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# GROAT ELEMENT CONCENTRATION AT DIFFERENT SPIKELETS OF OAT PANICLES (*Avena Sativa* L.) EVALUATED AT THREE TURKISH LOCATIONS

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**ABSTRACT**

**This research was carried out to determine the variation in spikelet groups, genotypes and environments for macronutrient (Ca, Mg and K) and micronutrient (Na, Cu, Fe, Mn and Zn) concentrations of oat (*Avena sativa* L.) groat. The panicles of 16 Turkish oat (*Avena sativa* L.) genotypes were obtained from three locations; Kahramanmaras, Konya and Cumra in Turkey in 2002-2003 cropping year. The panicles of each variety were divided into three spikelet groups as basal spikelet (BS), central spikelet (CS) and apical spikelet (AS). The oat groats belonging to spikelet groups were pooled to determine macronutrient and micronutrient concentrations. The results indicate that grain number (GNP) and grain weight per panicle (GWP) were significant for locations (L), genotypes (G) and spikelet groups (SG). Genotypes were significantly different for Ca, Mg and K concentrations. Locations had significant effect on Ca and Mg concentrations while there were not any significantly differences for spikelet groups. Locations had significantly effect on micronutrient concentrations (Na, Cu, Mn and Zn) except Fe concentration of oat groats. Genotypes were significantly different for all micronutrient concentrations, while spikelet groups were significant for only Zn concentrations. Location x genotype (L x G) interaction was significant for all micronutrient concentrations, while L x G interaction was significant for Ca and Mg concentrations in macronutrients.**

**Key Words; oat genotypes, spikelet groups, oat groat, macro and micronutrient and environment.**

## INTRODUCTION

Oat is generally planted for forage production over the world; its production for food consumption is also gradually expanded due to its balanced nutrition content for healthy diets. Oat foods are used primarily in hot and ready-to eat cereals, and some granolas, cookies, breads and other cereal products (Ozcan et al., 2006). Characteristics most commonly used to describe oat quality include test weight, groat percentage, groat weight, groat composition, protein, oil, and B-glucan concentrations are reported as the major compositional characteristics (Douglas et al., 2001). Besides, it was reported that a unique opportunity exists in agriculture to invest in developing more nutrient-dense staple crops that could help reduce not only energy but also nutrient malnutrition (Underwood, 2000). Plant breeders strive to develop cultivars high yielding and produce consistently high quality grain over a wide range of environments (Douglas et al., 2001). Breeding staple crops with high nutrient concentration in the grain has been proposed as a low cost sustainable strategy for reducing mineral deficiencies in humans and crops (Welch and Graham, 2000). Unfortunately, more than 2 billion people suffer from mineral deficiencies worldwide. Cereals, especially oat is rich in protein, has lots of beneficial minerals such as calcium, magnesium, copper, manganese, excellent source of zinc as well as highly available iron, whereas being very high in mineral and vitamin content (Demirbas, 2005). Oat groats are also rich in the antioxidant-like compounds, α-tocotrienol, α-tocophenol, and avenanthramides which are unique to oat (Yu et al., 2006).

In previous works, authors suggested that grain position may have a considerable impact on nutrient concentration (Simmons and Moss, 1978; Herzog and Stamp, 1983). However, there is too limited available research on distribution of macro and micronutrient concentrations within oat panicles in literature. Ozcan et al. (2006) reported that significant variation in composition of oat groats for only four varieties. A better understanding of the variation for macro and micronutrient concentrations in oat groats belong to different spikelet groups (basal, central and apical spikelet) in panicle was necessarily. Therefore, the aim of the research was to determine macro (Ca, Mg and K) and

micro (Na, Cu, Fe, Mn and Zn) nutrient variations in spikelet groups of 16 oat genotypes at three locations in Turkey.

## MATERIALS AND METHODS

### *Field Experiments*

Sixteen Turkish oat (*Avena sativa* L.) genotypes (Ankara-76, Ankara-84, Apak 2-3, Bozkir 1-5, Seydisehir, Erzurum, Amasya, Antalya, Tokat, Faikbey, Ordu, Sivas, Yesilkoy-1779 (Y-1779), Canakkale-Ovacik Village, (COV) Samsun-Ladik-Ibik Village (SLIV) and Yesilkoy-330 (Y-330)) were planted in Kahramanmaras (K.Maras) (37° 53' N, 36° 58' E.)**,** Konya center (37° 51' N, 32° 33' E) and Cumra (37° 34' N, 32° 38' E) of Konya province of Turkey. Planting dates were on 11th October 2002, 14th October 2002 and 5th November 2002 in Konya, Cumra and Kahramanmaras sites, respectively. Field experiments were carried out in a 'randomized complete block design' arranged as factorial with three replications, under rainfed conditions. Plot sizes were arranged as 6 x 1.2 m and each plot was six rows. Seed rates were at the 550 seeds $m^{-2}$ in the three locations. Some climatic data of locations and some chemical and physical traits of experiment soils sampled from 0-30 cm topsoil are shown in Table 1 and Table 2, respectively. Fertilizers were applied at the rate of 80 kg $P_2O_5$ $ha^{-1}$ and 80 kg N $ha^{-1}$ at planting and 100 kg N $ha^{-1}$ as top dressing at Kahramanmaras condition on 14th February, 69 kg $P_2O_5$ $ha^{-1}$, 27 kg N $ha^{-1}$ at planting and 40 kg N $ha^{-1}$ as top dressing at Konya and Cumra conditions on 12th March. Herbicide (Tribenuron-methyl (DF) 75%) was used for weed control at all locations. However, there was no chemical application to control pests and diseases.

**Table 1.** Some climatic and average temperature data for three locations during the experiment year (2002-03).

| Months | Rainfall (mm) | | | Temperature (°C) | | | Relative Humidity (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | K.Maras | Konya | Cumra | K.Maras | Konya | Cumra | K.Maras | Konya | Cumra |
| October | | 24.6 | 14.7 | | 12.8 | 13.0 | | 54.8 | 61.0 |
| November | 75.8 | 15.3 | 22.1 | 13.5 | 6.6 | 7.5 | 65.8 | 64.1 | 70.0 |
| December | 76.1 | 48.0 | 57.7 | 4.2 | -3.1 | -2.4 | 68.4 | 74.1 | 75.0 |
| January | 120.0 | 17.6 | 18.8 | 7.1 | 4.0 | 5.0 | 74.2 | 74.7 | 69.0 |
| February | 213.8 | 47.5 | 74.8 | 3.8 | -1.7 | -1.0 | 74.1 | 67.1 | 73.0 |
| March | 145.8 | 24.6 | 58.9 | 8.0 | 1.8 | 1.9 | 63.6 | 62.7 | 69.0 |
| April | 88.7 | 50.2 | 105.0 | 15.0 | 9.5 | 9.8 | 60.0 | 57.4 | 61.0 |
| May | 30.4 | 30.9 | 14.8 | 14.1 | 17.2 | 17.3 | 51.9 | 47.0 | 53.0 |
| June | 1.6 | 2.3 | 6.7 | 25.6 | 21.2 | 20.5 | 54.0 | 34.9 | 48.0 |
| July | - | 0.0 | 0.0 | - | 23.6 | 22.8 | - | 32.6 | 46.0 |
| Total | 752.2 | 326.8 | 373.5 | | | | | | |
| Mean | | | | 11.4 | 10.0 | 9.44 | 64.0 | 56.5 | 62.5 |

**Table 2** Physical and chemical traits of experiment soils sampled from 0-30 cm topsoil.

| Location | Texture | Saturation | pH | $CaCO_3$ (%) | $P_2O_5$ Kg $da^{-1}$ | $K_2O$ Kg $da^{-1}$ | Organic Matter % | Salt ( %) | Fe ppm | Cu ppm | Zn ppm | Mn ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K.Maras | Clay-Loamy | 59.8 | 7.4 | 19.8 | 9.9 | 140.0 | 2.0 | 0.11 | 8.4 | 1.7 | 0.2 | 5.7 |
| Konya | Clay | 68.0 | 8.0 | 36.6 | 3.6 | 173.9 | 1.1 | 0.04 | 1.6 | 0.8 | 0.7 | 4.8 |
| Cumra | Clay | 72.0 | 8.4 | 27.1 | 10.9 | 131.3 | 1.6 | 0.02 | 2.8 | 1.0 | 0.3 | 7.3 |

The panicles of 16 Turkish oat (*Avena sativa* L.) genotypes were obtained from Kahramanmaras**,** Konya and Cumra locations. At maturity stage, 10 main shoot panicles within the middle four rows of plots were harvested to record grain weight and total grain number per panicle as well as to prepare samples for further analysis. The panicles of each variety were divided among three spikelet groups as basal spikelet, central spikelet and apical spikelet. The groats belonging to spikelet groups were pooled to determine macronutrient (Ca, Mg and K) and micronutrient (Na, Cu, Fe, Mn and Zn) concentrations. Oat groats were ground then sampled according to spikelet groups to analyze.

### *Laboratory analysis*

Laboratory analysis was carried out by the modified methods of Martens and Lindsay (1990) and Peck and Soltanpour (1990). According to followed methods; all glassware and polyethylene containers were washed with tap water after each use, to eliminate possible contamination from detergents or materials and soaked in 6 N $HNO_3$ solutions and rinsed several times with distilled water. Finally, dried material was appropriately kept until use.

Dry digestion was carried out in an ash furnace for analytical samples. All standard solutions were prepared at analytical grade: Commercially available (1000 mg/ml), $Mg(NO_3)_26H_2O$, $Ca(NO_3)_24H_2O$, KCL, $Fe(NH_4)_2(SO_4)_26H_2O$, $MnSO_4H_2O$, $Zn(C_2H_3O_2)_2H_2O$, $Cu(C_2H_3O_2)_2H_2O$ and NaCl were used. Double distilled water was used for preparing the standards for calibration and dilutions.

### *Apparatus and Analytical Procedure*

A Perkin-Elmer 3110 flame atomic absorption spectrophotometer (FAAS) was used at a slit width of 0.4 nm with a 8-mA hollow cathode lamp for sodium, at a slit width of 1.4 nm with a 6-mA hollow cathode lamp for potassium, at a slit width of 0.2 nm with a 20 mA hollow cathode lamp for iron and manganese, at a slit width of 0.7

nm with a 15 mA hollow cathode lamp for zinc and copper, at a slit width of 0,7 nm with a 6 mA hollow cathode lamp for magnesium and at a slit width of 0.7 nm with a 10 mA hollow cathode lamp for calcium determination by FAAS (Jodral-Sedago et al., 2003). Samples were atomized for sodium (Na), potassium (K), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), magnesium (Mg) and calcium (Ca) determination at 589.0, 766.5, 248.3, 279.5, 2113.9, 324.8, 285.2 and 422.7 nm, respectively. All analyses were performed at peak height mode to calculate absorbance values.

The samples were placed in a porcelain cruse for pre-digestion by addition of $H_2SO_4$ 5% and heating at 90 °C for 45 min on a hot-plate block. Then, the pre-digested samples were placed on the ash furnace at 500 °C for 8 hours until the samples were completely ashed. After, ashing the samples were diluted to 50 ml with 1 N HCl.

Determination of macro and micro elements were carried out by direct aspiration into the flame atomic absorption spectrophotometer.

*Data Analysis*

Data was subjected to an analysis of variance utilizing a randomized complete block design arranged as factorial. Factors were locations, genotypes and spikelet groups in panicle. Linear regression analyses of macro, and micronutrient concentrations were done with SAS. The results were expressed as arithmetic mean and standard deviation.

## RESULTS AND DISCUSSION

Variance analysis showed that grain number (GNP) and grain weight per panicle (GWP) were significantly different for location (L), genotype (G) and spikelet groups (SG); L x G interaction was significant for GNP, while L x G and L x SG interactions were also significant for GWP (Table 3). Coefficient of variation values were determined as 34.53% and 35.58%, for GNP and GWP traits, respectively. It was due to wider variation among locations, especially for climatic and soil conditions (Table 1 and 2) and genotypes for GNP and GWP of oat plants.

**Table 3.** The average Ca, Mg, K, NGP and GWP values for Location, Genotype and Spikelet Groups and Interactions

| | | Macronutrients | | | Kernel | |
|---|---|---|---|---|---|---|
| | | **Ca (ppm)** | **Mg (ppm)** | **K (ppm)** | **GNP (grain)** | **GWP (g)** |
| | | ** | ** | ns | ** | ** |
| **Locations** | K.Maras | 1369 c | 1728 b | 2647 | 26.96 a | 0.732 a |
| | Konya | 1861 a | 1825 a | 2645 | 22.45 b | 0.713 a |
| | Cumra | 1750 b | 1656 c | 2620 | 16.29 c | 0.559 b |
| | LSD | 44.94 | 38.98 | 43.71 | 1.75 | 0.055 |
| | | ** | ** | ** | ** | ** |
| **Genotypes** | Ankara-76 | 1696 bcde | 1691 def | 2559 e | 18.28 de | 0.526 fg |
| | Ankara-84 | 1786 ab | 1711 cdef | 2597 bcde | 18.02 de | 0.474 g |
| | Apak 2 -3 | 1640 cdefgh | 1780 bcd | 2642 bcde | 22.06 bcd | 0.588 defg |
| | Bozkir 1-5 | 1602 efghi | 1656 f | 2626 bcde | 23.82 ab | 0.608 cdef |
| | Seydisehir | 1830 a | 1785 bc | 2666 bcd | 20.36 bcd | 0.660 bcde |
| | Erzurum | 1721 bcd | 1889 a | 2612 bcde | 26.45 a | 0.699 abcde |
| | Amasya | 1737 abc | 1724 cdef | 2583 cde | 26.66 a | 0.813 a |
| | Antalya | 1669 cdef | 1686 ef | 2610 bcde | 23.34 abc | 0.691 abcde |
| | Tokat | 1793 ab | 1778 bcd | 2641 bcde | 24.27 ab | 0.762 ab |
| | Faikbey | 1583 fghi | 1750 bcde | 2687 b | 23.19 abc | 0.808 a |
| | Ordu | 1656 cdefg | 1704 cdef | 2630 bcde | 26.95 a | 0.734 abc |
| | Sivas | 1625 defghi | 1702 cdef | 2569 de | 21.69 bcd | 0.635 bcdef |
| | Y-1179 | 1556 ghi | 1693 def | 2671 bc | 16.26 e | 0.574 efg |
| | COV | 1543 hi | 1692 def | 2664 bcd | 20.94 bcd | 0.738 ab |
| | SLIV | 1529 i | 1713 cdef | 2650 bcde | 19.45 cde | 0.704 abcd |
| | Y-330 | 1596 efghi | 1829 ab | 2793 a | 18.75 de | 0.671 bcde |
| | LSD | 103.78 | 90.01 | 100.94 | 4.05 | 0.13 |
| | | ns | ns | ns | ** | ** |
| **Spikelet Groups** | BS | 1669.42 | 1739.03 | 2630.04 | 22.120 b | 0.6211 b |
| | CS | 1651.39 | 1747.88 | 2644.18 | 25.861 a | 0.7937 a |
| | AS | 1660.97 | 1723.67 | 2639.85 | 17.736 c | 0.5881 b |
| | LSD | 44.94 | 38.98 | 43.71 | 1.75 | 0.055 |
| | Mean | | | | | |
| | CV (%) | 11.66 | 9.67 | 7.14 | 34.53 | 35.58 |
| **Location x Genotype** | | ** | ** | ns | ** | ** |
| **Location x Spikelet Group** | | ns | ns | ns | ns | * |
| **Genotype x Spikelet Group** | | ns | ns | ns | ns | ns |
| **Location x Genotype x Spikelet Group** | | ns | ns | ns | ns | ns |

**Significant at P<0.01; * Significant at P<0.05 ns: not significant

As average, grain number per panicle was determined as 26.96, 22.45 and 16.29 grains for Kahramanmaras, Konya and Cumra locations, respectively (Table 3). The highest GNP was obtained from Kahramanmaras, and the lowest GNP was obtained from Cumra. Grain weight per panicle was also determined as 0.732, 0.713 and 0.559 g

in Kahramanmaras, Konya and Cumra sites, respectively. This situation was due to climatic conditions of Kahramanmaras, especially with higher total rainfall and higher average temperature in cropping year than the other regions (Table 1). In Cumra location, GNP and GWP were the lowest; this situation was due to shortage for rainfall in May (Table 1), in which plants were at the heading and anthesis period.

Genotypes were significantly different for GNP. Bozkir1-5, Erzurum, Amasya Antalya, Tokat, Faikbey, Ordu and Erzurum genotypes had higher GNP than the other genotypes, and the lowest GNP was obtained from Y-1179 genotype (Table 3). It was due to genetic influence. In previous works, significant variations among genotypes for GNP were reported (Surek et al., 1997 and Kara et al., 2007).

Genotypes were significantly different for GWP. Amasya Antalya, Tokat, Faikbey and Ordu, COV and SLIV genotypes had higher GWP than the other genotypes (Table 3). This situation was due to genetic influence. In previous works, significant variations among genotypes for GWP were reported (Chapko and Brinkman, 1991; Buerstmayr et al., 2007).

GNP and GWP were significantly changed by the spikelet groups. The spikelet in the central of panicle had more and heavier grains and this spikelets were followed by BS and AS, respectively, however, BS and AS were at the same group (Table 3). The significant interaction between location x genotype for GNP and GWP may be due to a different response of genotypes to locations (Figure 1 and 2, respectively). Most of the genotypes had higher GNP and GWP in Kahramanmaras, while the most of them had the lowest GNP and GWP in Cumra except Amasya genotype, meanwhile, in Konya region, the genotypes, except Ordu and Sivas genotypes had GNP values between Kahramanmaras and Cumra regions (Figure 1 and Figure 2).

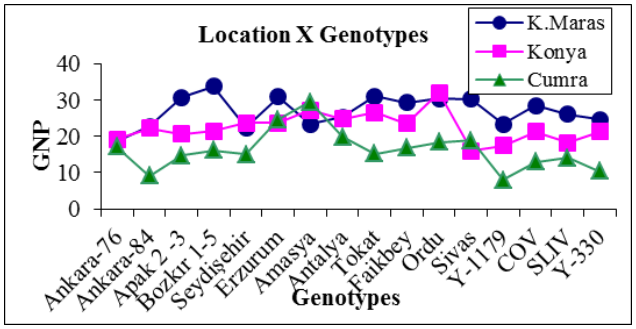


**Figure 1.** Location x Genotype Interaction for GNP

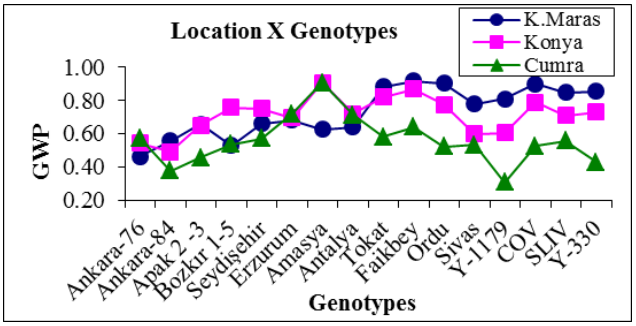


**Figure 2.** Location x Genotype Interaction for GWP

In all locations, CS had the highest GWP and in Konya and Cumra locations, GWP in BS was higher than AS (Fig. 3). In Kahramanmaras location, GWP in AS was higher than BS. It might be due to climatic conditions of Kahramanmaras region, especially lower mean temperature in May (Table 1), in which oat plants were in the grain filling period.

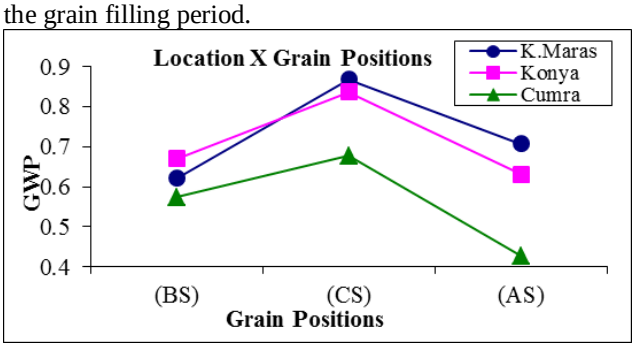


**Figure 3.** Location x Grain Position Interaction for GWP

*Macronutrient Concentrations*

Genotypes were significantly different for Ca, Mg and K concentrations (P<0.01). Locations had a significant effect on Ca and Mg concentrations (P<0.01), in case of Ca and Mg concentrations L x G interaction was also significant (P<0.01) (Figure 4 and 5). However, spikelet groups had no significant effect on Ca, Mg, and K concentrations (Table 3).

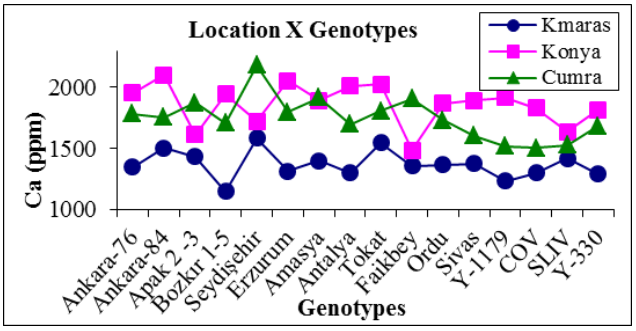


**Figure 4.** Location x Genotype Interaction for Ca

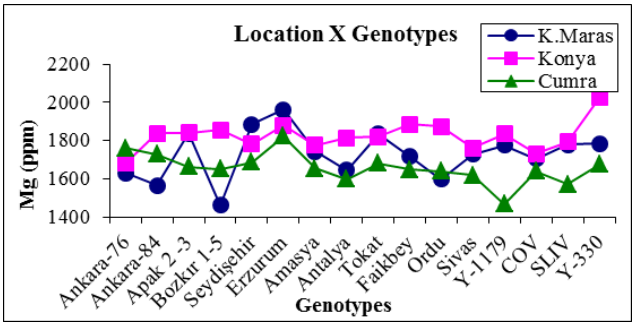


**Figure 5.** Location x genotype interaction for Mg

The results showed that K concentration was the highest compared to Ca and Mg, which Mg reached intermediate level, and Ca had the lowest concentration (Table 3).

Results showed that Konya location had the highest Ca and Mg concentrations; Kahramanmaras had the lowest Ca concentration, while Cumra had the lowest Mg concentration (Table 3). It might be due to climatic and soil condition of locations. $CaCO_3$ content and pH values of Konya and Cumra soils were higher than Kahramanmaras soils (Table 2), and this might be affected on Ca concentrations of oat groats in the locations. In a previous work, it was reported that Ca and Mg accumulations in maize were associated with soil pH, maturity class of plants, temperature and with deficiencies of other elements like Cu (Clark, 1983).

Genotypes were significantly different for macronutrient (Ca, Mg and K) concentrations. Ca concentrations were changed between 1830 and 1529 ppm (Table 3). Ca concentration was determined as the highest in the genotype Seydisehir and followed by Tokat, Ankara-84 and Amasya genotypes, while SLIV genotype had the lowest Ca concentration (Table 3). Variation in genotypes was wider for Ca concentration when compared to Mg and K concentrations (Table 3).

Mg concentrations were changed between 1889 ppm in Erzurum and 1656 ppm in Bozkir1-5 genotypes, Y-330 was another genotype with higher Mg concentration (1829 ppm, Table 3).

Potassium concentrations were changed between 2793 ppm in Y-330 and 2559 ppm in Ankara-76 genotype (Table 3). Y-330 was the only genotype which had higher Mg and K concentrations (Table 3). There were significant variations in genotypes for macronutrient concentrations. It was reported that oat is rich in Ca than any of the other cereal grains (Greaves and Hirst, 1929).

Groats belonging to different spikelet groups on panicles did not have any effect on macronutrient concentrations in oat (Table 3). Calderini and Ortiz-Monasterio (2003) reported that wheat grains in the different spikelet groups (grains in AS and CS) were similar for macronutrient concentrations.

*Micronutrient Concentrations*

Locations had a significant effect on micronutrient concentrations (Na, Cu, Mn and Zn) ($P<0.01$) except Fe of oat groats. Genotypes were significantly different for all micronutrient concentrations ($P<0.01$), while spikelet groups were significant for only Zn concentrations ($P<0.01$) (Table 4). Location x genotype interaction was significant for all micronutrient concentrations, while L x G x SG interaction was significant for only Zn concentration (Table 4).

For all environments, Na had the highest concentrations; Mn and Zn were mean, and Cu and Fe were the lowest. Na micronutrient concentration was higher in Kahramanmaras and similar to Cumra locations, while it was lowest in Konya location. Cu was higher in Kahramanmaras and Konya locations, whereas it was lower in Cumra location. Fe concentration was not significantly different for any location. Mn was the highest in Kahramanmaras location and followed by Konya and Cumra locations, respectively. Zn was the highest in Konya and followed by Cumra and Kahramanmaras locations, respectively. All these situations may be due to soil and climatic conditions of environments. The results of experiment soils analysis show that the higher salinity concentration in Kahramanmaras soils caused the higher Na concentration in this location (Table 2). Zhao *et al.*, (2007) also reported that salt treatments resulted in increases in Na concentration. Cu concentration was also the highest in soils of Kahramanmaras, while Zn concentration in soils of Konya and Cumra was higher than soils of Kahramanmaras (Table 2). Higher Zn concentration in Konya and Cumra locations were due to intensive Zn fertilizations in these locations, in recent years. In addition, different available rainfall in the locations may be effective on the differences of micronutrient concentrations for locations (Table 1).

Genotypes were significantly different for all micronutrient concentrations. Na concentrations were changed between 332.27 ppm in Apak2-3 genotype and 505.48 ppm in Erzurum genotype (Table 4). Our finding was similar to previous work by Zhao et al. (2007) who reported differences in Na concentration among genotypes. Salinity levels were significantly different in the experiment soils of the locations (Table 2). Therefore, genotypes had different Na concentrations in three locations. It caused significant location x genotype interaction (Figure 6). This result was in consistent with work by Zhao et al. (2007) who reported significant interaction between genotype and salinity level for Na concentration.

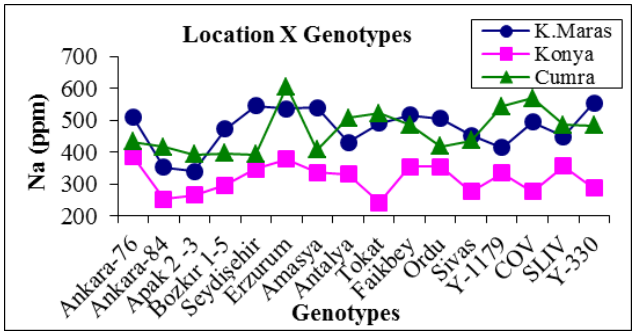


**Figure 6.** Location x Genotype Interaction for Na

Cu concentrations among genotypes were changed between 11.53 ppm in Seydisehir genotype and 15.86 ppm in Sivas genotype (Table 4). Meanwhile, Ordu, Erzurum, Antalya, Tokat, Faikbey and Y-330 genotypes were in the same group with Sivas genotype. Genotypes with higher Cu concentrations were landraces except Faikbey and Y-330 cultivars. It was reported that genotypic differences for Cu concentrations in wheat (Calderini and Ortiz-Monasterio, 2003) in oat (Brown and Mc Daniel, 1978), in triticale, wheat and ryegrass (Graham, 1978). Differences among genotypes have been attributed to variations in Cu uptake patterns or availability due to larger or smaller root systems (Clark, 1983).

**Table 4.** The average Na, Cu, Fe, Mn and Zn values for Location, Genotype and Spikelet Group and Interactions

| | | Micronutrients | | | | |
|---|---|---|---|---|---|---|
| | | **Na (ppm)** | **Cu (ppm)** | **Fe (ppm)** | **Mn (ppm)** | **Zn (ppm)** |
| | | ** | ** | ns | ** | ** |
| **Locations** | K.Maras | 474.78 a | 14.70 a | 16.51 | 57.81 a | 53.73 c |
| | Konya | 316.76 b | 14.99 a | 15.90 | 45.04 b | 130.23 a |
| | Cumra | 467.66 a | 12.87 b | 16.13 | 32.82 c | 79.90 b |
| | LSD | 19.04 | 0.72 | 0.97 | 1.81 | 2.32 |
| | | ** | ** | ** | ** | ** |
| **Genotypes** | Ankara-76 | 442.67 b | 13.51 cde | 16.43 abcd | 50.02 ab | 85.17 defg |
| | Ankara-84 | 340.23 d | 14.31 abcde | 15.32 cde | 49.82 ab | 87.73 cde |
| | Apak 2 -3 | 332.27 d | 14.17 bcde | 16.96 abc | 46.07 bc | 87.85 cd |
| | Bozkir 1-5 | 387.83 c | 13.42 de | 16.44 abcd | 38.94 de | 81.18 g |
| | Seydisehir | 428.09 bc | 11.53 f | 18.54 a | 41.75 d | 82.43 efg |
| | Erzurum | 505.48 a | 15.27 ab | 16.45 abcd | 52.49 a | 92.57 bc |
| | Amasya | 427.10 bc | 14.21 abcde | 17.76 ab | 46.36 bc | 87.07 def |
| | Antalya | 422.25 bc | 14.98 abcd | 16.64 abcd | 47.56 b | 94.01 b |
| | Tokat | 418.01 bc | 14.66 abcde | 16.98 abc | 47.29 b | 89.98 bcd |
| | Faikbey | 451.33 b | 14.25 abcde | 14.97 cde | 42.54 cd | 85.68 defg |
| | Ordu | 425.50 bc | 15.15 abc | 16.14 bcd | 47.97 b | 90.44 bcd |
| | Sivas | 388.48 c | 15.86 a | 16.06 bcd | 49.76 ab | 82.23 fg |
| | Y-1179 | 430.10 bc | 13.23 e | 14.64 de | 42.35 cd | 87.80 cd |
| | COV | 446.21 b | 13.84 bcde | 15.75 bcd | 42.37 cd | 86.41 defg |
| | SLIV | 429.65 bc | 14.08 bcde | 16.55 abcd | 40.98 de | 85.25 defg |
| | Y-330 | 440.62 b | 14.54 abcde | 13.29 e | 37.33 e | 101.40 a |
| | LSD | 43.97 | 1.66 | 2.24 | 4.19 | 5.34 |
| | | ns | ns | ns | ns | ** |
| **Spikelet Groups** | BS | 415.13 | 14.61 | 16.70 | 44.71 | 85.73 b |
| | CS | 419.54 | 13.78 | 15.71 | 44.61 | 89.34 a |
| | AS | 424.54 | 14.19 | 16.15 | 46.36 | 88.79 a |
| | LSD | 19.04 | 0.72 | 0.97 | 1.81 | 2.32 |
| | Mean | | | | | |
| | CV (%) | 19.55 | 21.86 | 25.78 | 17.28 | 11.35 |
| **Location x Genotype** | | ** | ** | ** | ** | ** |
| **Location x Spikelet Group** | | ns | ns | ns | ns | ns |
| **Genotype x Spikelet Group** | | ns | ns | ns | ns | ns |
| **Location x Genotype x Spikelet Group** | | ns | ns | ns | ns | ** |

**Significant at P<0.01, ns: not significant

Most of the oat genotypes, except Erzurum and Ordu genotypes had lower Cu concentrations in Cumra location; however, there were significantly differences among genotypes to respond to Kahramanmaras and Konya locations. It caused to significant location x genotype interaction for Cu concentrations (Figure 7). Despite, Cu concentration in the soils of Kahramanmaras location was higher than Konya and Cumra locations.

Cu concentrations of most genotypes grown in Kahramanmaras location were lower than those in Konya. It was due to higher $P_2O_5$ concentration in Kahramanmaras soils. Clark (1983) reported that higher $P_2O_5$ suppressed Cu uptake.

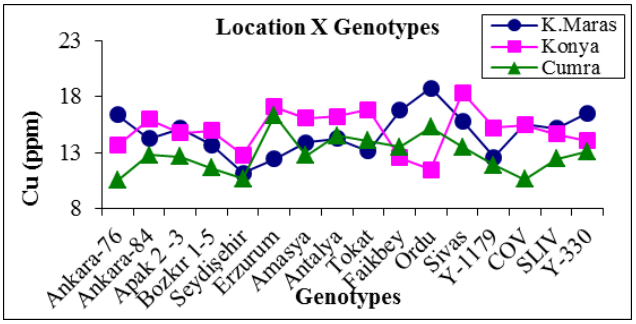


**Figure 7.** Location x Genotype Interaction for Cu

The highest Fe concentration was determined in Seydisehir cultivar (18.54 ppm), while the lowest Fe concentration was determined in Y-330 cultivar (13.29 ppm) (Table 4). Genetic influence for Fe concentrations in three wheat genotypes was reported by Calderini and Ortiz-Monasterio, (2003). In addition, plant genetic influence for Fe concentrations has been reported for many plant species for different years (Clark, 1983).

The highest Fe concentration was obtained from Amasya genotype in Cumra location, while the lowest Fe concentrations were obtained from Y-1179 and Y-330 cultivars in Konya and Cumra locations, respectively (Figure 8). Greaves and Hirst (1929) reported that differences for Fe concentrations, which were found between different samples grown under varying conditions was very great.

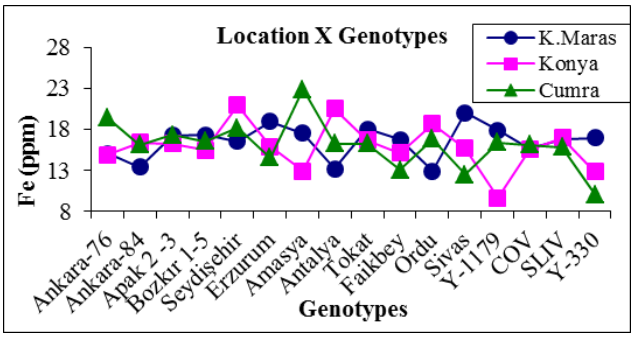


**Figure 8.** Location x Genotype Interaction for Fe

Erzurum genotype, which was also higher for Na, Cu and Fe concentrations, had the highest Mn concentration (52.49 ppm) and Y-330 cultivars had the lowest Mn concentration (37.33 ppm, Table 4). Significant genetic influences for Mn concentrations were reported in wheat (Calderini and Ortiz-Monasterio, 2003) and in oat (Nyborg, 1970 and Ozcan et al., 2006).

Response of genotypes was different to locations for Mn concentration. The highest Mn concentration was obtained from Sivas genotype and this was followed by Erzurum genotype in Kahramanmaras location, the lowest Mn concentration was obtained by Y-330 in Cumra location (Figure 9). In Konya location, the lowest Mn concentration was obtained from Faikbey genotype, while the highest was obtained from Antalya genotype (Figure 9). Clark (1983) reported that environmental factors (Ca, Fe, and Mn levels, pH, source of N and temperature) influenced the distribution of Mn concentrations.

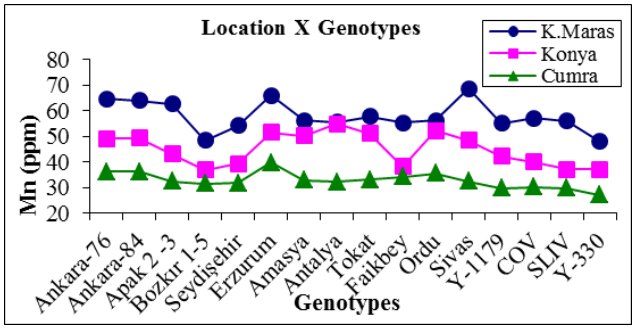


**Figure 9.** Location x Genotype Interaction for Mn

The highest Zn concentration was obtained from Y-330 cultivar (101.40 ppm), followed by Antalya genotype (94.01 ppm) (Table 4). The lowest Zn concentration was obtained from Bozkir 1-5 genotype with 81.18 ppm. In Zn concentrations were found to vary widely depending on oat varieties (Ozcan, et al., 2006). Clark (1983) also pointed out differences among plant genotypes for the absorption, translocation, accumulation, and use of Zn, for many plant species.

In general, genotypes had higher Zn concentrations in Konya location and Y-330 had the highest Zn concentration in this location, while the lowest Zn concentration was obtained from Bozkir 1-5 genotype in Kahramanmaras location. Genotypes had a different response to locations for Zn concentrations (Figure 10).

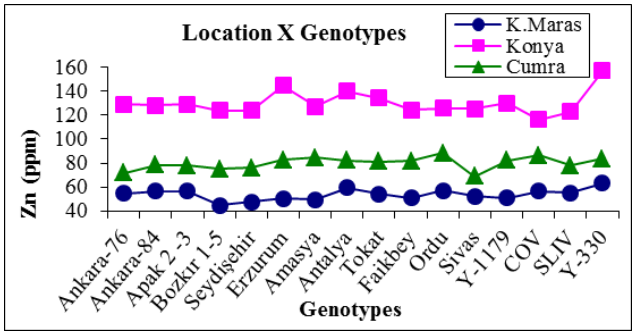


**Figure 10.** Location x Genotype Interaction for Zn

In addition, location x genotype x spikelet group interaction was significant for Zn concentrations. It was due to a different response of genotypes to locations and spikelet groups for Zn concentrations or significant changes of Zn concentrations for spikelet group of genotypes (Figure 11).

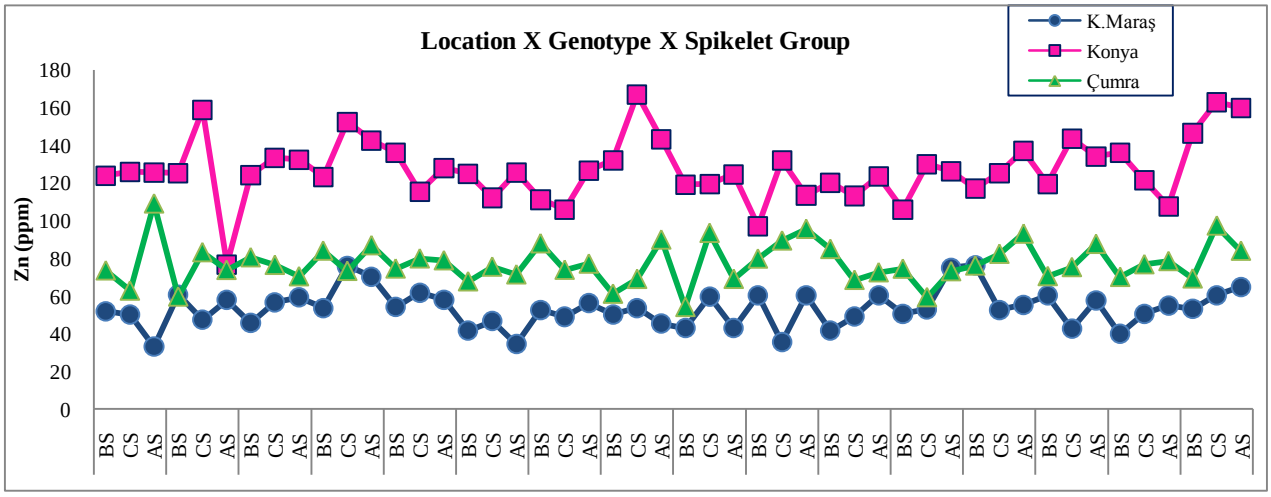


**Figure 11.** Location x Genotype x Spikelet Group Interaction for Zn

Zinc concentration was the only micronutrient significantly changing according to spikelet groups (Table 4). Central (89.34 ppm) and apical (88.79 ppm) spikelets had higher Zn concentrations than basal (85.73 ppm) spikelet (Table 4). Despite significance, these differences were quite small. In previous works, inter-spikelet differences in N concentration were smaller than those between proximal and distal grains within a wheat spikelet (Simmons and Moss, 1978; Herzog and Stamp, 1983).

## CONCLUSIONS

The current study revealed the micro and macronutrient concentrations of different oat spikelet groups grown at three locations. An important result from this study was Ca and Mg concentrations were affected by both locations and genotypes. Interestingly, Zn concentration of spikelet groups was different, while the others were not.

In conclusion, macro and micronutrient concentrations of oat groat could be improved by mostly favorable environments (available rainfall, soil pH, macro and micro element levels of soil, applying fertilizations in the recent years, etc.) and genotypes with higher macro and micro nutrient concentrations.

## LITERATURE CITED


Brown, J.C., M.E. Mc Daniel, 1978. Factors associated with differential response to two oat genotypes to zinc and copper stress. Crop Sci., 18: 817-820.

Buerstmayr, H., N. Krenn, U. Stephan, H. Grausgruber, E. Zechner, 2007. Agronomic performance and quality of oat (*Avena sativa* l.) genotypes of worldwide origin produced under central European growing conditions. Field Crops Res., 101:343-351.

Calderini, D.F., I. Ortiz-Monasterio, 2003. Grain position affects grain macronutrient and micronutrient concentrations in wheat. Crop Sci., 43:141-151.

Chapko, L.B., M.A. Brinkman, 1991. Interrelationships between panicle weight, grain yield, and grain yield components in oat. Crop Sci., 31:878-882.

Clark, R.B., 1983. Plant genotype differences in uptake, translocation, accumulation, and use of mineral elements required for plant growth. Plant and Soil, 72: 175-196.

Demirbas, A., 2005. ß-Glucan and mineral nutrient contents of cereals grown in Turkey. Food Chemistry, 90: 773-777.

Douglas, C.D., M.S. McMullen, J.J. Hammond, 2001. Genotypic and environmental effects on grain yield and quality of oat grown in North Dakota. Crop Sci., 41:1066-1072.

Graham, R.D., 1978. Tolerance of triticale, wheat and rye to copper deficiency. Nature, 281: 542-543.

Greaves, J.E., C.T. Hirst, 1929. The mineral content of grain. The Journal of Nutrition, 1(4): 293-298

Herzog, H., P. Stamp, 1983. Dry matter and nitrogen accumulation in grains at different ear positions in gigas semidwarf and normal spring wheats. Euphytica, 32: 511-520.

Jodral-Segado, A.M., M. Navarro-Alarcon, H.L.G. De La Serrana, M.C. Lopez-Martinez, 2003. Magnesium and calcium contents in foods from SE Spain: Influencing factors and estimation of daily dietary intakes. Science of The Total Environment, 312(1-3): 47-58.

Kara, R., Z. Dumlupinar, Y. Hisir, T. Dokuyucu, A. Akkaya, 2007. Evaluation of oat varieties for the yield components and grain yield under the Kahramanmaras conditions. Proceedings of VII. Field Crops Congress (in Turkish with English abstract), 121-125, 25-27 June 2007, Erzurum, Turkey.

Martens, D.C., W.L. Lindsay, 1990. Testing Soils for Copper, Iron, Manganese an Zinc. In: Soil Testing and Plant Analysis 3rd Ed. R.L. Westerman (ed). SSSA Book Series 3, Madison, WI, pp. 229-260.

Nyborg, M. 1970. Sensitivity to manganese deficiency of different cultivars of wheat, oats and barley. Can. J. Plant Sci., 50: 198-200.

Ozcan, M.M., G. Ozkan, A. Topal, 2006. Characteristics of grains and oils of four different oats (*Avena sativa* L.) Cultivars growing in Turkey. International Journal of Food Sciences and Nutrition, 57(5-6): 345-352.

Peck, T.R., P.N. Soltanpour, 1990. The Principles of Soil Testing. In: Soil Testing and Plant Analysis 3rd Ed. R.L. Westerman (ed). Soil Science of America,Inc. Madison, Wisconsin, pp. 1–9.

Simmons, R., D.N. Moss, 1978. Nitrogen and dry matter accumulation by kernels formed at specific floret in spikelet of spring wheat. Crop Sci., 18: 139-143.

Surek, H., J. M. Valantine, D. Hayward, 1997. Inheritance of some major genes and their associations with quantitative traits in cultivated oats (*Avena sativa* L). Journal of Aegean Agricultural Research Institute (Anadolu), 2: 8-10.

Underwood, B.A., 2000. Overcoming micronutrient deficiencies in developing countries: is there a role for agriculture? UNU Food Nutr .Bull., 21:356-360.

Welch, R.M., R.D. Graham, 2000. A new paradigm for world agriculture: productive, sustainable, nutritious, healthful food systems. UNU Food Nutr. Bull., 21:361-366.

Yu, J., G. Pressoir, W.H. Briggs, I. Vroh Bi, M. Yamasaki, J.F. Doebley, M.D. McMullen, B.S. Gaut, D.M. Nielsen, J.B. Holland, S. Kresovich, E.S. Buckler, 2006. A unified mixed-model method for association mapping that accounts for multiple levels of relatedness. Nat. Genet., 38: 203-208.

Zhao, G.Q., B.L. Ma, Ren, C.Z., 2007. Growth, gas exchange, chlorophyll fluorescence, and ion content of naked oat in response to salinity. Crop Sci., 47:123-131.