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EFFECT OF NPK FERTILIZER ON THE AVAILABILITY OF ZINC, IRON AND MAIZE YIELD IN CALCAREOUS SOIL

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ABSTRACT

A field experiment was carried out in the fields of the Department of Soil Sciences and Water Resources / College of Agriculture and Forestry/ University of Mosul to study the impact of mineral fertilization with N, P, and K on the concentration of iron and zinc in both soil and corn plant (*Zea mays* L.) grown in calcareous soil suffers from iron and zinc deficiency. The experiment was carried out in three replicates and included two factors: the first was fertilized with three levels, control treatment, the fertilization treatment with half the recommended amount, and finally, the fertilization treatment with the full recommended amount of N, P, and K, which is 320 kg N ha^{-1}, 200 kg P_2O_5 ha^{-1}, and 80 kg K_2O ha.$^{-1}$, the second factor is the measuring periods for the concentration of iron and zinc in the leaves, which are 15, 30, and 60 days after germination, in addition to measuring the concentration of the two elements in the seeds after harvest. The results showed a decrease in the available concentration of iron and zinc in the study soil, and the added NPK elements did not have a significant effect on the available concentration of these two elements in the soil, while it increased the concentration of iron and zinc in the leaves. It also increased the concentration and content of grains of the two elements. The highest concentration of the two elements and the highest grain yield were used as the full fertilizer recommendation for N, P, and K elements.

INTRODUCTION

Despite the small amount of iron and zinc that the plant needs, these two elements are considered among the necessary elements for which the plant is indispensable (AL-Hamandi *et al*., 2024 and Aljumaily *et al*., 2022). Iron is included in the synthesis of cytochrome, which is responsible for the transfer of electrons, it also participates in the oxidation and reduction processes that occur during the processes of respiration and photosynthesis, in addition to the participation of iron is involved in the formation of plant proteins, its entry into the synthesis of nitrogenase enzyme, and the activation of many enzymes, such as nitrate reductase (Bruns *et al*., 2006 and Al-Badrani, 2019). Zinc has an important role in many metabolic processes that occur in plants. It is a structural component, a catalyst, and a regulator of a large number of enzymes, it is also responsible for the formation of the amino acid tryptophane, which is involved in the manufacture of auxin (IAA), which is necessary for cell elongation (AL-Hamandi *et al*., 2024). Although zinc is not included in the formation of chlorophyll, it is involved in the enzymes responsible for the formation of chlorophyll. Zinc has a major role in the representation of nitrogen in plants. Hence, a deficiency of zinc leads to a sharp decrease in the level of RNA and the content of ribosomes in the cells, which causes inhibition of the formation of proteins and affects the formation of pollen grains (Hafeez *et al*., 2013).

One of the problems of calcareous soils is their low content of availability nutrients, especially the micronutrient ones, this is due to the chemical characteristics of these soils, including the high value of soil pH. Calcium carbonate is one of the soil components most capable of fixation microelements, especially iron and zinc, as lime can strongly absorb microelements, making them not available for plants (Naeem, 2015; Hassan, 2017 and Muhammed, 2022). Iraqi soils have a high content of calcium carbonate, which may reach 35%, and may exceed this percentage in some soils with depth, these soils are poor in organic matter and available nitrogen and phosphorus, and the lack of iron and zinc in them is considered a problem for many regions. The high degree of soil pH, the increase in the percentage of calcium carbonate in it, and the decrease in the percentage of organic matter have a direct impact on the decrease in its content of the available amount of iron and zinc (Ghaffari *et al*., 2011).

Corn is considered the third most important field crop in the world after wheat and rice. It is the staple food for 4.5 billion people from 94 developing countries, and the United States is considered the largest exporter of corn in the world (Al-Hamdany, 2008). Corn is characterized by its high production capacity, in addition to its multiple uses as human food, animal feed, in the industrial field, and the production of biofuels (Shiferaw *et al*., 2011), as corn is used to produce ethanol, which constitutes about 40% of corn production in the United States (Ranum *et al*., 2014).

To achieve high production of corn, it is necessary to add relatively high amounts of the elements N, P, and K, especially in Iraqi soils that suffer from a deficiency of these element (Zhang *et al*., 2013). These additions cause interference with other necessary elements that corn needs, especially iron and zinc (Mohammad, 2012 and Hasan, 2017). This research aimed to study the effect of increasing additions of N, P, and K fertilizers on the concentration of iron and zinc in both soil and corn plants grown in calcareous soil suffering from iron and zinc deficiency.

MATERIALS AND METHODS

A field experiment was carried out in the experimental field of the Department of Soil Sciences and Water Resources / College of Agriculture and Forestry/ University of Mosul, located within latitude (36°23¯02.87˭ N) and longitude (43°08¯02.18˭ E) during the 2023 agricultural season using loamy soil (Intisols). A soil sample was taken randomly before planting from the surface layer (0-30 cm), air-dried, ground, and passed through a 2mm sieve for the chemical and physical analysis Table 1.

The field was plowed twice horizontally and vertically, then smoothed and leveled, divided into three panels, and the distance between one panel and another was 1.5 m. Each panel included three experimental units; each unit's area was 1 × 1 m, and the distance between one experimental unit and another was 0.5 m. The experiment was designed according to a completely randomized design. The experiment included two factors, the first was fertilization at three levels, comparison treatment without fertilization, the fertilization treatment with half the recommended amount, and finally the fertilization treatment with the recommended amount of the elements N, P, and K, the second factor was the periods for measuring concentration of iron and zinc, which were 15, 30 and 60 days after germination. Fertilizers were added before planting, urea fertilizer 46% N, triple superphosphate fertilizer 47.5% P_2O_5, and potassium sulfate 50% K_2O, according to the recommended quantity for each element, which is 320 kg N ha^{-1}, 200 kg P_2O_5 ha^{-1}, and 80 kg K_2O ha^{-1} for fertilizers before respectively (Kumar *et al*., 2014).

Table (1): Some of the chemical and physical properties of the two soils studied.

Characteristic	Unit	Value
pH 1:1	----	7.4
EC 1:1	ds m^{-1}	0.90
Organic matter	g Kg^{-1}	11.00
Total Calcium carbonate	g Kg^{-1}	250
CEC	Cmolekg^{-1}	17.50
Available N	mg Kg^{-1}	14.00
Available P	mg Kg^{-1}	9.00
Available K	mg Kg^{-1}	325
Field capacity	g Kg^{-1}	220
Sand	g Kg^{-1}	455
Silt	g Kg^{-1}	315
Clay	g Kg^{-1}	230
Soil texture		Loam

Three seeds of corn, zp-glorya cultivars, were planted for each hole in lines on 15/7/2023, and the distance between one hole and another was 0.25 m. They were thinned to one plant per hole five days after germination. Samples of soil and all leaves of plant were taken from each experimental unit at (15, 30, and 60 days after germination) to estimate the concentration of availability of iron and zinc in the soil and total iron and total zinc in the leaves. The concentration of the two elements in the seeds was also estimated at the end of the experiment. The concentration of both iron and zinc in the soil was estimated based on the method presented by Tandon, (2005) using an extraction solution (DTPA) ratio of 1:2, then shaking, filtering, and measuring using an atomic absorption spectrophotometer.

After harvesting the crop on 5/11/2023, the seeds and leaves were collected (for each period separately), dried, ground, and digested using concentrated sulfuric acid H_2SO_4 and hydrogen peroxide H_2O_2 concentration 30%. The concentration of iron and zinc in the soil extract and the acidic extract of the plant was estimated using an atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

The effect of NPK and the measurement period on the concentration of available iron and zinc elements in the soil

It is noted from tables (2 and 3) that the concentration of iron and zinc in the research soil is less than the critical limit for these two elements in calcareous soils, which is 4 mg kg^{-1} for iron (Ghaffari *et al.*, 2011) and 1 mg kg^{-1} for zinc (Soltanpour and Schwab, 1977).

Table (2): Effect of fertilization with N, P, and K on the soil's available iron (ppm) during the measurement periods.

Fertilization treatments	Measurement period (day)			Fertilization effect
	P_1	P_2	P_3	
F_0	1.88	1.44	1.24	1.52
F_1	1.68	1.42	1.29	1.46
F_2	1.56	1.40	1.07	1,34
Periods effect	1.70	1.42	1.20	
Fertilization: 0.18 Periods: 0.18 Fertilization × periods: 0.31				least significant difference (LSD) at the 0.05

Table (3): Effect of fertilization with N, P, and K on the available zinc (ppm) in the soil during the measurement periods.

Fertilization treatments	Measurement period (day)			Fertilization effect
	P_1	P_2	P_3	
F_0	0.82	0.76	0.73	0.77
F_1	0.79	0.74	0.73	0.75
F_2	0.74	0.67	0.71	0.70
Periods effect	0.78	0.72	0.72	
Fertilization: 0.14 Periods: 0.14 Fertilization × periods: 0.25				least significant difference (LSD) at the 0.05

This may be due to the increased concentration of calcium carbonate, the high degree of soil reaction, and the decrease in the percentage of organic matter (Table 1), which exposes these two elements to precipitation and adsorption reactions, thus reducing their availability in the soil, as the high calcium carbonate in the soil leads to a high degree of soil pH and thus deposition iron on the soil as ferric hydroxides. The presence of calcium carbonate increases soil aeration, causing the oxidation of the available ferrous ions to ferric ions, which are less available. The high degree of soil reaction leads to an increase in the intensity of adsorption of zinc to the mineral (goethite), and this leads to a restriction of the movement of zinc, and the rate of dissolution of compounds containing zinc decreases, especially when the amount of calcium carbonate is high as a result of its precipitation in the form of zinc carbonate (Kumar, *et al.*, 2014) It is also noted from the previous two tables that the concentration of iron and zinc in the soil decreased with the addition of NPK fertilizers, and the highest decrease in the treatment (F_2) was when adding the full fertilizer recommendation, as the percentage of decrease was 11.84% and 9.09% for both iron and zinc respectively compared to the non-fertilized treatment (F_0) which recorded the highest concentration of the two elements (1.52 and 0.77) ppm respectively. Regarding the effect of the measurement period on the concentration of iron and zinc, it is noted that the available concentration of these two elements decreases with time, as the lowest concentration of iron (Table 2) in the measurement period P_3 was 1.20 ppm, a decrease of 29.41% from the highest concentration of iron (1.70 ppm) in the first measurement period. There was no significant difference in the concentration of zinc between the measurement periods P_2 and P_3 (Table 3), which was 0.72 ppm, and the percentage of decrease in these two treatments was 7.69% compared to the measurement period P_1, which recorded the highest zinc concentration of 0.78 ppm. Regarding the effect of the interaction between fertilization treatments and the measurement period on the concentration of iron and zinc, it is noted that the highest concentration of iron and zinc is 1.88 and 0.82 ppm, respectively, in the non-fertilized treatment at the first measurement period (F_0P_1), with an increase of 75.7% and 22.38% over the lowest concentration of the two elements, which is 1. 07 for iron in treatment F_2P_3 and 0.67 for zinc in treatment F_2P_2. The decrease in the concentration of iron and zinc with fertilization can be attributed to the formation of iron phosphate and zinc phosphate compounds as a result of the reaction of phosphorus added in the form of triple superphosphate fertilizer with both iron and zinc, thus precipitating these two elements in the soil (Gérard, 2016 and Zhang *et al*., 2017). The decrease in the concentration of iron and zinc in the soil over time may be due to increased absorption of the two elements by the plant with increased growth. In addition to the increase in sedimentation processes for the two elements over time and thus the available concentration of these two elements in the soil decreases (Bruns *et al*., 2006).

The effect of N, P, K and the measurement period on the concentration of iron and zinc in corn leaves

It is noted from Tables (4 and 5) that the lowest concentration of iron and zinc in corn leaves was in non-fertilized plants (comparison treatment F_0). Fertilization with the elements N, P and K led to an increase in the concentration of the two elements, and the highest increase was in the fertilization treatment with the complete recommendation fertilizer F_2, as the concentration of the two elements increased from 35.83 and 14.80 ppm in the comparison treatment to 54.11 and 15.47 in the treatment (F_2), with an increase rate of 51.01% and 4.52% for iron and zinc, respectively.

It is also noted that the concentration of iron and zinc increased over time as the concentration of the two elements in the leaves increased in the second and third measurement periods (except iron concentration in the P_2 measurement period, which decreased to 44.17 ppm). The increase in the concentration of the two elements in the leaves with fertilization may be due to the increased demand for these two elements due to improved plant growth as a result of adding mineral fertilizers, especially phosphate fertilizer, which increases the growth and depth of the roots, thus increasing the plant's ability to extract these two elements from the soil and increasing their concentration within the plant, the highest concentration of iron and zinc was in the measurement period P_3, which recorded 49.71 and 17.02 ppm for the two elements, respectively, while the lowest concentration of the two elements in the first measurement period P_1. The results are consistent with the results of (Xue *et al*., 2014), who indicated that fertilization with NPK elements increases the concentrations of microelements in corn, especially iron and zinc.

Table (4): Effect of fertilization with N, P, and K on iron concentration (ppm) in corn leaves during the measurement periods.

Fertilization treatments	Measurement period (day)			Fertilization effect
	P_1	P_2	P_3	
F_0	34.64	34.22	38.64	35.83
F_1	46.20	51.67	52.50	50.12
F_2	57.70	46.64	58.00	54.11
Periods effect	46.18	44.17	49.71	
Fertilization: 5.97 Periods: 5.97 Fertilization × periods :10.33				least significant difference (LSD) at the 0.05

Table (5): Effect of fertilization with N, P, and K on zinc concentration (ppm) in corn leaves during the measurement periods.

Fertilization treatments	Measurement period (day)			Fertilization effect
	P_1	P_2	P_3	
F_0	13.78	13.83	16.80	14.80
F_1	14.41	14.45	17.15	15.33
F_2	15.12	16.65	17.11	15.47
Periods effect	14.43	14.97	17.02	
Fertilization: 0.94 Periods : 0.94 Fertilization × periods: 1.64				least significant difference (LSD) at the 0.05

Effect of N, P, and K on grain yield, concentration and seeds content of iron and zinc

The results of Table (6) indicate that mineral fertilization led to an increase in the yield of corn grains, and the highest yield was when using the full recommendation for the three elements N, P, and K, as the yield increased to 728 gm m^{-2}, a 75.8% increase over the non-fertilizer treatment that recorded the lowest yield 414 gm m^{-2}, This increase in grain yield can be attributed to the important role played by the elements N, P and K in the plant, in addition to the stimulating role of these elements in increasing the absorption of other elements such as iron and zinc (Tables 4 and 5) the results are consistent with the results of (Kumar *et al*., 2015 and Gul *et al*., 2015) and are also consistent with what Liu *et al*., (2011), indicated who observed an increase in corn grain yield by 23% when fertilized with NPK compared to non-fertilized plants. The results of the table indicate an increase in the concentration of iron and zinc and the amount absorbed from these two elements in the seeds with increasing mineral fertilization, this may be due to an increase in the concentration of these two elements in the leaves and thus an increase in the concentration and content of the two elements in the seeds.

Table (6): Effect of fertilization with N, P, and K on grain yield, seed concentration and grain content of iron and zinc.

Fertilization treatments	Grain yield (g m^{-2})	Iron		Zinc	
		conc. (ppm)	Content mg m^{-2}	conc. (ppm)	Content mg m^{-2}
F_0	414	57.16	23.66	21.41	8.86
F_1	584	58.03	33.88	21.66	12.64
F_2	728	61.54	44.80	22.83	16.62
LSD	38.02	10.91	4.538	2.243	3.549

This is consistent with what was indicated by Palai *et al*., (2020) who noted that fertilization with NPK caused an increase in the seeds' content of microelements, including iron and zinc, it also agrees with the results of Karki *et al*., (2005) who indicated a significant increase in the concentration and absorbed amount of zinc when fertilized with (120 kg N + 26.2 kg P + 41.5 kg K ha^{-1}) compared to (60 kg N + 13.2 kg P + 20.8. kg K ha^{-1}).

CONCLUSIONS

From the above, we conclude that adding mineral fertilizers for N, P, and K increases the concentration and content of iron and zinc in corn leaves and grains, and the highest grain yield was when the full fertilizer recommendation for N, P, and K was used.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

تأثير سماد NPK في جاهزية الزنك والحديد وحاصل الذرة الصفراء في تربة كلسية

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الخلاصة

نفذت تجربة حقلية في أحد حقول قسم علوم التربة والموارد المائية التابع لكلية الزراعة والغابات/ جامعة الموصل بهدف دراسة تأثير التسميد المعدني بعناصر N وP وK في تركيز عنصري الحديد والخارصين في كل من التربة ونبات الذرة الصفراء (*Zea mays* L.) المزروع في تربة كلسية تعاني من نقص الحديد والخارصين. نفذت التجربة بثلاث مكررات وتضمنت عاملين الاول التسميد بثلاث مستويات من التوصية السمادية وهي معاملة المقارنة ومعاملة التسميد بنصف الكمية الموصي بها واخيرا معاملة التسميد بالكمية الموصي بها من عناصر N وP وK وهي 320 كغم N هـ$^{-1}$ و200 كغم P_2O_5 هـ$^{-1}$ و80 كغم K_2O هـ$^{-1}$ اما العامل الثاني فهو فترات قياس تركيز عنصري الحديد والخارصين في الاوراق وهي (15 و30 و60) يوم

بعد الانبات بالإضافة الى قياس تركيز العنصرين في البذور بعد الحصاد. بينت النتائج انخفاض تركيز عنصري الحديد والخارصين الجاهزين في تربة الدراسة ولم يكن لعناصر NPK المضافة تأثيرا معنويا في التركيز الجاهز لهذين العنصرين في التربة، بينما زاد من تركيز الحديد والخارصين في الاوراق كما زاد من تركيز ومحتوى الحبوب من العنصرين وكان اعلى تركيز للعنصرين واعلى حاصل حبوب عند استخدام التوصية السمادية الكاملة لعناصر N و P و K.

الكلمات المفتاحية: التربة الكلسية، الحديد الجاهز، الخارصين الجاهز، الذرة، سماد NPK.

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