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MINERAL NUTRIENT COMPOSITIONS OF FIELD-GROWN WEED AND MAIZE (*Zea mays* L.) PLANTS IN TERMS OF COMPETITION

Ibrahim Ilker Ozyigit[1,2,*], Ilhan Dogan[3*], Sedat Karadeniz[1], Zeki Severoglu[1], Goksel Demir[4], Ibrahim Ertugrul Yalcin[5] and Celal Yarci[1]

[1]Marmara University, Faculty of Science & Arts, Department of Biology, 34722, Goztepe, Istanbul, Turkey. [2]Kyrgyz-Turkish Manas University, Faculty of Science, Department of Biology, 720038, Bishkek, Kyrgyzstan. [3]Sakarya University of Applied Sciences, Vocational School of Health Services at Akyazi, 54400, Sakarya, Turkey. [4]University of Health Sciences Turkey, Faculty of Hamidiye Health Sciences, Department of Occupational Health and Safety, 34668, Uskudar, Istanbul, Turkey. [5]Bahcesehir University, Faculty of Engineering and Natural Sciences, Department of Civil Engineering, 34353, Besiktas, Istanbul, Turkey
[*]Corresponding author(s): ilker.ozyigit@manas.edu.kg, ilhandogan@subu.edu.tr

Amaranthus retroflexus L., *Convolvulus arvensis* L., *Cynodon dactylon* (L.) Pers. var. *villosus*, *Datura stramonium* L., *Echinochloa crus-galli* (L.) Beauv and *Portulaca oleracea* L. are weeds commonly seen in agricultural fields. Weeds pose serious threat to agricultural production. This study focuses on mineral nutrient uptake competition arisen between maize and weed species. Maize (*Zea mays* L.) was planted in a model field in Emirli Village-Istanbul/Turkey and the above-mentioned weeds were allowed to be grown along with maize. Then, weed and maize species along with their co-located soil samples were collected from the field and mineral element (Al, B, Ca, Cu, Fe, K, Mg, Mn, Na, Ni and Zn) contents in the plant parts (root, branch and leaf) of weeds and maize and their co-located soils were determined using ICP-OES. To reveal the rate of mineral nutrient removal capabilities of maize and the weed species grown in the same field, comparisons were done in terms of maize-weed competition. According to our data, better accumulation capabilities were performed by maize for K, Mn, Ni and Zn; *A. retroflexus* and *C. arvensis* for B; *C. arvensis*, *D. stramonium* and *P. oleracea* for Ca; *C. dactylon* for Cu and Zn; *A. retroflexus*, *C. arvensis* and *C. dactylon* for Fe; *E. crus-galli* and *P. oleracea* for Mg and *E. crus-galli* for Na.
Keywords: Competition, Corn, Maize, Mineral elements, Weeds, *Zea mays* L.

INTRODUCTION

Weeds are widely seen in agricultural fields. Competition for mineral nutrients, mostly for nitrogen, phosphorus and potassium occurs between crop and weed species in natural ecosystems in terms of existence (Blaix *et al.,* 2018) and weeds generally show better abilities for absorbing and accumulating of mineral nutrients in their bodies in relatively large amounts (Corre-Hellou *et al.,* 2011; Srivastava and Hu, 2020). Respect to having different growth characteristics, crop and weed species differ in their competing abilities (Reddyl *et al.,* 2018).
Weeds as crop pests are mostly underestimated and cause significant productivity losses in agriculture each year (Chhodavadia *et al.,* 2014; Soltani *et al.,* 2017). Weed outbreaks have impacts in terms of human farming activities including increasing farm costs, being harmful to crops and spreading fast to other fields (Liebman *et al.,* 2016). Although various factors come into play, the occurrence of yield crop losses attributed to weeds depends on crop species used and plantation region. According to estimations, the yield losses because of weeds are about 10% in the less developed countries and 25% in the least developed countries (Harker, 2000; Zimdahl, 2013; Matloob *et al.,* 2015; Ozata, 2019).
Maize, a large cereal crop species belonging to Poaceae family is grown in 591.900 hectares and the production is 6.000.000 tones in Turkey as being the third most important crop after wheat and barley. Maize is the leading cereal crop cultivated throughout the world and the leading country in maize production is China (22%), and the other countries are USA (18%), Brazil (10%), and India (5%) (Tarim Orman, 2019). Maize is utilized for the production of a large variety of items including human food, animal feeds, biofuels, and other industrial goods (Veljkovic *et al.,* 2018). As a result of its economic importance, it is advantageous to protect maize from competing species of plants.
A plant considered as weed utilizes all resources and appears to be shown up as the results of agricultural practices, regional soil characteristics and climate (Vidotto *et al.,* 2016; Shaw, 2018). Among weeds, *Amaranthus retroflexus*; Redroot pigweed, is a monoecious annual flowering plant in the Amaranthaceae family native to the tropical Americas but seen on most continents (Eshete *et al.,* 2016; Deng, 2017; Iamonico and Palmer, 2020), *Convolvulus arvensis*; field bindweed, a climbing perennial plant in the Convolvulaceae

family native to Europe and Asia (Kaur and Kalia, 2012; Shekhawat *et al.,* 2017), *Cynodon dactylon* var. *villosus*; a perennial plant in the Poaceae family native to Europe and Asia (Naderi and Rahiminejad, 2015), *Datura stramonium*; also commonly known as thorn apple, stinkweed or Devil's apple, an erect freely branching annual plant in the Solanaceae family native to North America but seen in all the world's warm and moderate regions (Jiménez-Lobato *et al.*, 2018), *Echinochloa crus-galli*; also commonly known as cockspur, water grass or barnyard grass, an erect annual cosmopolitan plant in the Poaceae family (DiTomaso and Healv, 2003; Fried *et al.,* 2020), and *Portulaca oleracea*; also commonly known as common purslane and verdolaga, a succulent annual plant in the Portulacaceae family showing an extensive distribution throughout the world (Yazici *et al.,* 2007; Vaidya *et al.,* 2020) are recognized as a serious problem on agricultural production in Turkey.

Although many tactics have been implemented in recent years for weed control, the threat posed by weeds continues constantly for agricultural productivity (Chhodavadia *et al.*, 2014; Mahadi, 2014; Deng, 2017). Agricultural systems are in difficulty in preventing occurrences of new herbicide resistant weeds due to genetic alterations on weed populations. The purpose of this work is analyzing the competition capabilities of 6 commonly seen weed species in agricultural fields used for maize production in Turkey in which posing a serious problem for agricultural practices in terms of mineral nutrient uptake engagement. The results obtained from this study, could be used in establishing information foundation and in developing new strategies for the alleviation of this problem.

MATERIALS AND METHODS

All experiments were conducted at a field (40°58′56.52″N 29°20′47.00″E) in Emirli Village of the Pendik district, Istanbul (Fig. 1). *Amaranthus retroflexus* L., *Convolvulus arvensis* L., *Cynodon dactylon* (L.) Pers. var. *villosus*, *Datura stramonium* L., *Echinochloa crus-galli* (L.) Beauv and *Portulaca oleracea* L. and maize (*Zea mays* L.) were grown together for one month. After one month, the plant parts (leaf, branch and root) of maize and weeds along with their co-located soil samples were collected and subjected to experimental procedures for the determination of mineral nutrient uptake and accumulation capabilities of the plant species in order to show the competition rates between them.

Emirli Village (40°59′14″N 29°20′02″E) is in Pendik district of Istanbul, close to Omerli reservoir (the biggest water source of Istanbul) located on the Asian side of the city (Coskun and Alparslan, 2009; Pendik Municipality, 2020). While rainy Oceanic (Black Sea) and cold Balkan climates dominate the region during the winter periods, the climate in summer periods is hot and dry (Tayar *et al.*, 2013). The lowest and highest temperatures are seen in January (average 5.7ºC) and August (average 22.9ºC), respectively. The lowest and highest precipitations are seen in July (average 26 mm) and December (average 126 mm), respectively (Table 1) (MGM, 2020).

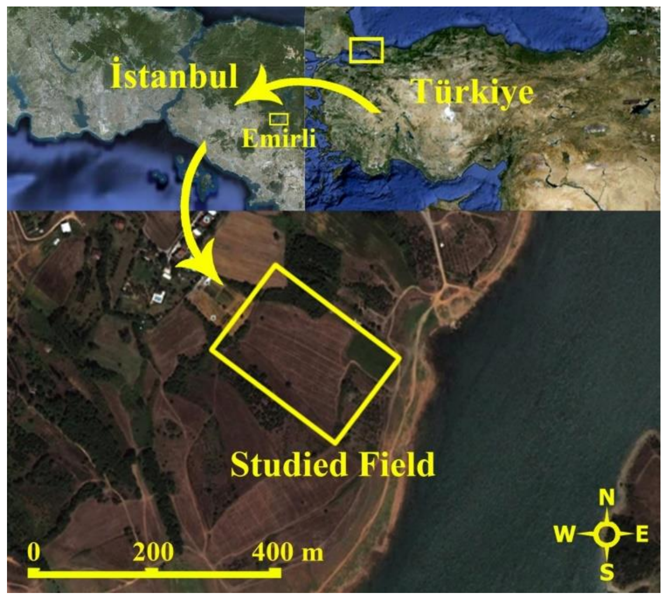

Figure 1. Map showing the study area (the location of the maize field in Emirli Village in Pendik District-Istanbul) (40°58′56.52″N 29°20′47.00″E).

Temperate climate with adequate water supply is the demand for gaining the highest yielding for maize production (Nafziger, 2016). For maize, the germination starts around 10-11°C and fastens when the soil temperature reaches around 15°C at the depth of 5-10 cm. Although maize prefers warm

Table 1. Climate data for Emirli Village-Istanbul, belonging to 2020 (MGM, 2020).

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Avg. Temp. (°C)	5.7	6.3	7.5	11.8	16.1	20.5	22.8	22.9	19.8	15.7	11.9	8.3
Min. Temp. (°C)	2.5	3.0	3.8	7.4	11.5	15.5	18.0	18.3	15.3	11.8	8.3	5.1
Max. Temp. (°C)	8.9	9.6	11.3	16.2	20.8	25.5	27.7	27.5	24.4	19.6	15.5	11.5
Avg. Temp. (°F)	42.3	43.3	45.5	53.2	61.0	68.9	73.0	73.2	67.6	60.3	53.4	46.9
Min. Temp. (°F)	36.5	37.4	38.8	45.3	52.7	59.9	64.4	64.9	59.5	53.2	46.9	41.2
Max. Temp. (°F)	48.0	49.3	52.3	61.2	69.4	77.9	81.9	81.5	75.9	67.3	59.9	52.7
Precipitation /Rainfall (mm)	108.0	72.0	68.0	51.0	37.0	28.0	26.0	37.0	54.0	82.0	93.0	126.0

climates to grow, extreme temperatures (>38°C) adversely affect plant growth causing damages. The optimum temperatures for optimum growth are between 25-30°C.

Based on our purpose, the plantation was done in April in our model maize field according to given information in Table 1. It was the right time for the plantation and following germination period and no excessive temperature was observed (<38°C) around the area throughout the cultivation period. Irrigation was not a problem during the experimental period because of water reservoir close to our field and the soil type was appropriate for growth.

Before the plantation of the maize seeds, the field was maintained weed-free and after the plantation and following the emergence, weeds allowed to be grown along with maize seedlings for one month in terms of estimating competition between them. No herbicides were used during the experimental period. The size of the maize field was 21.5 acres. Maize and weed species were hand-harvested after one-month experimental period. Two experiments were run, one for control (an area of the field was kept weed-free and only maize seedlings allowed to be grown) and the other for estimation of competition (weed and maize species allowed to be grown at the same time). The two experiments were identical. For the evaluation of the mineral nutrient statuses of the maize and weeds and their co-located soils, the concentrations of B, Ca, Cu, Fe, K, Mg, Mn, Na, Ni, and Zn (in mg kg^{-1} DW) were determined using inductively coupled plasma optical emission spectroscopy (PerkinElmer-Optima 7000 DV). For this, maize, weed and their co-located soil samples (8 samples were taken for each species) were collected from the field and for the analytical measurements of each sample; three repetitions were done for the statistical analyses.

For the determination of mineral nutrient concentrations, isolated plant parts were oven-dried at 80°C for 48 h. After transferring oven-dried samples (0.5 g taken for each) into Teflon vessels, 8 mL of 65% (v/v) HNO_3 (Merck) was added into each sample. Along with the collection of plant materials, also co-located soil sampling of the top 10 cm (about 500 g) were carried out by using a stainless steel shovel. After oven-drying at 80°C for 48 h and passing through a 2-mm sieve, they (0.3 g for each) were weighted and treated with 9 mL 65% (v/v) HNO_3, 3 mL 37% (v/v) HCl and 2 mL 48% (v/v) HF (Merck). Mineralization of the samples was carried out in a microwave oven (Berghof-MWS2). The operation parameters were as follows: 5 min. at 145°C, 5 min. at 165°C and 20 min. at 175°C. After cooling and filtration (using Whatman filters) of the samples, the volume (for each) was made up to 50 mL with ultrapure water (Human-Zeneer Power II) in volumetric flasks and stored in falcon tubes. The determination of element (Al, B, Ca, Cu, Fe, K, Mg, Mn, Na, Ni and Zn) concentrations (in mg kg^{-1} DW) was carried out using a calibration curve, which was prepared by the utilization of 10, 50, 100, 250 and 500 mg/L of standard solutions from multi-element stock solutions (1000 mg/L, Merck) (Altay *et al.,* 2013). The measurements were done by inductively coupled plasma optical emission spectroscopy (PerkinElmer-Optima 7000 DV).

All of the statistical evaluations were done through utilizing dry weights of parts (root, branch and leaf) of the plant species and their co-located soil samples via using MANOVA (Multivariate analysis of variance) with Tukey's post-hoc HSD for plant species by the application of IBM SPSS Statistics 20 software. Significant difference in expression is accepted at the $p= 0.01$ level.

RESULTS

In this study, mineral nutrient status of maize and 6 common weed species were measured to find out the competition capabilities of these species in agricultural fields. The obtained values from the parts of the plants and co-located soil samples were shown in Table 2. According to our results, the average lowest and highest element accumulations (Al, B, Ca, Cu, Fe, K, Mg, Mn, Na, Ni and Zn) in the plant parts of maize (mg kg^{-1} DW) were found to be ~43.97 and ~971.27 in branches and roots for Al, ~3.1 and ~9.87 in leaves and branches for B, ~1244.34 and ~2266.2 in branches and roots for Ca, ~4.95 and ~6.22 in branches and roots for Cu, ~22.77 and ~131.84 in branches and roots for Fe, ~5817.84 and ~7260.91 in branches and roots for K, ~873.6 and ~1396.29 in roots and branches for Mg, ~8.75 and ~61.83 in branches and roots for Mn, ~401.97 and ~1330.51 in branches and roots for Na, ~1.83 and ~5.87 in leaves and roots for Ni, ~18.45 and ~28.93 in roots and branches for Zn, respectively (Table 2). The average lowest and highest element accumulations in the plant parts of weeds (mg kg^{-1} DW) were found to be ~14.47 and ~623.08 in branches of *D. stramonium* and roots of *E. crus-galli* for Al, ~4.05 and ~17.62 in roots of *E. crus-galli* and leaves of *A. retroflexus* for B, ~1133.6 and ~4871.2 in branches of *C. dactylon* and roots of *C. arvensis* for Ca, ~2.4 and ~10.64 in roots of *D. stramonium* and roots of *E. crus-galli* for Cu, ~18.5 and ~662.0 in branches of *D. stramonium* and roots of *C. dactylon* for Fe, ~1652.04 and ~7932.08 in branches of *P. oleracea* and leaves of *E. crus-galli* for K, ~547.16 and ~3683.83 in roots of *C. arvensis* and leaves of *A. retroflexus* for Mg, ~2.75 and ~79.83 in branches of *D. stramonium* and leaves of *A. retroflexus* for Mn, ~228.53 and ~1574.63 in branches of *P. oleracea* and roots of *E. crus-galli* for Na, ~0.49 and ~8.62 in branches of *P. oleracea* and roots of *E. crus-galli* for Ni, ~1.02 and ~27.62 in roots of *E. crus-galli* and leaves of *C. dactylon* for Zn, respectively. The average lowest and highest element values of co-located soils (in mg kg^{-1}DW) were found as ~6020.48 for Al, ~2.55 for B, ~864.95 for Ca, ~5.04 for Cu, ~3696.82 for Fe, ~2368.5 for K, ~1082.15 for Mg, ~167.75 for Mn, ~86.34 for Na, ~9.95 for Ni, ~14.0 for Zn, respectively. According to the literature, the normal values of essential micronutrients (in mg kg^{-1} DW)

Table 2. Concentrations of Al, B, Ca, Cu, Fe, K, Mg, Mn, Na, Ni, and Zn (mg kg^{-1} DW). The mean difference is significant at 0.01 (**) level by the Tukey's test and multivariate analysis of variance (MANOVA).

		Zea mays	*Amaranthus retroflexus*	*Convolvulus arvensis*	*Cynodon dactylon*	*Datura stramonium*	*Echinochloa crus-galli*	*Portulaca oleracea*
Al	Leaf	48.21±0.505^{a}	91.16±1.019^{**d}	137.62±1.387^{**d}	97.69±1.066^{**c}	140.72±5.76^{**f}	151.68±2.18^{**b}	104.65±1.04^{**e}
	Branch	43.97±1.004^{a}	66.09±0.685^{**d}	105.39±1.116^{**d}	49.48±0.512^{**c}	14.46±0.155^{**f}	53.33±1.860^{**b}	31.97±0.344^{**e}
	Root	971.26±10.36^{a}	354.06±3.63^{**d}	287.88±1.478^{**d}	517.18±5.69^{**c}	31.57±0.490^{**f}	623.08±5.80^{**b}	85.52±0.889^{**e}
	Soil				6020.5±215.23			
B	Leaf	3.10±0.033^{e}	17.62±0.280^{**a}	11.63±0.142^{**b}	11.62±0.127^{**d}	9.078±0.095^{**d}	4.932±0.051^{**f}	9.212±0.099^{**c}
	Branch	9.87±0.078^{e}	14.94±0.364^{**a}	11.55±0.131^{**b}	6.74±0.080^{**d}	8.345±0.083^{**d}	4.382±0.050^{**f}	9.353±0.097^{**c}
	Root	7.22±0.171^{e}	11.62±0.226^{**a}	9.136±0.102^{**b}	5.97±0.061^{**d}	6.359±0.065^{**d}	4.046±0.045^{**f}	8.630±0.093^{**c}
	Soil				2.55±0.080			
Ca	Leaf	140.94±23.27^{e}	1402.3±14.91^{**c}	3537.4±39.65^{**a}	1848.4±19.97^{**f}	2158.6±22.87^{**b}	2206.9±23.99^{**d}	4093.1±36.94^{**b}
	Branch	1244.3±13.45^{e}	2492.7±23.98^{**c}	2294.4±23.62^{**a}	1133.6±11.90^{**f}	3689.8±43.97^{**b}	1856.5±17.00^{**d}	1656.6±15.86^{**b}
	Root	2266.2±23.09^{e}	3396.0±34.23^{**c}	4871.2±31.82^{**a}	1359.3±14.83^{**f}	2723.8±27.82^{**b}	2225.8±23.64^{**d}	2921.8±25.86^{**b}
	Soil				864.95±20.89			
Cu	Leaf	5.95±0.046^{d}	5.84±0.062^{**e}	9.886±0.104^{**b}	8.751±0.093^{**a}	9.318±0.078^{**e}	4.592±0.048^{**c}	7.115±0.064^{**c}
	Branch	4.95±0.051^{d}	4.31±0.047^{**e}	4.801±0.052^{**b}	7.723±0.084^{**a}	2.762±0.031^{**e}	3.683±0.040^{**c}	5.694±0.060^{**c}
	Root	6.22±0.046^{d}	4.47±0.043^{**e}	5.934±0.058^{**b}	8.939±0.086^{**a}	2.400±0.025^{**e}	10.64±0.113^{**c}	6.174±0.066^{**c}
	Soil				5.04±0.113			
Fe	Leaf	71.84±0.500	107.14±1.09**	137.39±1.41**	111.51±1.15**	121.28±1.24**	67.79±0.783**	108.96±1.18**
	Branch	22.77±0.235	71.00±0.790**	87.48±0.925**	40.66±0.444**	18.505±0.209**	29.67±0.303**	37.24±0.381**
	Root	131.84±1.47	193.99±2.09**	242.72±2.30**	661.99±4.71**	33.598±0.341**	429.71±4.63**	107.96±1.10**
	Soil				3696.8±100.41			
K	Leaf	6909.6±57.22	3807.2±40.76**	4336.0±46.13**	6661.6±52.38**	1822.3±19.70**	7932.1±70.02**	2116.6±10.70**
	Branch	5817.8±41.18	4436.9±44.26**	4027.0±42.14**	5046.7±44.21**	5818.5±40.10**	2896.1±24.62**	1652.0±97.90**
	Root	7260.9±73.14	6354.9±52.61**	3059.1±32.91**	3904.7±41.50**	2914.1±31.45**	5999.1±42.11**	2937.3±24.45**
	Soil				2368.5±60.47			
Mg	Leaf	1224.3±11.48	3683.8±40.04**	2961.0±31.87**	1829.5±15.28**	1679.3±19.56**	2483.7±27.44**	3287.7±36.07**
	Branch	1396.3±14.93	2011.1±20.84**	863.59±7.277**	2145.9±21.45**	2417.8±23.97**	2258.5±25.35**	2717.8±29.57**
	Root	873.60±8.99	624.14±6.333**	547.16±5.614**	661.32±7.110**	885.51±3.75**	1382.6±13.88**	2305.4±22.52**
	Soil				1082.2±28.70			
Mn	Leaf	17.74±0.184^{b}	79.83±0.842^{**a}	41.13±0.461^{**e}	26.12±0.284^{**c}	71.11±0.797^{**c}	21.00±0.211^{**d}	34.44±0.387^{**e}
	Branch	8.750±0.087^{b}	6.525±0.063^{**a}	6.520±0.058^{**e}	12.85±0.132^{**c}	2.748±0.028^{**c}	16.64±0.189^{**d}	7.127±0.075^{**e}
	Root	61.83±0.656^{b}	15.88±0.166^{**a}	14.64±0.158^{**e}	41.37±0.441^{**c}	6.119±0.071^{**c}	33.78±0.575^{**d}	18.81±0.193^{**e}
	Soil				167.75±3.79			
Na	Leaf	598.10±6.85	505.79±5.276**	397.46±4.36**	700.36±7.17**	395.65±4.08**	1514.4±16.83**	518.61±5.57**
	Branch	401.97±4.28	1485.4±15.41**	388.41±4.21**	899.59±8.76**	259.33±2.78**	1033.4±11.47**	228.53±2.52**
	Root	1330.5±14.6	1560.6±15.03**	566.86±6.14**	1296.5±13.47**	329.04±3.27**	1574.6±17.27**	313.96±3.45**
	Soil				86.34±3.722			
Ni	Leaf	1.834±0.018^{c}	0.634±0.007^{**e}	0.861±0.009^{**e}	7.391±0.075^{**b}	1.833±0.020^{**d}	2.319±0.027^{**a}	1.064±0.012^{**e}
	Branch	3.184±0.035^{c}	0.663±0.006^{**e}	0.557±0.006^{**e}	1.885±0.021^{**b}	1.226±0.014^{**d}	1.865±0.019^{**a}	0.486±0.005^{**e}
	Root	5.874±0.042^{c}	0.640±0.008^{**e}	0.657±0.007^{**e}	2.972±0.035^{**b}	0.763±0.008^{**d}	8.617±0.094^{**a}	0.615±0.006^{**e}
	Soil				9.949±0.389			
Zn	Leaf	21.57±0.232	5.392±0.099**	4.963±0.113**	27.61±0.288**	1.245±0.092**	2.307±0.078**	11.47±0.119**
	Branch	28.93±0.300	10.66±0.114**	3.968±0.183**	17.46±0.126**	5.210±0.143**	2.252±0.097**	9.075±0.126**
	Root	18.45±0.219	4.195±0.090**	3.316±0.102**	16.19±0.212**	1.574±0.017**	1.021±0.051**	7.705±0.081**
	Soil				14.00±0.409			

in crop plants are in the ranges of from 10-100 for B, 5-30 for Cu, 50-250 for Fe, 30-300 for Mn, 0.5-5 for Ni and 20-150 for Zn, respectively (Kabata-Pendias and Pendias, 2001; Kacar and Katkat, 2007; Blume *et al.*, 2015). Normal values of essential macronutrients (mg kg^{-1} DW) in plants lie between 1000-50000 for Ca, 10000-50000 for K, 1500-10000 for Mg and 100-100000 for Na (often beneficial for plants) (Kabata-Pendias and Pendias, 2001; Kacar and Katkat, 2007). Soils (mg kg^{-1}) contain B, Cu, Mn, Ni and Zn within the broad ranges of from 20-200, 25-75, 10-9000, 0.2-450, 3-300, respectively (Kabata-Pendias and Pendias, 2001; Kacar and Katkat, 2007; Kabata-Pendias and Mukherjee, 2007). The mean levels in soils (in mg kg^{-1}) for B, Cu, Mn, Ni and Zn vary from 22-45, 13-24, 270-525, 12-34, 45-100, respectively (Kabata-Pendias and Pendias, 2001). The approximate concentrations of Al, Ca, Fe, K, Mg and Na (in mg kg^{-1}) in soils are 40000, 13700, 50000, 25000, 8400 and 10000, respectively (Kabata-Pendias and Pendias, 2001; Kacar and

Table 3. Correlation coefficients between the roots and leaves of 7 plant species used in this study.

	Al Root	B Root	Ca Root	Cu Root	Fe Root	K Root	Mg Root	Mn Root	Na Root	Ni Root	Zn Root
Al Leaf	-0.549**	-0.327	0.293	0.103	0.100	-0.529**	0.090	-0.653**	-0.314	-0.026	-0.831**
B Leaf	-0.511**	0.726**	0.387*	-0.352*	0.075	-0.237	-0.335*	-0.591**	0.002	-0.723**	-0.271
Ca Leaf	-0.585**	0.116	0.495**	-0.001	-0.206	-0.724**	0.600**	-0.457**	-0.740**	-0.386*	-0.317
Cu Leaf	-0.535**	0.113	0.339*	-0.421*	-0.029	-0.802**	-0.325	-0.430**	-0.684**	-0.665**	-0.029
Fe Leaf	-0.748**	0.472**	0.581**	-0.526**	-0.132	-0.790**	-0.250	-0.710**	-0.650**	-0.884**	-0.279
K Leaf	0.880**	-0.517**	-0.450**	0.818**	0.685**	0.640**	-0.251	0.794**	0.791**	0.864**	0.402*
Mg Leaf	-0.480**	0.663**	0.578**	-0.060	-0.107	-0.145	0.256	-0.585**	-0.048	-0.439**	-0.528**
Mn Leaf	-0.630**	0.595**	0.403*	-0.775**	-0.458**	-0.187	-0.287	-0.759**	-0.207	-0.681**	-0.538**
Na Leaf	0.442**	-0.669**	-0.439**	0.821**	0.518**	0.419*	0.236	0.350*	0.587**	0.869**	-0.163
Ni Leaf	0.249	-0.510**	-0.719**	0.502**	0.830**	-0.099	-0.221	0.418*	0.278	0.221	0.534**
Zn Leaf	0.523**	-0.127	-0.582**	0.335*	0.482**	0.173	-0.094	0.747**	0.261	0.148	0.963**

**.Correlation is significant at the 0.01 level (2-tailed); *.Correlation is significant at the 0.05 level (2-tailed).

Table 4. Correlation coefficients between the elements determined in the roots of 7 plant species used in this study.

	B	Ca	Cu	Fe	K	Mg	Mn	Na	Ni	Zn
Al	-0.290	-0.401*	0.530**	0.347*	0.823**	-0.269	0.931**	0.751**	0.773**	0.617**
B		0.634**	-0.560**	-0.422*	0.013	-0.156	-0.367*	-0.107	-0.708**	-0.070
Ca			-0.430**	-0.470**	-0.277	-0.159	-0.580**	-0.401*	-0.520**	-0.526**
Cu				0.796**	0.270	0.187	0.543**	0.547**	0.734**	0.212
Fe					0.068	-0.237	0.371*	0.537**	0.391*	0.279
K						-0.217	0.654**	0.853**	0.640**	0.309
Mg							-0.072	-0.352*	0.077	-0.102
Mn								0.582**	0.699**	0.818**
Na									0.639**	0.259
Ni										0.185

**. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed).

Katkat, 2007; Kabata-Pendias and Mukherjee, 2007; Landon, 2014; Barker and Pilbeam, 2015).

In this study, post-hoc comparisons using the Tukey HSD test indicated that there is a significant difference in the mean scores of Al, B, Ca, Cu, Fe, K, Mg, Mn, Na, Ni, and Zn. Tukey HSD post-hoc tests are reported as homogenous subset output. Since the main effect in MANOVA table is found as significant, the Homogenous Subsets can be interpreted (Table 2). The results of Tukey test belong to the plant parts of 7 plant species were obtained in terms of using *p* values based on the data from the elements' concentrations of maize and the other six weed species. According to Table 2, considering homogeneous subsets expressions, *A. retroflexus* with *C. arvensis* for Al, *C. dactylon* with *D. stramonium* for B, *D. stramonium* with *P. oleracea* for Ca, *E. crus-galli* with *P. oleracea* and *A. retroflexus* with *D. stramonium* for Cu, *C. dactylon* with *D. stramonium* and *C. arvensis* with *P. oleracea* for Mn, and *A. retroflexus* and *C. arvensis* with *P. oleracea* for Ni are located in the same groups. Herein, the mineral elements taken by the plants from the soil are found to be at the same relative ratio in the plant parts used reflecting relative same distribution rates.

The data for correlation coefficients determined by using elements' concentrations from root and leaf parts of maize and weed species were given in Table 3 (between root and leaf parts) and Table 4 (in root part). When referring the data found in table 3 and 4, the values selected were at least equal to 0.50 and/or above. This situation statistically showed the dimension of the relationship between the elements and the parts in which the plant is taken up. Those with positive high correlations were interpreted as the two values were in interaction parallelly, while those with negative high correlations were interpreted as while one value increases while the other one decreases significantly in opposite way. These significant correlations in both tables show that there were interactions between plants used in this work depending on the competition.

DISCUSSION

In the current work, it was noticed that the concentrations of Al, Ca, Cu, Fe, Mn, Na, Ni and Zn were within normal ranges in the plant parts of maize but some fluctuations were noticed (Table 2). Similar observations were done for the concentrations of Al, B, Ca, Cu, Fe, K, Mg, Mn, Na and Ni in the plant parts of all studied weeds. The concentrations of Al, Ca, Cu, Fe, Mg, Na and Ni in the plant parts of weeds were found to be within the normal ranges although some fluctuations were observed as well. The concentrations of B, K, Mn and Zn were found to be lower than the normal ranges as seen in Table 2. (Kabata-Pendias and Pendias, 2001; Kacar and Katkat, 2007; Blume *et al.*, 2015), although the concentrations of B, Ca, Cu, Fe, K, Mg and Na from the experimental field (soil) were found to be lower than the normal ranges and though the concentrations of Mn, Ni and Zn were found to be within normal ranges (Kabata-Pendias and Pendias, 2001; Kacar and Katkat, 2007; Kabata-Pendias and Mukherjee, 2007; Landon, 2014; Barker and Pilbeam, 2015).

The concentrations of B, Ca (except in *A. retroflexus*), Cu (except in *A. retroflexus* and *E. crus-galli*), Fe (except in *E. crus-galli*), Mg and Mn (in mg kg^{-1} DW) were higher in leaves of all studied weeds in comparison with leaves of maize showing better ability for having those mineral elements by indicated weed species than maize whereas the concentrations of K (except in *E. crus-galli*), Na (except in *C. dactylon* and *E. crus-galli*), Ni (except in *C. dactylon* and *E. crus-galli*) and Zn (except in *C. dactylon*) were higher in leaves of maize in comparison with leaves of all studied weeds showing better ability for having those mineral elements by maize than indicated weed species. From our data, it can be said that active accumulations of B, Ca, Cu (except in *E. crus-galli*), K (except in *D. stramonium*), Mg and Na were observed in leaves of maize and in leaves of weed species. Also, active Al deposition was noticed in leaves of *D. stramonium*, *E. crus-galli*, *P. oleracea* and *Z. mays*.

In general, maize for K, Mn, Ni and Zn; *A. retroflexus* and *C. arvensis* for B; *C. arvensis*, *D. stramonium* and *P. oleracea* for Ca; *C. dactylon* for Cu and Zn; *A. retroflexus*, *C. arvensis* and *C. dactylon* for Fe; *E. crus-galli* and *P. oleracea* for Mg; *E. crus-galli* for Na were found to be having better accumulation capabilities from the surrounding environments. However, the amounts of mineral elements accumulated in the plants in our work indicating a race between maize and weed species in terms of efforts for having enough mineral elements for their metabolisms is obvious. According to our results, the average highest accumulation for Al was found to be in maize (26%), followed by *E. crocus-galli* (21%) whereas the average lowest accumulations for Al were found to be in *D. stramonium* (5%) and *P. oleraceae* (5%). The average highest and lowest accumulations were found to be in *A. retroflexus* (24%) and *E. crocus-galli* (7%) for B; *C. arvensis* (21%) and *C. dactylon* (9%) for Ca; *C. dactilon* (19% and 29%) and *D. stramonium* (11% and 6%) for Cu and Fe; maize (21%) and *P. oleraceae* (7%) for K; *P. oleraceae* (22%) and maize (9%) for Mg; *A. retroflexus* (19%) and *P. oleraceae* (11%) and *C. arvensis* (11%) for Mn; *E. crocus-galli* (25%) and *D. stramonium* (6%) for Na; *E. crus-galli* (28%), followed by *C. dactilon* (27%) and maize (24%), and *C. arvensis* (4%) and *A. retroflexus* (5%) for Ni, respectively (Fig. 2). It seems that the average accumulation amounts of the elements by each species were not related with their body sizes but due to the needs for their metabolisms. Also, *A. retroflexus* (11%) is found to be having minimum accumulation capability for Cu along with *D. stramonium*. Nickel is known as not a beneficial mineral nutrient for some plant species and it is also not a very important mineral nutrient for some plant species. Also, some plant species have capability for taking up Ni efficiently from the soil (Ozyigit and Dogan, 2014). An interesting result from our study is that among the all plant species used in this work, 3 of them (79%) showed the highest capacity for accumulating of Ni whereas 4 of them (21%) showed lower capacity for accumulating of Ni. A similar result was observed for Zn. Zn is an important mineral nutrient for plant species and in this present work, the highest accumulations for Zn were done by maize (33%) and *C. dactylon* (30%) whereas the lowest accumulations for Zn were done by *E. crocus-galli* (3%) and *D. stramonium* (4%).

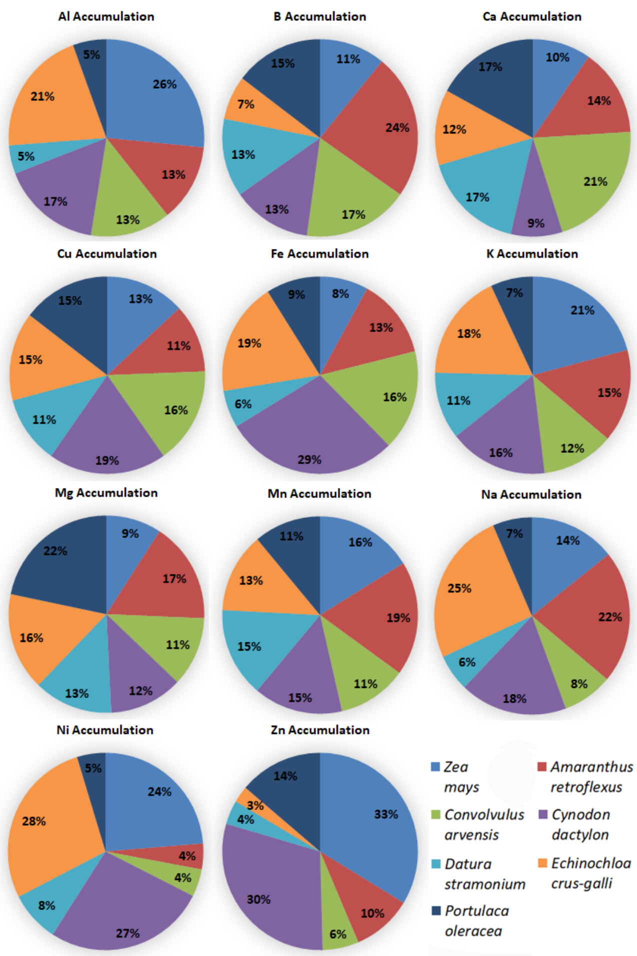

Figure 2. Pie charts of % accumulations in maize (*Zea mays* L.) and weed species used in this study.

It is known that some plant species as accumulators are particularly good in accumulation of Zn. In this work, while the accumulation amounts for Ca, Cu, K, Mg, Mn and Na were close to each other in the plant species, some plant species showed much better ability in the accumulations of

Al, B, Fe, Ni and Zn in comparison with the others. In comparing of the plants used in this study, maize was the first for the accumulations of Al, K and Zn, while second for Mn, the third for Ni, the fourth for Na, the fifth for Cu, the sixth for B, Ca and Fe, and the seventh for Mg. This shows that although some mineral elements are accumulated at high rates by maize, it does not have better accumulation capabilities for some mineral elements in comparison with the others in terms of competition. A competitive study related with uptake and accumulation of mineral nutrients between cold-tolerant maize and weed species was performed using weedy and weed free areas and in that study, the P, Ca and N contents of the samples collected from weed-free areas were found to be 3.17, 3.24 and 4.73 times greater in comparison with weedy areas (Lehoczky *et al.*, 2013). A study performed by Safdar *et al.* (2016) showed that maize grain yield losses due to *Parthenium hysterophorus* (an invasive weed species) were varied between 21 and 53% and N, P, and K uptake increases by *P. hysterophorus* were also recorded in comparison with maize. A research conducted by Glowacka (2012) showed that the weeds examined contained higher Cu content in comparison with maize and Zn content in maize was less than the weed species studied. Also, competitiveness in the uptake of Mn and Fe showed species specificity. Among the weeds used in this work, *Chenopodium album* L. and *Galinsoga parviflora* Cav. were the most competitive in accumulating Mn and *Cirsium arvense* L. showed higher ability to accumulate Fe, quite higher than maize and other weeds species. Also, a similar study done once again by Glowacka (2011) revealed that all the studied weed species showed more competitiveness than maize for Ca, K and Mg accumulations. The most competitive species in comparison with maize were *C. arvense* for Ca, *G. parviflora* for K and *C. album* and *Polygonum lapathifolium* L. subsp. *lapathifolium* for Mg. In another study, 14-63% maize yield losses were recorded due to competition occurred between maize and *D. stramonium* that is a weed commonly found in maize fields (Cavero *et al.*, 1999). Additionally, in a similar study performed by Ghasemi-Fasaei and Mansoorpoor (2015) showed that Fe concentration was found to be higher in five studied weeds in comparison with maize and the highest Mn concentration was determined in above-ground parts of *E. crus-galli*. The concentrations of Mn, Fe and Cu in *E. crus-galli* tissues and the concentrations of Fe and Cu in *C. arvensis* tissues in fields studied were noticeably higher in comparison with maize.

Weed control is an important issue for preventing yield losses and lowering of production costs as well as for preserving product quality (Mahadi 2014; Rasool and Khan 2016; Soltani *et al.,* 2017). In another study, the evaluation of tembotrione in an attempt to increase the uptake of mineral nutrient efficiency in maize in a field was done in comparison with *Cyperus rotundus* L., *C. dactylon*, *Phyllanthus niruri* L. and *Digitaria sanguinalis* (L.) Scop. in weedy check plots (Akhtar *et al.,* 2017). A successive research was conducted by Mahadi (2014) in order to obtain the best weed control and having the highest contents of N, P and K in leaves of maize using atrazine plus metolachlor by 2.6 kg ai ha^{-1} application. By application of weed management strategies, not only the mineral nutrient accumulation, but also almost all growth parameters of crops including plant height, dry matter, number of functional leaves, leaf area index and various photosynthetic parameters are influenced positively in terms of competition (Rasool and Khan, 2016; Deewan *et al.*, 2017).

Conclusions: The results showed that some mineral nutrients (B, Ca, Cu, K, Mg and Na) were actively accumulated by maize and weed species used in this study. The concentration ranges of mineral elements (except B) in leaves of maize were found to be in insufficient levels due to the competition occurred between maize and weed species. In general, maize for K, Mn, Ni and Zn; *A. retroflexus* and *C. arvensis* for B; *C. arvensis*, *D. stramonium* and *P. oleracea* for Ca; *C. dactylon* for Cu and Zn; *A. retroflexus*, *C. arvensis* and *C. dactylon* for Fe; *E. crus-galli* and *P. oleracea* for Mg; *E. crus-galli* for Na were found to be having better accumulation capabilities. Finally, the inadequate uptake of some minerals including B, Ca, Cu, Mg, Na and Zn as shown in our study for maize was due to the competition with weeds. The losses in productivity can be preventable by supplying those minerals in adequate amounts.

Conflict of interest: The authors declare that there is no conflict of interest.

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