# Mineral composition of wheat species as influenced by different fertilizer sources and different weed control practices

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# Abstract

This research was carried out to determine the effects of agronomic practices on the mineral composition of organically-grown wheat species. In terms of all nutrients evaluated, the mineral content of wheat showed significant differences according to crop years, varieties, weed control 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 Kırik 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 control 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.


# Introduction

High nutrition quality of wheat grain is an important precondition for human and animal health. It appears that about half of all diseases are 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. Agriculture that produces healthy food contributes to the prevention of diseases and this aspect is often underestimated. The 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. The problem of the latter is that of latent (slight or hidden) deficiencies, which occur much more frequently than do acute (visible) deficiencies.

Wheat is the most important staple crop in temperate zones and is in increasing demand in countries undergoing urbanization and industrialization. In addition to being a major source of starch and energy, wheat also provides substantial amounts of a number of components which are essential or beneficial for health, notably protein, vitamins (notably B vitamins), dietary fiber, and minerals (Shewry and Hey, 2015). Wheat grain also contains a number of elements (Cu, Zn, Fe, Ni, Mn) vital to our biological functions, but hazardous to our health in high concentrations (Conti *et al.* 2000; Skrbic and Onjia 2007). It also contains some toxic elements (As, Pb, Hg, Cd). There are three groups of minerals of interest to 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). Still, it would be important to emphasize that they are all toxic and what makes them non-toxic are the amounts (dosages) themselves. The fine line between the essential and toxic is relative to the amount and intake through food. In agronomic studies related to wheat, the parts related to mineral content are generally not taken into account. Heavy metals are important and highly persistent environmental pollutants, and their toxicity is an increasingly important problem for ecological and nutritional phenomena (Ahmad *et al.* 2019; Munir *et al.* 2019; Siddique *et al.* 2019; Wajid *et al.* 2020; Ugulu et *et al.* 2021). Literature searches have shown that there are not enough studies on the effects of fertilizer sources and other agronomic practices (like showing densities or weed control treatment on mineral content of wheat plants in agricultural systems. According to the 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.

The mineral content of wheat is not evaluated much in agronomic studies. Whereas; the mineral content of wheat is different according to the agronomic applications, the climate-soil conditions of the region and the varieties. In fact, as a result of agronomic practices, the 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. In the present study the effects of different fertilizer sources and weed control methods on mineral contents of two wheat varieties were investigated for two 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 2x3x7 factorial scheme, with 3 replicates. In previous study, the factors were 2 wheat varieties (Kırik and Doğu-88), 3 weed control 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), Leonardite, Organic Fertilizer (OF), Cattle Manure (CM)]. After harvesting, the spikes were threshed and grains were stored at -20 $^{o}$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 (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.

Properties of the experimental soils, climate characteristics, crop management, sowing and harvesting dates, application rates, and important characteristics of OMs were provided in our previous study (Öztürk *et al.* 2012).

***Statistical Analysis:*** The significance of treatment means was evaluated with standard analysis of variance techniques. Mean values of each treatment were presented in tables. The DUNCAN test was used to compare the differences among treatment means at the 0.05 probability level. The statistical analyses were performed with SAS.

## Results And Discussion

In the current study, the effect of different fertilizer sources (organic matter, organic fertilizer and mineral fertilizer) and weed control 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 control methods and fertilizer sources on mineral content were significant ($P < 0.05$), (Table 1 and 2).

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.

**Copper (Cu):** Average cupper content of entire treatments was found to be 3.93 ppm. Kırik 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, Leonardite, OF and CM fertilizer sources were 6.74, 1.75, 5.47, 4.79, 2.80, 3.03 and 2.99 ppm, respectively. 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 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/WHO (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. Kırik 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. 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. Kırik 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.

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 more 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).

**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 SJ, 1997; Strauss 1999). Average Se content of entire treatments was 0.549 ppm. Kırik 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, Leonardite, OF and CM fertilizer sources were 0.911, 0.230, 0.364, 0.628, 1.136, 0.306 and 0.271 ppm respectively.

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. Kırik 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, Leonardite, 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.

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/WHO (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 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. Ghambari 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. Kırik 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, Leonardite, OF and CM fertilizer sources were 0.02417, 0.00335, 0.01722, 0.01267, 0.01076, 0.00943 and 0.00809 ppm respectively. 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/WHO (2001). Further, low amounts of heavy metals, especially of Cd and Pb are regarded as of considerable importance (Hussain, 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. Kırik 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, Leonardite, OF and CM fertilizer sources were 0.221, 0.049, 0.173, 0.099, 0.258, 0.092 and 0.095 ppm, respectively.

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 s, 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/WHO (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).

**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. Kırik 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, Leonardite, OF and CM fertilizer sources were 0.415, 0.095, 0.243, 0.220, 0.127, 0.129 and 0.134 ppm, respectively. 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. Kırik 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, Leonardite, OF and CM fertilizer sources were 8.85, 1.71, 3.75, 4.36, 2.50, 2.37 and 2.45 ppm, respectively. 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. Kırik 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, Leonardite, OF and CM fertilizer sources were 0.630, 0.052, 0.117, 0.354, 0.571, 0.090 and 0.076 ppm, respectively. 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/WHO (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 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 control 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 Kırik 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 control 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.

# Declarations

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## Tables

**Table 1.** Copper (Cu), Iron (Fe), Manganese (Mn), Selenium (Se) and Zinc (Zn) concentrations of organic wheat under some treatments, *

| | 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 | | | | | |
| Kırik | 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 control | | | | | |
| 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 |

| | | | | | |
|---|---|---|---|---|---|
| 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 control (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 |

[1] The difference between means with the same letter is not significant ($P<0.01$).

* The difference between means with different letters is significant at $p<0.01$ level.

**Table 2.** Cadmium (Cd), Cobalt (Co), Chrome (Cr), Nickel (Ni) and Lead (Pb) concentrations of organic wheat under some treatments, *

| | 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 | | | | | |
| Kırik | 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 control | | | | | |
| 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 |

| | | | | | |
|---|---|---|---|---|---|
| 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 control (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 |

[1] The difference between means with the same letter is not significant (P<0.01).

* The difference between means with different letters is significant at $p<0.01$ level.