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# Effect of Irrigation Water on Accumulation of Heavy Metal and Mineral Element in Some Vegetables

Etem OSMA[1], Salih MUTLU[1], Ahmet AKSOY[2], Veli İLHAN[1]

**ABSTRACT:** In this study, the effects of irrigation water on vegetables were analysed. Samples that we analysed were pepper (*Capsicum annuum* L.), tomatoes (*Solanum lycopersicum* L.), and eggplant (*Solanum melongena* L.) were raised using running water and river water and collected from both normal land and riverside soils. After pretreating the collected samples in the laboratory, ICP-MS elemental analysis was conducted. Results are evaluated using SPSS 19 Statistical Package Software and expressed as mean we found that there is significant differences in the content metals of the samples (soil, roots and fruits) collected from three different area. We also evaluated the correlation between the soils and the roots vegetable in terms of heavy metals (or mineral). It was clear that there is a significant effect of irrigation water on the vegetables.

**Key words*:*** Heavy metals, ICP-MS, irrigation, mineral elements, vegetables

# Sulama Suyunun Bazı Sebzelerde Ağır Metal ve Mineral Elementlerin Birikimine Etkisi

**ÖZET:** Bu çalışma ile sulama suyunun sebzeler üzerinde ki etkileri araştırılmaya çalışılmıştır. Normal arazi ve nehir kenar topraklarından olmak üzere üç farklı örnek alan hazırlanmıştır. Bu alanlarda normal şebeke suyu ile nehir suyu kullanılarak, biber (*Capsicum annuum* L.), domates (*Solanum lycopersicum* L.) ve patlıcan (*Solanum melongena* L.) yetiştirilmiştir. Toplanan örnekler, laboratuvarda ön işlemden geçirildikten sonra ICP-MS te element analizi yapılmıştır. Elde edilen sonuçlar doğrultusunda SPSS 19 İstatistik Paket Programı ile istatistiksel değerlendirmeler yapılarak, üç farklı alandan toplanan örneklerin metal içeriği bakımından toprak, kök ve meyveler arasında farklılıklar tespit edilmiştir. Ayrıca metal açısından toprak ile sebzelerin kökleri arasındaki korelasyon ile toprak-kök arasındaki ilişki de belirlenmiştir. Sulama suyunun, sebzelerde önemli etkisinin olduğu açıktır.

**Anahtar Kelimeler:** Ağır metaller, ICP-MS, mineral element, sebze, sulama

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[1] Erzincan Universitesi, Fen Edebiyat Fak., Biyoloji Bölümü, Erzincan, Türkiye
[2] Akdeniz Üniversitesi, Fen Edebiyat Fak., Biyoloji Bölümü, Antalya, Türkiye
Sorumlu yazar/Corresponding Author: Etem OSMA, eosma@erzincan.edu.tr

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## INTRODUCTION

Food security is one of the most important problems of the world (D'Mello, 2003; Mapanda et al., 2007; Gebrekidan et al., 2013). When agricultural lands are exposed to polluted water for a long time, toxic metals can reach up to high concentrations (Nayek et al., 2010). The amount and content of water is one of the factors limiting irrigation. Considering the gradual decrease of water resources in recent times, the proper use of available water sources is one of the most important responsibilities of humankind. Unless the precautions are not taken for effective water purification, the ground and surface water as well as soil may lose their characteristics gradually. In many regions of the world, agricultural activities have been mainly maintained on riversides. However, the contaminations from industrialization, agricultural activities and urbanization could mix with river water which may result in serious metal accumulation in the vegetables. Therefore, the contaminative matters should be well removed from river water which is used in irrigation in surrounding areas (Xi bai et al., 2008; Mahmood and Malik, 2014).

Each plant needs a metal concentration to develop. At lower or higher concentrations, vegetable damage could occur in different ways. The consumptions of vegetables, in which heavy metals accumulation is high, could be harmful for the people's and animal's life, since heavy metals could also start to accumulate in living beings in long term consumption (Xi bai et al., 2008; Mahmood and Malik, 2014). Even at low concentrations, some metals can accumulate and create damage because people and animals do not have evacuation mechanism (Arora et al., 2008; Kiziloglu et al., 2008; Mapanda et al., 2007). The waste water is an important source for enriching the poor soils of arid and semi-arid areas. Through the increase at urbanization and industrialization, there are several contaminative matters mixing into water. Through the use of those matters in agricultural areas, several problems are arisen (Taberi and Salehi, 2009). Although the waste water sources are beneficial for vegetables, they can cause soil pollution and degradation of food quality due to the contaminative factor mixing into water. Metal accumulation in plants depends upon the plant species, and productivity depends upon metal uptake of the plants (Khan et al., 2008).

Karasu River is one of the most important major rivers in Anatolia, in Turkey, flowing to the river Euphrates and forms an important basin in that region. With this study, we first aimed to evaluate the effect of Karasu on agricultural products. Secondly, we aimed to look at the differences in samples from three different areas. Thirdly, we aimed to measure the correlation between soil and the roots of vegetables in terms of elemental analysis.

## MATERIALS AND METHODS

Vegetable cropping was primarily administered in an area where there is no industrialization, urbanization and traffic. Yalnızbağ district of Erzincan province was selected as being proper to the required characteristics.

**Table 1.** Sampling area and its characteristics

| Sample Areas | Characteristics |
|---|---|
| I | Normal land soil and running water |
| II | Normal land soil and river water |
| III | Riverside soil and river water |

**Table 2**. The names of vegetables in English, Turkish, and their Latin names

| English | Turkish | Scientific Name |
|---|---|---|
| Pepper | Biber | *Capsicum annuum* L. |
| Eggplant | Patlıcan | *Solanum melongena* L. |
| Tomatoes | Domates | *Solanum lycopersicum* L. |

Cropping of vegetables was administered into the riverside soil with medium-level organic matter content (Table 1.). The soil samples were taken from 3 different areas during the harvest season, and their elemental analyses were performed by using a ICP-MS. Vegetables were planted to the determined sample areas in May. While peppers were planted 40 cm intervals, tomatoes with eggplant were planted with approximately 50 cm intervals. Regular irrigation was maintained until the mid-September. No other application (fertilizer, pesticide, etc.) apart from water was used. Irrigation was made with running River water (Figure 1.). The vegetable samples were collected in July, August and September. In soil, root and fruit samples, the data related to mineral element and heavy metals were obtained.

The samples of vegetables were collected from some areas of Yalnızbağ in Erzincan. Totally 3 different localities of 3 different vegetables including pepper, tomatoes and eggplant were studied (Table 2.). The samples were taken by hand using vinyl gloves, and carefully packed into polyethylene bags (Alam et al., 2003). Only the edible parts of each vegetable were analysed. In addition, the soil samples were collected from the sampling sites. The samples were divided into two sub-samples; the samples in the first sub-group were thoroughly washed several times with tap water, and subsequently by distilled water in order to to remove dust particles in a standardized procedure; the rest of the vegetables were untreated, and then oven dried at 80$^{o}$C for 24 h. At each site, the soils were sampled from the top 10 cm by means of a stainless steel trowel to avoid contamination. To ensure consistent distribution of metals in the soil samples, all materials were grounded in a micro-hammer cutter, and filtered via a 1.5-mm sieve (Demirezen and Aksoy, 2006; Osma et al., 2013).

Dried and milled samples were powdered, and kept in clean polyethylene bottles. In addition, the soil samples were collected with a stainless steel crab. These samples were dehydrated in open air, and passed through a 2-mm sieve. After homogenization, the soil samples were stored in clear paper bags prior to the analysis (Demirezen and Aksoy, 2006; Osma et al., 2013).

Preparation of the samples was actualized in a microwave according to USEPA 3052 method. It took 10 minutes to heat the device up to 180°C, and also waited for 10 minutes for solubilisation at 180°C. After cooling, sonar 50 ml was completed, and thinned down to appropriate concentrations. For micro elements, 1.967 gr Titriplex V (DTPA= Diethylene Triamino Penta Acetic Acid), 1.470 gr $CaCl_{22}H_2O$ (Calcium Chloride Dehydrate), 14.92 gr Triethanolamine were weighed. The weighed compounds were grounded into the erlenmeyer, and dissolved in 900 ml ultra-pure water. Then pH of solution was adjusted to 7.3, and final volume was adjusted to 1000 ml. For the macro elements, 77.08 gr ammonium acetate was weighed and dissolved in 800 ml ultra-pure water. The pH was adjusted to 7, and the final volume was adjusted to 1000 ml. Finally, the prepared samples were analysed in ICP-MS as previously described (Knudsen et al., 1982, Kacar and İnal, 2008, Kacar, 2009).

In statistical analysis, p-values $\leq 0.05$ were regarded as significant; the mean value of samples at 95% confidence interval, standard deviation, and ANOVA were used. Multiple comparison tests as Tukey HSD, and Dunnett (2-sided) were used to identify the significant differences. In addition, the correlation between soil and root was examined.

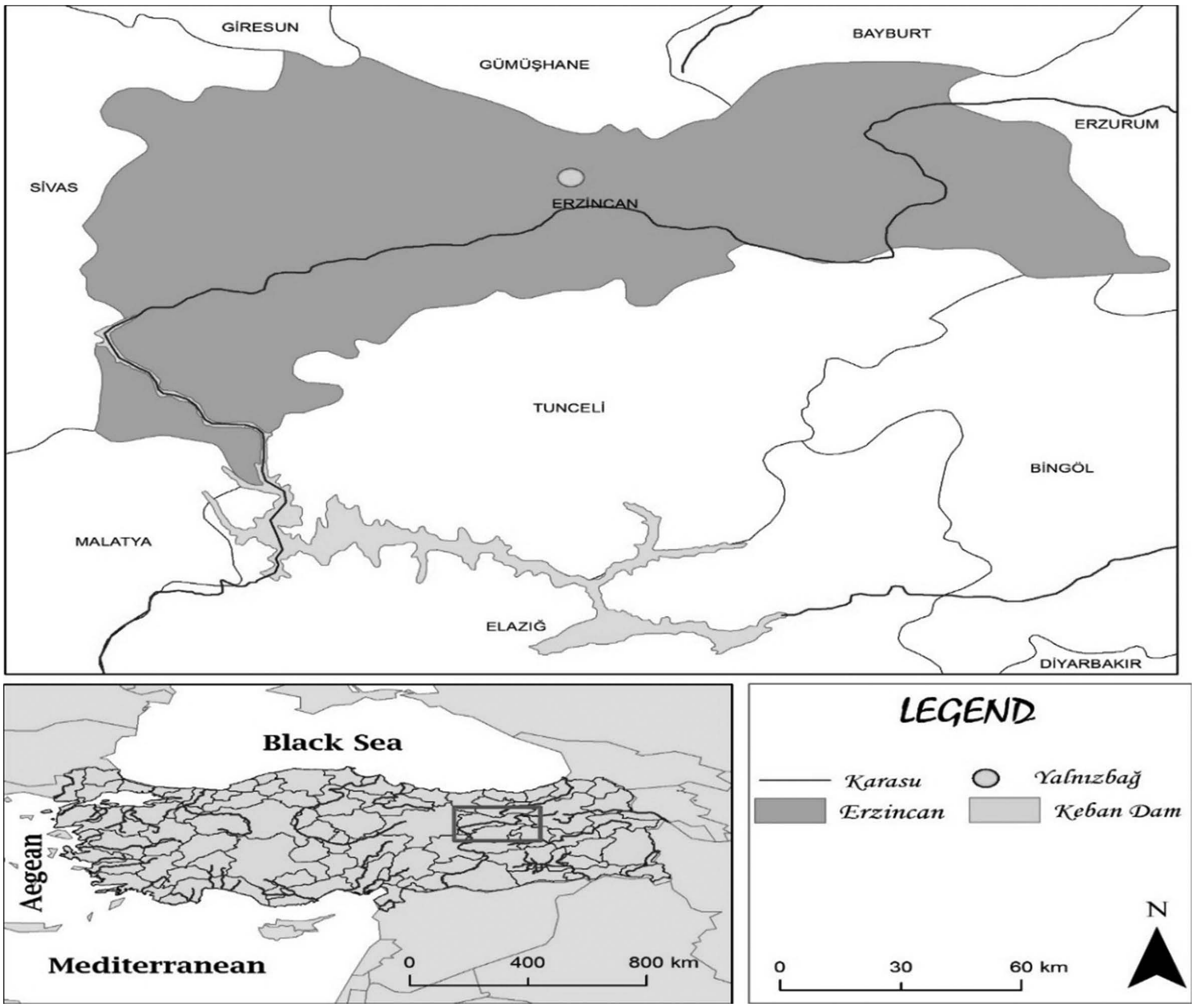


**Figure 1.** Study area

## RESULTS AND DISCUSSION

Significant differences were noticed after evaluation of our results in the vegetable samples due to water sources used in the fields causing changes in the metal accumulation patterns of the vegetables. The water source, normal or river water, used in the field over three months were found to be the main reason leading to occurrences of the differences in the samples in terms of metal accumulation. As a result of continues irrigation practices, the uptake and accumulation of metals by the vegetables were steadily increased. The vegetables grown in different soils were subjected to experimental procedures for the determination of the metal concentration levels they have in their related organs (roots and fruits) and the analyses were conducted to show the differences between them.

According to our data, the range of values of element concentrations in roots varied between 2 180-10 870 μg g$^{-1}$ dw for Mg, 6 350-79 070 μg g$^{-1}$ dw for K, 1 361-25 253 μg g$^{-1}$ dw for Ca, 820.3- 5 332.7 μg g$^{-1}$ dw for P, 535,1-3 688 μg g$^{-1}$ dw for Fe, 13.5-117.5 μg g$^{-1}$ dw for Cr, 15.3-657.4 μg g$^{-1}$ dw for Cu, 21.1-149.9 μg g$^{-1}$ dw for B, 41.8-456.4 μg g$^{-1}$ dw for Mn, 29.9-155.2 μg g$^{-1}$ dw for Zn, 1.9-25.1 μg g$^{-1}$ dw for Co, 0-10.4 μg g$^{-1}$ dw for Mo and 613.5-7 137 μg g$^{-1}$ dw for Al (Table 4-6).

According to our results, the highest and lowest values of element accumulation in vegetables varied between 345.4-2 613 μg g$^{-1}$ dw for Mg, 54 950-148 600 μg g$^{-1}$ dw for K, 1 505-3 051 μg g$^{-1}$ dw for Ca, 620.5-8 125 μg g$^{-1}$ dw for P, 147-298.7 μg g$^{-1}$ dw for Fe, 0-7.2 μg g$^{-1}$ dw for Cr, 16.3-40.2 μg g$^{-1}$ dw for Cu, 63.1-125.8

μg $g^{-1}$ dw for B, 21.4-80.2 μg $g^{-1}$ dw for Mn, 37.5-136 μg $g^{-1}$ dw for Zn, 0-3.2 μg $g^{-1}$ dw for Co, 0.7-3.4 μg $g^{-1}$ dw for Mo and 19.5-217.1 μg $g^{-1}$ dw for Al (Table 4-6).

According to our results from the soil analyses, the experimental areas of II and III were found to be having high amount of metal concentration. It was found that while the concentrations of Ca, P, Fe, Cr, B, Mn and Al were found to be high in the experimental area of III the concentrations of K, Cu, Zn, Co, and Mo were found to be high in the experimental area of I in the roots of pepper. The metal concentrations for the root samples of eggplant and tomato were found to be high in the experimental areas of II and III and in the experimental area of I, respectively The statistical analyses performed on the values belonging to the roots of the peppers, eggplants and tomatoes experimental results were pointed out significant differences in the metal intensity levels between the experimental areas (Table 3).

**Table 3.** Mean metal (μg $g^{-1}$ dw weight) concentrations in soil. (Keys: *p<0.05; **p<0.01; ***p<0.001 significant).

| Elements | I | II | III | Significance (p) |
|---|---|---|---|---|
| Mg | 27 110 | 26 970 | 20 330 | *** |
| K | 1 482 | 1 381 | 2 184 | *** |
| Ca | 38 750 | 39 510 | 42 590 | *** |
| P | 210.5 | 182.5 | 325.9 | *** |
| Fe | 22 300 | 22 020 | 25 210 | *** |
| Cu | 13.4 | 14.5 | 18 | *** |
| B | 13.5 | 14.6 | 21.3 | *** |
| Mn | 483.1 | 490.96 | 544.9 | *** |
| Zn | 19.6 | 20.7 | 26.8 | *** |
| Cr | 156.6 | 154.9 | 126.8 | *** |
| Co | 24.8 | 25.2 | 20.3 | *** |
| Al | 5 812 | 5 719 | 6 697 | *** |

Metal concentration levels detected in the fruits of pepper were high in the experimental areas of II and III. When the metal concentration data belonging to the fruits of eggplant was analysed, the increments ~~of~~ in the concentrations of several metals were noticed in the experimental area of II during the experimental period Similar findings were seen for, the metal concentrations in the fruit samples of vegetables grown in the experimental area of II When comparisons done for the experimental areas where pepper, eggplant, and tomato were grown, significant differences were seen in terms of metal concentration levels. Changes depending on the irrigation practice patterns were observed in metal concentration levels (Table 4-6).

**Table 4.** Metal concentration (µg $g^{-1}$ dw weight) in the roots and fruits of pepper (*p<0.05; **p<0.01; ***p<0.001 significant).

| Elements | Root | | | Significance (p) | June (Fruit) | | | August (Fruit) | | | September (Fruit) | | | Significance (p) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | | I | II | III | I | II | III | I | II | III | |
| Mg | 10 870 | 2 180 | 9 417 | *** | 1 030 | 1 215 | 765.5 | 1 585 | 1 319 | 1 538 | 1 396 | 1 090 | 2 613 | *** |
| K | 55 260 | 13 100 | 48 240 | ** | 59 580 | 89 310 | 71 180 | 78 920 | 96 940 | 106 400 | 79 470 | 73 310 | 148 600 | *** |
| Ca | 13 290 | 1 361 | 13 330 | *** | 2 923 | 2 008 | 2 501 | 1 982 | 1 880 | 1 842 | 2 318 | 2 244 | 2 087 | * |
| P | 1 251 | 1 284 | 1 779 | | 2 067 | 3 976 | 1 714 | 4 184 | 3 414 | 5 141 | 3 956 | 4 183 | 8 125 | *** |
| Fe | 643.2 | 705.9 | 3.688 | *** | 262.5 | 193.5 | 239.1 | 183.3 | 221.5 | 236.2 | 240.9 | 237.9 | 254.9 | *** |
| Cr | 77.8 | 20.5 | 117.5 | *** | 0 | 0 | 0 | 0 | 0 | 7.2 | 2.2 | 0 | 4.2 | * |
| Cu | 657.4 | 24 | 53.7 | ** | 22.1 | 24 | 23.1 | 21.5 | 24 | 24.6 | 32.8 | 29.2 | 40.2 | *** |
| B | 81.5 | 51.7 | 149.9 | | 69.9 | 96.8 | 68.5 | 104.5 | 106.1 | 71.1 | 63.1 | 97.3 | 90.7 | |
| Mn | 324.9 | 73.3 | 456.4 | ** | 35.6 | 40.9 | 35.9 | 37.3 | 39.4 | 80.2 | 49.2 | 52.8 | 77.9 | *** |
| Zn | 148.6 | 35.9 | 48.4 | ** | 42.3 | 99.6 | 46 | 63.9 | 66.5 | 70 | 68.8 | 51.6 | 136 | *** |
| Co | 25.1 | 4.5 | 23.3 | *** | 0.9 | 1.5 | 0.7 | 0.8 | 1 | 2.2 | 1.5 | 1.3 | 3.2 | ** |
| Mo | 10.4 | 2.5 | 6.9 | *** | 3.4 | 2.1 | 1.9 | 1.6 | 1.8 | 2.1 | 2.3 | 0.7 | 3.4 | ** |
| Al | 5.404 | 1.947 | 7.137 | *** | 30.4 | 25.2 | 19.5 | 48 | 29.1 | 58.4 | 31.1 | 31.8 | 111.1 | *** |

**Table 5.** Metal concentration (µg $g^{-1}$ dw weight) in the roots and fruits of eggplant (*p<0.05; **p<0.01; ***p<0.001 significant)

| Elements | Root | | | Significance (p) | June (Fruit) | | | August (Fruit) | | | September (Fruit) | | | Significance (p) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | | I | II | III | I | II | III | I | II | III | |
| Mg | 2 476.2 | 5 100 | 5 530 | *** | 1 231 | 744.2 | 1 015 | 1 418 | 1 159 | 914.1 | 1 355 | 1 098 | 1 243 | * |
| K | 6 350 | 11 070 | 20 650 | ** | 99 810 | 79 920 | 95 920 | 118 300 | 91 370 | 74 860 | 96 930 | 106 600 | 67 060 | ** |
| Ca | 4 201.7 | 16 120 | 21 390 | *** | 1 747 | 2 556 | 2 283 | 2 012 | 1 962 | 2 518 | 1 579 | 1 505 | 3 051 | ** |
| P | 889.1 | 820.3 | 1 310 | | 3 357 | 620.5 | 1 791 | 4 414 | 2 505 | 987.1 | 4 264 | 3 637 | 1 854 | *** |
| Fe | 535.1 | 840.6 | 1 128 | *** | 147 | 191.3 | 161.6 | 208.8 | 223.3 | 234.3 | 231.6 | 298.7 | 231.7 | |
| Cr | 13.5 | 38.8 | 46.4 | ** | 5.9 | 0 | 0 | 2 | 3.1 | 4.4 | 0 | 0 | 0 | * |
| Cu | 15.3 | 28.4 | 23 | ** | 19 | 16.3 | 16.3 | 20.4 | 20.4 | 17.8 | 19.9 | 24.4 | 18.4 | *** |
| B | 42.1 | 63.2 | 72.7 | | 103.2 | 64.2 | 102.4 | 110.1 | 73.6 | 100.8 | 120.3 | 125.8 | 102.2 | |
| Mn | 41.8 | 219.9 | 203.9 | *** | 38.9 | 29.7 | 39.1 | 46.5 | 40.4 | 36.7 | 38.7 | 37 | 32.8 | |
| Zn | 29.9 | 144.7 | 61.2 | *** | 48.5 | 37.5 | 41.4 | 43.4 | 58.5 | 48.2 | 55 | 48.1 | 38.1 | |
| Co | 1.9 | 6.2 | 7.3 | *** | 0.3 | 0 | 0.1 | 0.1 | 0.4 | 0 | 0.2 | 0 | 0 | * |
| Mo | 0 | 1 | 2.5 | *** | 1.1 | 1.8 | 0.7 | 2.9 | 2.9 | 2.2 | 1.8 | 1.4 | 1.8 | * |
| Al | 613.5 | 2.704 | 3.115 | *** | 45.2 | 24.8 | 65.2 | 74.3 | 49.1 | 32.2 | 46.3 | 50.3 | 55.9 | ** |

**Table 6.** Metal concentration (μg $g^{-1}$ dw dry weight) in the roots and fruits of tomatoes. (*p<0.05; **p<0.01; ***p<0.001 significant).

| Elements | Root | | | Significance (p) | August (Fruit) | | September (Fruit) | | | Significance (p) |
|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | | I | II | I | II | III | |
| Mg | 8 887 | 7 078 | 6 252 | *** | 589.4 | 365.7 | 466.3 | 577.6 | 345.4 | ** |
| K | 73 850 | 64 650 | 79 070 | | 54 950 | 41 890 | 73 340 | 74 470 | 58 930 | * |
| Ca | 23 210 | 19 200 | 25 253 | | 2 434 | 2 438 | 2 333 | 2 193 | 2 407 | |
| P | 5 197 | 5 332.7 | 2 629 | *** | 1 589 | 1 152 | 2 448 | 3 628 | 1 179 | ** |
| Fe | 1 237 | 928.8 | 716.7 | ** | 221.1 | 223.1 | 187.9 | 208.3 | 276.9 | *** |
| Cr | 59.5 | 26.8 | 48.7 | * | 0 | 0 | 0 | 3.8 | 0 | *** |
| Cu | 31.3 | 43.1 | 41.7 | | 19.6 | 18.8 | 21.1 | 22.1 | 20.7 | * |
| B | 21.1 | 34.1 | 64 | ** | 54.8 | 70.5 | 68.8 | 49.9 | 74.9 | |
| Mn | 307.3 | 200.9 | 187.2 | *** | 22.9 | 21.4 | 22.3 | 24.2 | 24.2 | *** |
| Zn | 155.2 | 55.2 | 116.6 | *** | 39.5 | 53.1 | 45.9 | 71.5 | 46.9 | *** |
| Co | 12.4 | 12.1 | 8.3 | | 0 | 0 | 0 | 0.7 | 0 | *** |
| Mo | 5.8 | 5 | 5.4 | | 0.2 | 0.1 | 0.6 | 0.5 | 0.5 | |
| Al | 3.338 | 1.853 | 1.520 | *** | 50.2 | 58.8 | 136.4 | 89.5 | 217.1 | *** |

The values of each metal in roots and fruits of the study plants and the values of each metal in the co-located soil samples collected from research fields were statistically evaluated and analysis of correlation co-efficient for each metal was done between the roots of the research plants and their co-located soil samples. Our correlation co-efficient results revealed significant positive and negative relationships for some metals between the research plant and soil samples. Relatively high positive relationship was observed between tomato plant and collocated soil samples in comparison with other positive relationships existed between other research plants and their co-located soil samples (Table 7).

**Table 7.** Correlation between metal concentration in soil and the vegetables (*p<0.05; **p<0.01).

| Elements | Soil-Pepper | Soil-Eggplant | Soil-Tomatoes |
|---|---|---|---|
| Mg | 0.265 | -0.583** | 0.519** |
| K | 0.422* | 0.301 | 0.186 |
| Ca | 0.327 | 0.530** | 0.371 |
| P | 0.241 | 0.371 | -0.822** |
| Fe | 0.315 | -0.066 | -0.205 |
| Cr | -0.266 | -0.649** | -0.552** |
| Cu | -0.169 | 0.120 | -0.550** |
| B | 0.550** | 0.300 | 0.500** |
| Mn | 0.394* | -0.191 | -0.604** |
| Zn | -0.283 | -0.423* | 0.047 |
| Co | -0.280 | -0.539** | 0.733** |
| Al | 0.545** | 0.004 | -0.548** |

When comparisons were done between the data from our research and the data from other studies, the concentrations of Fe, Al, Ca, and B were found to be relatively high whereas the concentrations of other metals were found to be relatively similar in the roots of plant samples B was present in high concentrations in fruits of research plants, and depending upon irrigation practices, its concentration level could go up further. Adequate levels of mineral elements were required for normal growth and development of plants (Kacar and İnal, 2008; Kacar, 2009).

In comparison of metal concentrations in soils, the data obtained by Liu et al. (2005) revealed higher amounts than ours, and similar results to ours (except the data for Ni) were noticed by Rattan et al. (2005) were parallel to our data except from Ni, and the data of Zhanga et al. (2008) were associated with ours.

When we compared the data of our study with the other studies; we noticed that Mireles et al. (2004) determined lower values in terms of Cu, Ni and Pb elements. The data obtained by Sharma et al. (2007) were in parallel to ours except from Pb. According to the study carried out by Gebrekidan et al. (2013), the data he obtained was lower than ours in terms of Cu and Zn, and higher in terms of Pb. The data obtained by Nayek et al. (2010) were higher than ours in terms of Cr and Cd, and parallel with the other metals. The data obtained by Wang et al. (2012) and Mahmood and Malik (2014) in their study were associated with the data we obtained. It was determined by Khan et al. (2013) in their study they carried out with waste water and normal study that Pb, Ni and Cd data were higher than ours. The concentrations of metals obtained by Ekholma et al. (2007) in their study they carried out upon different fruits had lower values rather than our values. The data obtained by Avcı and Deveci (2013) revealed parallel results to ours for the concentration levels of Co, Zn, Cr and Cu whereas the concentration levels for other elements were higher than ours.

## CONCLUSIONS

In conclusion, it was showed that contents of water source have a great impact on agricultural productivity. Depending upon irrigation applications, metal concentrations in fruits of research plants were increased during the experimental period in our study. Irrigation is an important factor in the improvement of productivity efforts because for adequate development of the plants, sufficient amounts of mineral elements found in water are needed but if water used for irrigation is contaminated it creates a toxic impact on the production rivers having different characteristics are used in the agricultural activities all around the world. Accordingly, the rivers used for agricultural practices should be protected from the negative impacts of environmental problems. Moreover, the countries should be tighten the regulations upon water management issues. The qualities and contents of irrigation waters and the products grown by using irrigation waters should be subjected to analyses periodically for monitoring the statuses of rivers.

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