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EFFECTS OF DIFFERENT IRRIGATION LEVELS AND NITROGEN DOSSES ON MINERAL CONTENTS OF MAIZE GRAINS

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Abstract
This study was conducted to determine the effects of different irrigation levels and nitrogen doses on macro and micronutrient contents of maize grains. Experiments were conducted with 3 different irrigation levels (100, 75 and 50% of field capacity) and 3 different nitrogen doses (100, 200 and 300 kg ha^{-1}). Experiments were conducted in summer-growing seasons of the years 2013-2014 in split plots experimental design with 3 replications (irrigation levels on main plots and nitrogen doses on sub-plots).
Grain N, P, B, Na, Fe, Mn, Zn and Mg contents increased and K, Ca, S, and Cu, contents decreased with increasing irrigation levels. Grain N, P, S, Cu, Fe and Mn contents increased. Grain K, Ca, and Mg contents initially increased and then decreased later on with increasing nitrogen doses. Nitrogen treatments were found to be as much effective as irrigation levels on grain mineral contents. Supportive treatments (irrigation, nitrogen) are recommended to eliminate mineral deficiencies in maize culture of the regions with water stress conditions.

Keywords: maize, irrigation, nitrogen fertilizer, macro element, micro element

1. INTRODUCTION

Inorganic elements, minerals commonly found in nature play significant roles in human growth and development. Besides macro and micronutrients, humans need vitamins and minerals to improve or preserve their health. Macro nutrients constitute the primary energy source of human body. Vitamins and minerals are required for various biochemical processes in human body. Since human body is not able to produce minerals, they play a critical role in preservation of health (Kara et al. 2016). Mineral deficiencies in human diets recess emotional and physiological development and increase infectious diseases especially in children, pregnant and nursing women (Hussain et al. 2010; Paiva et al. 2017). Cereals are the most common nutrients since they constitute the primary source of calorie in human diets. Therefore, cereals are the greatest sources of carbohydrates, protein, fat and minerals for humans.

Maize is cultivated in various climate zones of the world and with rich nutrient contents, it is used in human and animal feeding as a significant cereal crop. Maize is also used as a raw material in starch-based sugar, starch, oil and feed industries (Kara 2011).

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Irrigation and fertilization are the most important inputs in agriculture and they both have significant effects on yield and quality (Kaplan et al. 2016; Islam et al. 2012). Irrigation water and nitrogen management are the critical issue in maize culture to improve yield levels and to reduce environmental pollution (Ashraf et al. 2016). There is a close relationship between soil moisture content and availability of plant nutrients. The greatest benefit from fertilizer treatments is achieved under irrigated conditions. Nutrient uptake is limited under deficit water applications (Hussaini et al. 2008).

Recent increases in world population, current drought and climate change and various anthropogenic activities gradually reduced the amount of water allocated to agriculture (World Bank 2006). Increasing industrial and domestic uses have made water a deficit source for agriculture (Rijberman 2006). Arid and semi-arid regions cover about one-third of world surface and deficient water resources of such areas also significantly restrict agricultural activities. In these regions, low-efficiency irrigation methods are used to deliver about 85% of available water and such a case then aggravate water deficiency (Er-Raki et al. 2010). Water is the most significant factor restricting yields in agricultural activities. There is a need for appropriate irrigation programs in these regions to get maximum yield per unit area (Kızıloğlu et al. 2009).

When applied through proper methods and at appropriate doses, irrigation and nitrogen treatments reduce the yield losses in maize. These two parameters have a positive correlation. (Di Paolo and Rinaldi 2008). Grain mineral composition is directly related to available nutrients at plant root zone. Available water content at root zone is the most significant factor effecting plant nutrient uptake (Kara et al. 2016). Eryüce and Kılıç (2001) reported that insufficient irrigations resulted in quite low nutrient uptake of maize plants. According to researchers, about 368 liters of water is required for 1 kg dry matter production in maize. In this study, effects of different irrigation levels and nitrogen doses on grain mineral content of maize plants were investigated.

2. MATERIALS AND METHODS

Field Experiments

This research was conducted in 2013-2014 for two years at Kayseri (39°48'N; 38°73'E) province of Turkey. Simon hybrid maize cultivar was used as the plant material of the study. Seed were sown in 6x4.2 m plots at 70x15 cm spacing. Based on field capacity, 3 different irrigation levels (50%, 75% and 100%) and 3 different nitrogen doses (10, 20 and 30 kg/da N) were applied to experimental plots. Experiments were conducted in split plots experimental design with 3 replication. Irrigations were placed on main plots and nitrogen doses were placed on sub-plots. Amount of irrigation water to be applied was determined weekly with a neutron meter and irrigations were performed through drip lines. Nitrogen doses were determined based on soil analyses. Half of the nitrogen was applied at sowing and the other half was applied when the plants reached to a height of 50 cm. Together with nitrogen fertilization, 18 kg/da P_2O_5 was also applied at sowing. Hoeing and chemical treatments were performed for weed control throughout the growing season. Morphological observations were performed and plants were harvested at milk-dough stage. Side effects were taken into consideration while calculating yields.

Soil and Climate Characteristics

Seeds were sown on 23rd of April in the first year and on 28th of April in the second year. Temperatures of the experimental years were generally similar with the long-term averages. Precipitations of the first year were lower than the long-term averages in the first year and higher in the second. Relative humidity values of the experimental years were generally lower than the long-

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term averages. Unexpected low temperatures were also experienced for short durations in experimental years, but they were not indicated in Table 1.

Table 1. Precipitation, temperature, and relative moisture data of experimental site

Months	Temperature (˚C)			Precipitation (mm)			Relative Humidity (%)		
	2013	2014	Long Term*	2013	2014	Long Term*	2013	2014	Long Term*
April	12.1	14.1	10.7	43.6	2.9	54.8	56.2	44.3	62.6
May	18.1	16.7	15.1	31.3	39.7	52.0	44.7	50.4	60.8
June	21.1	19.7	19.1	12.6	52.9	39.1	38.7	46.8	55.3
July	22.5	25.2	22.6	3.4	0.0	10.3	36.9	33.7	49.5
August	22.5	25.1	22.0	0.8	47.4	5.3	36.0	37.4	49.8
September	17.0	18.8	17.1	10.3	85.4	13.3	44.1	54.2	54.4
October	9.2	11.7	11.5	52.5	54.4	30.5	58.9	68.1	64.0
Mean	17.5	18.7	16.8	-	-	-	45.0	47.8	56.6
Total	-	-	-	154.5	282.7	205.3	-	-	-

*from 1970 to 2013

Soil samples were taken from 0-30 and 30-60 cm soil profiles in both years (2013 and 2014 years). All soil samples were analyzed in Erciyes University, Agricultural Faculty, Soil Science and Plant Nutrition Department. Soil was sandy-loam in texture with low lime and salt contents, rich in potassium (K_2O) and phosphorus (P_2O_5), slightly alkaline and poor in organic matter in in both years (Table 2).

Table 2. Physical and chemical characteristics of soils of the experimental site

Property	2013		2014	
	0-30 cm	30-60 cm	0-30 cm	30-60 cm
Clay (%)	13.10	8.94	12.58	9.18
Silt (%)	4.16	10.40	5.11	9.55
Sand (%)	82.74	80.66	82.31	81.27
Class	Sandy-Loamy	Sandy-Loamy	Sandy-Loamy	Sandy-Loamy
pH	7.94	7.75	7.48	7.60
Organic Matter (%)	1.05	1.27	1.09	1.14
$CaCO_3$ (%)	0.28	0.27	0.24	0.29
K_2O (kg ha^{-1})	1092.20	755.14	1184.20	842.34
P_2O_5 (kg ha^{-1})	89.63	11.56	110.41	12.58
EC (mmhos/cm^{-1})	0.96	0.23	0.83	0.27

Grain Mineral Content Analyses

Maize grain samples were dried in an oven at 70 °C for 48 hours. Dried grain samples were then ground in a mill with 1 mm sieve and made ready for mineral analyses. For grain nutrient analyses, about 0.5 g dry plant samples were taken and samples were then subjected to wet digestion in 10 ml nitric + perchloric acid mixture until having 1 ml samples. Following the digestion process,

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resultant solutions were diluted with distilled water and readings were performed in ICP OES (Inductively Couple Plasma spectrophotometer) (Perkin-Elmer, Optima 4300 DV, ICP/OES, Shelton, CT 06484-4794, USA) to determine sample P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu and B contents (Mertens 2005).

Statistical Analyses

Experimental data were subjected to variance analysis using SAS (SAS Inst. 1999) statistical software in accordance randomized block experimental design to compare the treatment means. The LSD multiple range test was employed to compare the treatment means as a complement of the ANOVA procedure.

3. RESULTS AND DISCUSSIONS

This study conducted determine of irrigation level and nitrogen fertilization doses on maize grain macro and micronutrient in 2013 and 2014 years.

Macronutrients

Effects of different irrigation levels and nitrogen doses on maize grain macro and micronutrients of maize were investigated in this study. The effects of different irrigation levels and nitrogen doses on grain macro nutrients are provided in Table 3. Different irrigation levels and nitrogen doses had significant effect on grain macro nutrients ($p<0.01$).

Irrigation x nitrogen interaction had highly significant effects on macro nutrients, except for N. The greatest grain N content was obtained from N_3 nitrogen treatment (2661.99 ppm) and I_{100} irrigation treatment (2615.78 ppm) and the lowest N content was obtained from N_1 nitrogen treatment (2008.76 ppm) and I_{50} irrigation treatment (2339.02 ppm). The lowest grain P content (5087.60 ppm) was obtained from $I_{50}xN_1$ treatment, and the greatest P content (8398.53 ppm) was obtained from $I_{100}xN_3$ treatment and the treatment of $I_{50}xN_2$ (8321.58 ppm) was also placed in the same statistical group. Maize grain K contents varied between from 6411.47 to 7984.05 ppm with the lowest K content value in $I_{75}xN_3$ treatment and the greatest K content value in $I_{50}xN_2$ treatment (Table 3).

The grain Ca contents varied between from 1535.36 ppm to 3961.84 ppm with the greatest Ca content value in $I_{100}xN_2$ treatment and the lowest Ca content value in $I_{50}xN_1$ treatment. Maize grain Mg contents varied between 878.68 - 1935.59 ppm with the greatest value in $I_{100}xN_3$ treatment and the lowest Mg contents value in $I_{75}xN_1$ treatment. There were not significant differences in Mg contents of $I_{100}xN_3$ and $I_{100}xN_2$ treatments. The greatest grain S content was obtained from $I_{50}xN_3$ treatment (3521.73 ppm) and the lowest S content was obtained from $I_{100}xN_2$ treatment (2379.41 ppm).

Micro Elements

Effects of different irrigation levels and nitrogen doses on grain micronutrients are provided in Table 4. As can be inferred from Table 4, different irrigation levels had significant effects on all micronutrients, except for B and Na ($p<0.01$). On the other hand, different nitrogen doses had highly significant effects on all micronutrients, except for B ($p<0.01$). Irrigation x nitrogen interaction had highly significant effects on all micronutrients ($p<0.01$).

While both irrigation levels and nitrogen doses did not have significant effects on grain B contents, irrigation x nitrogen interaction had significant effects on B contents ($p<0.05$). The lowest B content was obtained from $I_{50}xN_3$ treatment (9.83 ppm) and the greatest B content was obtained from $I_{100}xN_3$ treatment (10.56 ppm). The greatest Cu content (18.61 ppm) was obtained from $I_{50}xN_2$ treatment, and the lowest Cu content (17.23 ppm) was obtained from $I_{100}xN_1$ treatment. Grain Fe

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contents increased with increasing irrigation levels and nitrogen doses. The greatest Fe content was obtained from $I_{100}xN_2$ treatment (8.85 ppm) and the lowest Fe content was obtained from $I_{100}xN_1$ treatment (2.49 ppm). Grain Mn contents were significantly influenced by irrigation levels and nitrogen doses and increased with increasing irrigation levels and nitrogen doses. The greatest Mn content (7.32 ppm) was obtained from $I_{100}xN_3$ treatment, and the lowest Mn content (2.81 ppm) was obtained from $I_{100}xN_1$ treatment. Grain Na contents increased with increasing irrigation levels but decreased with increasing nitrogen doses. The greatest Na content (315.28 ppm) was obtained from $I_{100}xN_2$ treatment, and the lowest Na content (288.35 ppm) was obtained from $I_{50}xN_3$ treatment. The lowest Zn content was obtained from $I_{50}xN_2$ treatment (33.54 ppm) and the greatest Zn content was obtained from $I_{100}xN_3$ treatment (56.17 ppm).

Table 3. Effects of different irrigation levels and nitrogen doses on grain macro nutrients

N (ppm)				
Irrigation Levels	Fertilizer Doses			Means
	N1	N2	N3	
I_{50}	2109.33^{d}	2387.04^{bcd}	2520.69^{bc}	2339.02^{B}
I_{75}	2184.67^{cd}	2413.47^{bcd}	2562.63^{ab}	2386.92^{B}
I_{100}	2332.27^{bcd}	2612.40^{ab}	2902.67^{a}	2615.78^{A}
Means	2208.76^{C}	2470.97^{B}	2661.99^{A}	

Irrigation Levels: ** ; Fertilizer doses:** ; Irrigation levels× Fertilizer doses: NS

P (ppm)				
Irrigation Levels	Fertilizer Doses			Means
	N1	N2	N3	
I_{50}	5087.60^{f}	5891.13^{cd}	6106.11^{c}	5694.94^{B}
I_{75}	5740.25^{d}	5949.94^{cd}	5406.58^{e}	5697.59^{B}
I_{100}	6613.15^{b}	8321.58^{a}	8398.53^{a}	7777.75^{A}
Means	5813.66^{B}	6719.55^{A}	6637.07^{A}	

Irrigation Levels:** ; Fertilizer doses:** ; Irrigation levels× Fertilizer doses: **

K (ppm)				
Irrigation Levels	Fertilizer Doses			Means
	N1	N2	N3	
I_{50}	7780.16^{a}	7984.05^{a}	7814.30^{a}	7859.50^{A}
I_{75}	7165.99^{b}	7757.49^{a}	6411.47^{c}	7111.65^{B}
I_{100}	6470.04^{c}	7220.02^{b}	6954.88^{b}	6881.65^{C}
Means	7138.73^{A}	7653.85^{A}	7060.21^{B}	

Irrigation Levels: ** ; Fertilizer doses:** ; Irrigation levels× Fertilizer doses: **

Ca (ppm)				
Irrigation Levels	Fertilizer Doses			Means
	N1	N2	N3	
I_{50}	1535.46^{f}	1853.92^{d}	1709.03^{e}	2388.66^{A}
I_{75}	2148.85^{b}	1966.16^{c}	1924.32^{cd}	2013.11^{B}
I_{100}	1709.27^{e}	3961.84^{a}	1494.89^{f}	1699.47^{C}
Means	1797.86^{B}	2593.97^{A}	1709.41^{C}	

Irrigation Levels:** ; Fertilizer doses:** ; Irrigation levels× Fertilizer doses: **

Mg (ppm)				
Irrigation Levels	Fertilizer Doses			Means
	N1	N2	N3	
I_{50}	942.31^{d}	1107.76^{c}	953.03^{d}	1001.03^{C}
I_{75}	878.68^{e}	1127.59^{c}	1140.83^{c}	1049.03^{B}
I_{100}	1381.10^{b}	1921.39^{a}	1935.59^{a}	1746.03^{A}
Means	1067.36^{C}	1385.58^{A}	1343.15^{B}	

Irrigation Levels: ** ; Fertilizer doses:** ; Irrigation levels× Fertilizer doses: **

S (ppm)				
Irrigation Levels	Fertilizer Doses			Means
	N1	N2	N3	
I_{50}	3077.37^{c}	3269.98^{b}	3521.73^{a}	3289.69^{A}
I_{75}	2699.11^{d}	2502.63^{e}	2421.89^{e}	2541.21^{B}
I_{100}	2456.20^{e}	2379.41^{e}	2635.33^{d}	2490.31^{C}
Means	2744.23^{B}	2717.34^{B}	2859.65^{A}	

Irrigation Levels:** ; Fertilizer doses:** ; Irrigation levels× Fertilizer doses: **

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Table 4. Effects of different irrigation levels and nitrogen doses on grain micronutrients

B (ppm)

Irrigation Levels	Fertilizer Doses			Means
	N1	N2	N3	
I_{50}	10.41^{ab}	10.07^{abc}	9.83^{c}	10.10^{B}
I_{75}	9.97^{bc}	10.25^{abc}	10.34^{ab}	10.18^{AB}
I_{100}	10.24^{abc}	10.13^{abc}	10.56^{a}	10.31^{A}
Means	10.20^{A}	10.15^{A}	10.24^{A}	

Irrigation Levels: NS; Fertilizer doses: NS; Irrigation levels× Fertilizer doses: *

Zn (ppm)

Irrigation Levels	Fertilizer Doses			Means
	N1	N2	N3	
I_{50}	37.21^{e}	33.54^{f}	45.40^{c}	38.71^{B}
I_{75}	39.27^{d}	37.90^{de}	38.74^{de}	38.63^{B}
I_{100}	43.53^{c}	50.97^{b}	56.17^{a}	50.22^{A}
Means	40.00^{C}	40.80^{B}	46.77^{A}	

Irrigation Levels: **; Fertilizer doses: **; Irrigation levels× Fertilizer doses: **

Cu (ppm)

Irrigation Levels	Fertilizer Doses			Means
	N1	N2	N3	
I_{50}	18.24^{ab}	18.61^{a}	18.07^{abc}	18.31^{A}
I_{75}	17.68^{bc}	17.65^{bc}	18.23^{ab}	17.85^{B}
I_{100}	17.23^{c}	17.36^{c}	17.96^{abc}	17.52^{C}
Means	17.72^{B}	17.87^{AB}	18.09^{A}	

Irrigation Levels: **; Fertilizer doses: **; Irrigation levels× Fertilizer doses: *

Fe (ppm)

Irrigation Levels	Fertilizer Doses			Means
	N1	N2	N3	
I_{50}	2.49^{g}	3.84^{f}	6.97^{b}	4.43^{C}
I_{75}	4.64^{e}	4.92^{e}	5.34^{d}	4.97^{B}
I_{100}	6.03^{c}	8.85^{a}	8.84^{a}	7.91^{A}
Means	4.39^{C}	5.87^{B}	7.05^{A}	

Irrigation Levels: **; Fertilizer doses: **; Irrigation levels× Fertilizer doses: **

Mn (ppm)

Irrigation Levels	Fertilizer Doses			Means
	N1	N2	N3	
I_{50}	3.14^{fg}	3.34^{f}	2.94^{gh}	3.14^{C}
I_{75}	4.57^{d}	3.58^{e}	5.14^{c}	4.43^{B}
I_{100}	2.81^{h}	5.56^{b}	7.32^{a}	5.23^{A}
Means	3.50^{C}	4.16^{B}	5.13^{A}	

Irrigation Levels: **; Fertilizer doses: **; Irrigation levels× Fertilizer doses: **

Na (ppm)

Irrigation Levels	Fertilizer Doses			Means
	N1	N2	N3	
I_{50}	313.65^{a}	302.83^{ab}	288.35^{b}	301.61^{B}
I_{75}	302.61^{ab}	310.02^{a}	301.09^{ab}	304.57^{AB}
I_{100}	302.31^{ab}	315.28^{a}	305.76^{a}	307.78^{A}
Means	306.19^{A}	309.38^{A}	298.40^{B}	

Irrigation Levels: NS; Fertilizer doses:*; Irrigation levels× Fertilizer doses: *

There is a positive correlation between the available moisture in root zone and root water uptake (Albrizio et al. 2010). Root nutrient uptake decreases under dry conditions, reduced transpiration rates from the roots to shoots and destructed active transportation systems significantly restrict nutrient transport (Viets 1972, Hsiao 1973, Kramer and Boyer 1995). Water stress and nitrogen deficiency was reported to restrict root growth and development (Sharp and Davies 1979, Kaplan et al. 2014). Weak root system reduces plant nutrient uptake from the soil. In this study, reductions were observed in plant N, B, Fe, Mn, Zn and Na uptakes with water deficits.

Negative impacts of water stress on photosynthetic parameters result in changes in chemical composition (Ali et al. 2010). Leaf stomas close in plants under water stress, then carbohydrate quantity decreases and carbohydrate and protein metabolites like proline and glycine accumulate in leaves (Pelleschi et al. 1997). The nutrients accumulated in leaves cannot be transported to grain because of water deficit, then grain protein and N contents decrease. In present study, decreases were observed in grain N contents with decreasing irrigation levels.

It was reported in previous studies that increasing water stress reduced plant growth development and yields. But, several other studies indicated increased quality with increasing water stress. High

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K and Ca concentrations were observed at greater water deficits (Rouphael et al. 2008). In this study, increasing grain K and Ca contents were observed with decreasing irrigation levels.
Nitrogen treatments increase N, P, K and S contents of both the plants and the grains (Jackson 2000). Plant S requirement and metabolism is closely related to N nutrient of the plants (Reuveny et al. 1980) and plant N metabolism is also influenced by plant S status (Duke and Reisenauer 1986). N deficiency reduce S use efficiency of the plants (Abdallah et al. 2010). Drought stress decreases total P accumulation in plants and thus have negative effects on plant growth and development (Al-Karaki and Al-Raddad 1997).
Different rages for Fe and Zn concentrations may be related to soil and environmental conditions or genotypic variation (Amiri et al. 2015). Water deficit reduces the quantities of elements like Mg, Mn and Fe playing a role in enzyme activity, protein synthesis and photosynthetic activity of the plants (Arpali et al. 2016). Although drought influences uptake of different nutrients, low soil moisture levels also reduce the uptake of these elements from the roots. Drought reduces uptake of Mn, Zn and Fe -like minerals able to dissolve in sufficient water. Fe significantly reduces oxidative stress in plants and drought incidents. Fertilization and irrigation increase plant Zn, Mn and B uptakes (Bender et al. 2013).
Drought resistant cultivars usually have greater mineral uptakes than the other cultivars (Yasar et al. 2014), thus differences are observed in grain mineral contents. Amiri et al. (2015) carried out a study with different wheat genotypes and reported increasing Fe contents with drought stress. Kutman et al. (2011) indicated that nitrogenous fertilization improved Zn availability and increased Fe and Zn uptake from the soil and thus increased grain Fe and Zn contents.
Mg plays a significant role in activation of an enzyme responsible for respiration and photosynthesis and exists in structure of chlorophyll. Mg contents of all cultivars generally decrease under drought conditions. Significantly decreasing Mg contents were reported with increasing drought stress (Ashraf et al. 1998; Yu et al. 2007) and resultant decreases then had negative effects on photosynthetic activity and grain formation (Slamka et al. 2011). Mg deficiency under drought stress also reduce chlorophyll content, stomal conductance and photosynthetic activity (Korkmaz et al. 2007).
Calcium has distinctive effects on cell walls, membrane structure, cell division, photomorphonogenesis-like various structural and physiological processes and also has a protective impact against stress conditions (Nayyar 2003). In present study, increasing water stress increased grain Ca accumulation.

4. CONCLUSIONS

Increasing irrigation levels increased N, P, B, Na, Fe, Mn, Zn and Mg contents and decreased K, Ca, S, and Cu contents. Increasing nitrogen doses increased N, P, S, Cu, Fe and Mn contents. With increasing nitrogen doses, K, Ca, and Mg, contents initially increased and then decreased later on. Nitrogen treatments were found to be as much effective as irrigation levels in mineral uptake of maize plants from the soil and both treatments (irrigation levels and nitrogen doses) had significant effects on uptake of different nutrients from the soil. However, both treatments increased uptake of Fe and Zn which were considered as the most common deficiencies worldwide. High irrigation levels and nitrogen doses are recommended in maize culture of the regions with nutrient deficiencies.

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