Mn (ppm)	Se (ppm)	Zn (ppm)
Years					
2006–07	3.10 c	26.6 c	64.4 c	0.321 c	8.13 c
2007–08	4.87 a	61.5 a	95.9 a	0.821 a	15.34 a
2008–09	3.83 b	40.3 b	78.6 b	0.505 b	10.55 b
Average	3.93	42.8	79.6	0.549	11.34
Cultivars					
Kirik	4.08 a	43.6 a	77.5 b	0.671 a	13.25 a
Doğu-88	3.79 b	42.0 b	81.8 a	0.427 b	9.43 b
Weed management					
Weedy control	3.75 b	46.1 a	81.2 a	0.637 a	10.54 c
Hand weeding	3.67 c	44.5 b	80.4 b	0.551 b	11.39 b
Dense sowing	4.38 a	37.8 c	77.2 c	0.458 c	12.09 a
Fertilizers					
Control	6.74 a	60.2 a	106.8 a	0.911 b	17.51 a
NP	1.75 f	27.7 g	58.8 f	0.230 g	6.14 e
Bio	5.47 b	45.1 c	92.1 c	0.364 d	12.33 c
Bio SR	4.79 c	50.8 b	96.9 b	0.628 c	9.47 d
Leonardit	2.80 e	41.9 d	56.8 g	1.136 a	9.24 d
OF	3.03 d	34.2 f	70.5 e	0.306 e	9.48 d
CM	2.99 d	40.0 e	75.8 d	0.271 f	15.25 b
Sources of Variation	*F values*				
Year (Y)	2294.37**	4522.46**	4055.00**	1584.93**	3398.26**
Cultivar (C)	187.66**	26.58**	227.53**	1115.03**	2766.30**
Weed management (W)	430.90**	284.39**	72.84**	200.04**	151.33**
Fertilizer (F)	3894.10**	713.55**	2616.09**	1338.52**	1670.00**
Y×C	35.41**	108.82**	46.95**	18.23**	394.83**
Y×W	80.48**	1179.69**	14.91**	3.22**	21.50**
Y×F	165.24**	72.10**	35.72**	161.46**	30.86**
C×W	114.56**	32.95**	122.70**	254.03**	14.07**
C×F	98.98**	101.29**	164.86**	302.34**	87.83**
W×F	128.36**	95.77**	115.25**	51.67**	131.45**
Y×C×W	53.73**	87.59**	77.67**	32.28**	61.81**
Y×C×F	39.14**	45.27**	13.28**	12.23**	52.78**
Y×W×F	40.58**	51.89**	32.56**	30.11**	30.74**
C×W×F	128.87**	89.61**	54.81**	114.67**	77.01**
Y×C×W×F	62.00**	60.00**	37.29**	37.84**	11.14**
Variation coefficient (%)	5.28	6.85	3.48	12.96	6.23

[a]Means followed by the same letter in the same column are not significantly different at $P \leq 0.05$ as determined by the Duncan's test (*$P < 0.05$, **$P < 0.01$)

of the present study indicated that Cu content in wheat grains was below the acceptable limit 73.30 mg/kg as suggested by the FAO (2001). Lakhdar et al. (2009) and Ugulu et al. (2021) reported lower Cu value in wheat grown under farmyard manure and wastewater applied conditions as compared with the present study. Lakhdar et al. (2009) reported lower Cu value (2.58 mg/kg) in wheat grown under farmyard manure applied condition. On the other hand, Ugulu et al. (2021) reported that high Cu value in wheat grown under wastewater applied condition was obtained in Pakistan.

Iron (Fe) It has been estimated that globally 43% of children and 29% of women of reproductive age have anemia, and about half of these cases result from iron deficiency (WHO 2015). Average Fe content of entire treatments was 42.8 ppm. Kirik and Doğu-88 varieties had of 43.6 and 42.0 ppm Fe concentrations, respectively. Iron concentrations of weedy control, hand weeding, and dense sowing were 46.1, 44.5 and 37.8 ppm, respectively; and Fe concentrations of control, NP, Bio, Bio SR, Leonardit, OF and CM fertilizer sources were 60.2, 27.7, 45.1, 50.8, 41.9, 34.2 and 40.0 ppm respectively (Table 4). The highest Fe content was obtained from control treatment (no fertilizer). These variations in grain minerals had nutritional implications primarily favouring the organic grain; however, organic management and, specifically, elimination of soluble fertilizers did not induce dramatic increases in grain mineral concentrations. Ryan et al. (2004) emphasized that the effect of organic and traditional farming practices on the Fe content of wheat in Australia was insignificant (Ryan et al. 2004).

Present findings on Fe content of wheat varieties were close to findings of Zhao et al. (2009); Hernandez Rodriguez et al. (2011); Suchowilska et al. (2012); greater than the findings of Al-Gahri and Almussali (2008); Ficco et al. (2009) and lower than findings of Hussain et al. (2010); Nuss and Tanumihardjo (2010); Gao et al. (2012); Kovacevic et al. (2013); Ugulu et al. (2021). In a previous study, genotype × environment interaction was also found to be significant in terms of iron content (Ciudad-Mulero et al. 2021).

Manganese (Mn) Average Mn content of entire treatments was 76.9 ppm. Kirik and Doğu-88 cultivars had 77.5 and 81.8 ppm Mn contents, respectively. Manganese concentrations of weedy control, hand weeding, and dense sowing were 81.2, 80.4 and 77.2 ppm, respectively and manganese concentrations of control, NP, Bio, Bio SR, Leonardit, OF and CM fertilizer sources were 106.8, 58.8, 92.1, 96.9, 56.8, 70.5 and 75.8 ppm, respectively (Table 4).

Olgun et al. (2017) reported mean Mn content as 9.01 mg/kg for 12 bread wheat cultivars in the present study mean Mn content of two wheat cultivars was 76.9 mg/kg which was much higher that the finding of Gao et al. (2012), Kovacevic et al. (2013) and Olgun et al. (2017). The higher Mn content of two wheat cultivar might be due genetic make-up of cultivars and different environmental factors (Zhao et al. 2009; Jaskulska et al. 2018; Bulut 2022b).

Selenium (Se) Although selenium (Se) is not considered essential element for the healthy growing plants, it is an essential micronutrient for both humans and animals. In humans and livestock, Se is incorporated into a number of functional selenoproteins such as the antioxidant glutathione (GSH) peroxidase enzymes (Kumar et al. 2011). Wheat is also a good source of trace minerals like Se and Mg which is essential nutrients for good health (Shewry et al. 2006; Topping 2007). There is also increasing evidence that Se plays an important protective role both in the human immune system and in the prevention and suppression of a number of specific disorders such as carcinomas, cardiovascular diseases, cystic fibrosis and low fertility (Fairweather-Tait 1997; Strauss 1999). Average Se content of entire treatments was 0.549 ppm. Kirik and Doğu-88 cultivars had 0.671 and 0.427 ppm Se contents, respectively. Selenium content of weedy control, hand weeding, and dense sowing were 0.637, 0.551 and 0.458 ppm, respectively and Se content of control, NP, Bio, Bio SR, Leonardit, OF and CM fertilizer sources were 0.911, 0.230, 0.364, 0.628, 1.136, 0.306 and 0.271 ppm respectively (Table 4).

Soils are frequently low in available Se, and hence the food sources of many countries are deficient in Se (Rayman 2002; Lyons et al. 2003). Selenium availability in soils depends upon soil pH, redox potential, calcium carbonate level, cation exchange capacity, and organic carbon, iron (Fe) and aluminum (Al) levels (Lyons et al. 2005). Similar to present results, Se content for wheat have been variable (Lyons et al. 2005).

Zinc (Zn) Average of entire treatments was found to be 11.34 ppm. Kirik and Doğu-88 cultivars had zinc concentrations respectively of 13.25 and 9.43 ppm; zinc concentrations of weedy control, hand weeding, and dense sowing were respectively determined as 10.54, 11.39 and 12.09 ppm; and zinc concentrations of control, NP, Bio, Bio SR, Leonardit, OF and CM fertilizer sources were respectively found to be 17.51, 6.14, 12.33, 9.47, 9.24, 9.48 and 15.25 ppm (Table 4).

Two factors contribute to the low contents of bioavailable iron and zinc in wheat: the low concentrations of these minerals in white flour, which is most widely consumed, and the presence of phytates in mineral-rich bran fractions (Balk et al. 2019). The results of the present study indicated that Zn contents in wheat samples (overall mean 11.34 ppm) were below the permissible limit 99.4 mg/kg as given by the FAO (2001). Regionally, grain Fe and Zn concentration was found to be lower in high-yielding regions. The concentration of Zn ranged from 12.95 to 25.83 mg/kg in the grains of the wheat variety (Lasani-08) (Ugulu et al. 2021) and 16.41 to 24.80 mg/kg in the grains of 12 bred wheat varieties (Olgun et al. 2017). Differences in grain Zn contents among varieties could be associated with differences in adaptation ability of genotypes. Our results were found to be lower than the results obtained (35.3 mg/kg) from wheat applied wastewater by Hassan et al. (2013) in Pakistan. Tarighi et al. (2012) reported that the Zn content of wheat varieties enriched with cattle manure varied in the range of 9–30 mg kg^{-1} and the difference between varieties was significant. Tarighi et al. (2012) In general, cultivation of wheat plant (cv. Backcross) resulted in a lower Zn uptake relative to the Alvand cultivar. However, the plants Zn concentration of both cultivars depended on the rate and type of the applied manure (organic or inorganic sources). Both cultivars showed that plants grown in soil treated with ZnSO4 accumulated significantly greater Zn in their root

Table 5 Cadmium (*Cd*), Cobalt (*Co*), Chrome (*Cr*), Nickel (*Ni*) and Lead (*Pb*) concentrations of organic wheat under some treatments[a]

	Cd (ppm)	Co (ppm)	Cr (ppm)	Ni (ppm)	Pb (ppm)
Years					
2006–07	0.002 c	0.078 c	0.093 c	2.28 c	0.081 c
2007–08	0.026 a	0.220 a	0.326 a	5.23 a	0.544 a
2008–09	0.008 b	0.123 b	0.163 b	3.62 b	0.183 b
Average	0.012	0.140	0.194	3.71	0.269
Cultivars					
Kirik	0.01212 b	0.160 a	0.222 a	3.42 b	0.268
Doğu-88	0.01235 a	0.121 b	0.166 b	4.00 a	0.271
Weed management					
Weedy control	0.01437 a	0.132 b	0.212 a	3.76 b	0.254 c
Hand weeding	0.01183 b	0.156 a	0.212 a	4.30 a	0.271 b
Dense sowing	0.01051 c	0.133 b	0.158 b	3.07 c	0.283 a
Fertilizers					
Control	0.02417 a	0.221 b	0.415 a	8.85 a	0.630 a
NP	0.00335 g	0.049 f	0.095 e	1.71 e	0.052 g
Bio	0.01722 b	0.173 c	0.243 b	3.75 c	0.117 d
Bio SR	0.01267 c	0.099 d	0.220 c	4.36 b	0.354 c
Leonardit	0.01076 d	0.258 a	0.127 d	2.50 d	0.571 b
OF	0.00943 e	0.092 e	0.129 d	2.37 d	0.090 e
CM	0.00809 f	0.095 de	0.134 d	2.45 d	0.076 f
Sources of Variation	*F values*				
Year (Y)	26419.3**	2315.29**	2865.82**	1857.11**	6700.16**
Cultivar (C)	6.38*	484.48**	481.49**	214.80**	0.50
Weed management (W)	631.30**	82.39**	194.46**	320.82**	24.21**
Fertilizer (F)	3209.16**	1245.16**	1068.22**	2167.38**	3438.89**
Y × C	33.12**	70.53**	295.36**	10.04**	150.29**
Y × W	3470.50**	11.85**	118.98**	14.95**	7200.00**
Y × F	1000.83**	119.43**	142.41**	216.57**	622.12**
C × W	426.10**	80.29**	90.79**	12.10**	158.80**
C × F	142.50**	114.53**	107.56**	80.41**	43.96**
W × F	597.06**	117.98**	239.76**	482.38**	137.73**
Y × C × W	208.97**	38.58**	175.19**	42.97**	67.15**
Y × C × F	200.33**	54.72**	108.89**	52.36**	217.14**
Y × W × F	280.18**	51.03**	125.83**	101.93**	107.78**
C × W × F	346.94**	68.03**	227.20**	66.26**	348.20**
Y × C × W × F	204.99**	27.99**	159.78**	8.59**	134.53**
Variation coefficient (%)	7.15	12.02	12.85	10.36	12.34

[a]Means followed by the same letter in the same column are not significantly different at $P \leq 0.05$ as determined by the Duncan's test (*$P < 0.05$, **$P < 0.01$)

tissue compared to those grown in soil treated with cow manure. A significant increase in the shoot, spike and root Zn concentration was observed as the loading rate of cow manure increased. Ghanbari and Mameesh (1971) reported that wheat Fe content was significantly influenced by date of planting but not by seeding rates or nitrogen fertilization.

Cadmium (Cd) Average Cd content of entire treatments was 0.012 ppm. Kirik and Doğu-88 cultivars had 0.01212 and 0.01235 ppm Cd concentrations, respectively. Cadmium concentrations of weedy control, hand weeding, and dense sowing were as 0.01437, 0.01183 and 0.01051 ppm, respectively and Cd concentrations of control, NP, Bio, Bio SR, Leonardit, OF and CM fertilizer sources were 0.02417, 0.00335, 0.01722, 0.01267, 0.01076, 0.00943 and 0.00809 ppm respectively (Table 5). Cadmium was extensively used in pigments, batteries, plastics, and metal coatings. The effects of Cd are known to be carcinogenic (Khan et al. 2019). According to the treatment, the average Cd content of wheat was 0.012 ppm. Our findings are in line with Stefanovic's findings in Serbia (Stefanovic et al. 2008). This value was found to be very much lower than the value (0.925–0.98 mg/kg) obtained from the study conducted on wheat in Pakistan (Ugulu et al. 2021). The fact that the soils where the study was conducted were not exposed to chemical contamination may have revealed these results. In this study, the concentration of Cd was present within the safe limit (0.2 mg/kg) reported by the FAO (2001). Further, low amounts of heavy metals, especially of Cd and Pb are regarded as of considerable importance (Hussain et al. 2012). None of the genotypes investigated in this study reached the maximum permitted value for Pb and Cd (EC 2006). Today, microelement malnutrition is considered worldwide problem and about a half of the world's population is suffering from microelement malnutrition (Welch and Graham 2004).

Cobalt (Co) Average Co content of entire treatments was 0.140 ppm. Kirik and Doğu-88 cultivars had 0.160 and 0.121 ppm cobalt concentrations, respectively. Cobalt concentrations of weedy control, hand weeding, and dense sowing were 0.132, 0.156 and 0.133 ppm, respectively and Co concentrations of control, NP, Bio, Bio SR, Leonardit, OF and CM fertilizer sources were 0.221, 0.049, 0.173, 0.099, 0.258, 0.092 and 0.095 ppm, respectively (Table 5).

In a study on wheat grain, flour and seed coat, the concentration of Co was found to be in the range of 1.036 to 1.113 mg/kg (Ugulu et al. 2021). These results, which were carried out in Pakistan, were found to be higher than our results. According to these findings, all Co concentrations in wheat grains were found below the permissible limit 50 mg/kg as given by the FAO (2001). Concentrations were significantly lower in treatments with NPK fertilizer than in unfertilized grain. Adding organic resources such as crop residues, green manure and livestock manure to soil has a number of beneficial effects on micronutrient nutrition including additional supply of some nutrients with the added organic matter, increase in ion exchange capacity and thus of the fractions of easily available nutrients, improved soil structure, increased accessibility of soil for plant roots, stimulation of microbial activities. All these effects promote plant growth, development of the root system and thus also its capacity to acquire micronutrients (Schulin et al. 2009; Bulut 2022a, b).

Chrome (Cr) The chromium compounds are usually toxic and carcinogenic to humans. It can be found in all forms such as liquid, gas, or solid state in plants, animals, and rocks (Dogan et al. 2014). Average Cr content of entire treatments was 0.194 ppm. Kirik and Doğu-88 cultivars had 0.122 and 0.166 ppm Cr concentrations, respectively. Chrome concentrations of weedy control, hand weeding, and dense sowing were 0.212, 0.212 ve 0.158 ppm, respectively and Cr concentrations of control, NP, Bio, Bio SR, Leonardit, OF and CM fertilizer sources were 0.415, 0.095, 0.243, 0.220, 0.127, 0.129 and 0.134 ppm, respectively (Table 5). Concentrations of Cr in grain were of the same level as reported by Andersson (1992) for Swedish wheat grain varying between 0.01 and 0.03 mg/kg grain dry weight. Chromium concentrations in manure fertilized grain were significantly higher than in NPK fertilized wheat. In a study conducted with different organic fertilizer sources and Lasani-08 wheat cultivar in Pakistan, the Cr content varied between 0.493 to 1.154 mg/kg (Ugulu et al. 2021). Chromium concentrations decreased in NPK-fertilized grain and amounted to 0.01 mg Cr/kg after 40 years (Kirchmann et al. 2009). On the other hand, it has been reported by Wyszkowski and Brodowska (2020), that the Cr content increased by 15% with nitrogen fertilization. Cary et al. (1975) found a highly significant relationship between Fe and Cr concentrations in wheat seeds. The Cr values obtained from the current study are well below the level that will pose a health risk.

Nickel (Ni) Average Ni content of the entire treatments was 3.71 ppm. Kirik and Doğu-88 cultivars had 3.42 and 4.00 ppm Ni concentrations, respectively. Nickel concentrations of weedy control, hand weeding, and dense sowing were 3.76, 4.30 and 3.07 ppm, respectively and Ni concentrations of control, NP, Bio, Bio SR, Leonardit, OF and CM fertilizer sources were 8.85, 1.71, 3.75, 4.36, 2.50, 2.37 and 2.45 ppm, respectively (Table 5). Similar to our results, Hamner et al. (2013) has stated that application of inorganic fertilizer (NPK) decreased Ni concentrations in wheat grain compared with the unfertilized treatment. Higher rates of mineral N fertilization caused a decrease in Ni concentration in wheat grain compared with unfertilized treatments in the long-term field trials (Hamner et al. 2013). Long-term manure application did not lead to increased Ni concentrations in crops either. Their results indicate that application of sewage sludge or cattle manure at permitted rates of 700 and 3000 kg/ha per year did not increase Ni concentration in the tested crops (Hamner et al. 2013).

Lead (Pb) Average Pb content of entire treatments was 0.269 ppm. Kirik and Doğu-88 cultivars had 0.268 and 0.271 ppm Pb concentrations, respectively. Lead concentrations of weedy control, hand weeding, and dense sowing were 0.254, 0.271 and 0.283 ppm, respectively and Pb concentrations of control, NP, Bio, Bio SR, Leonardit, OF and CM fertilizer sources were 0.630, 0.052, 0.117, 0.354, 0.571, 0.090 and 0.076 ppm, respectively (Table 5). Our findings for Pb contents were higher than Stefanovic's findings (Stefanovic et al. 2008). In Pakistan, the determined mean Pb contents of the wheat grain were between 0.504 and 1.997 mg/kg. This Pb values were much higher than the permissible limit (0.30 mg/kg) suggested by the FAO (2001) (Ugulu et al. 2021). The values (mean 0.269 ppm) determined in the current study were also lower than the permissible Pb limits. But are also higher than the Pb values (0.06 to 0.2 mg/kg) in wheat samples irrigated with wastewater in Sargodha City (Pakistan) (Ahmad et al. 2019). Mineral element uptake of plants may be influenced by soil, genetic factors and environment effects (Stefanovic et al. 2008; Zhang et al. 2014).

Conclusions

Wheat is included in daily diets of almost all cultures. However, number of studies about the effects of agronomic practices on quality traits, especially of mineral composition of wheat species is not sufficient. Therefore, the present study was conducted to determine the effects of agronomic practices on the mineral content of organic wheat production. In terms of all nutrients evaluated, the mineral content of wheat showed significant differences according to crop years, varieties, weed management methods and fertilizer sources. Such variations were mostly attributed to environmental and genetic factors and their interactions. As the average of all factors, the Cu, Fe, Mn, Se, Zn, Cd, Co, Cr, Ni and Pb contents of the ground wheat grain were 3.93, 42.8, 79.6, 0.549, 11.34, 0.012, 0.140, 0.194, 3.71 and 0.269 mg/kg, respectively. According to the wheat varieties, the Kirik was superior in terms of Cu, Fe, Se, Zn, Co and Cr, and the Dogu-88 was superior in terms of Mn, Cd, and Ni. The effect of weed management methods on mineral content was variable. According to fertilizer sources, the highest mineral content was obtained from the non-fertilizer applied control plots. The lowest mineral contents were obtained from chemical fertilization, cattle manure and organic fertilizer applications. There was no significant increase in the mineral content of wheat with organic fertilization, however, organic agriculture still preserves its place in terms of healthy food. As a result, it has been determined that the values obtained for all mineral elements were not at a level that pose a risk to the environment, human and animal health according to WHO.

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Conflict of interest S. Bulut, A. Özturk, N. Yıldız and M.M. Karaoğlu declare that they have no competing interests.

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