Response of maize (Zea mays L.) growth to potassium application and Zn and Cu spray and its content in soil

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Abstract

. The study was conducted in the Experiment Station belong to Department of Soil Sciences and Water Resources, College of Agriculture, Tikrit University, Saladin Governorate during fall season of 2023 in gypsiferous soil, maize plants Gloria variety, of Serbian origin was planted to study effect of adding potassium fertilizer and spraying zinc and copper on growth characteristics of maize plants and mineral content of soil, study included addition of Potassium sulphate at a concentration of (41.5% K) as a source of potassium at three levels (0, 100, 200) kg K ha-1 as (K0, K1, K2), respectively , second factor was copper sulphate (CuSo4.5H2o) sprayed with three concentrations (0, 15, 35) mg Cu L-1 as (C0, C1, C2) respectively and third factor was spraying zinc sulphate fertilizer (ZnSo4.7H2o) at three concentrations (0, 50, 100) mg Zn L-1 as (Z0, Z1, Z2), respectively. Experimental results showed that potassium fertilizer (K2) excelled in giving it highest plant height, leaf area and soil potassium availability of 193.98 cm, 618.11 cm2 and 154.69 (mg kg-1 soil), respectively. Zinc spray treatment (Z2) also excelled in giving highest increase in plant height, leaf area and soil zinc availability of 189.54 cm , 605.94 cm2 and 0.548 (mg kg-1 soil), respectively. Copper spraying treatment (C2) also excelled it gave highest values for studied traits of 190.78 cm, 601.50 cm2, 0.446 and 0.274 (mg kg-1 soil) for plant height, leaf area, soil zinc and copper availability respectively. These traits were significantly impacted by twice and triple interactions between the research factors.

Keywords: maize, zinc, foliar application, copper, growth

*part of M.Sc. Thesis for first authors.

INTRODUCTION

Fertilizers are applied to plants in order to supply one or more of elements required for growth. Basic fertilizers are those that may be given directly to soil; foliar spraying is a technique that plants can use in addition to fertilizers [1]. Plants require nutrients they require for growth and development because these nutrients are formed into chemicals that are essential for plant's internal metabolic activities. These elements are found in soil, but their availability might not be sufficient for plants because of high soil acidity, which makes them less ready, or because they don't move around as much. Additionally, competition between positive ions affects how well roots absorb these elements from the soil, so using compound fertilizers and their solutions is a crucial way to ensure that element deficiencies are treated more quickly during crucial stages of plant life [2, 3].

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Potassium is an element that easily moves from leaves to other plant tissues. It is also rapidly absorbed, with an average increase in amount absorbed from it exceeding average production of plant dry matter. During early stages of a plant's growth, potassium builds up inside the plant, particularly in new and vital parts relative to older parts, particularly the lower leaves of the plant, before moving to other parts of the plant. Potassium is found in relatively significant amounts in soils, but most of it is not exchangeable and is quickly lost when it takes the form of dissolved salts such phosphates, chlorides, and sulfate in addition to nitrates, this prevents plants from absorbing potassium, is crucial for absorbing carbon dioxide from the air, according to numerous studies, and its shortage lowers the rates at which photosynthesis occurs [4, 5]. Potassium participates in several stages of production of proteins in plants, which increases absorption of nitrogen and production of proteins. It also promotes growth of meristematic tissues by increasing division of live plant cells, an essential component of cell division. It also aids in production of carbohydrates and building blocks of sugars that are produced in leaves and delivered to their storage locations. Furthermore, because potassium affects how well plants absorb water, it actively regulates the mechanism that opens and closes stomata. This helps to raise osmotic potential of plant cells and permits water to enter them, causing swelling or an increase in turgor pressure, both of which are essential for cell expansion [4, 6, 7]. Many studies have proven role of potassium in plant growth and elements availability, in a study conducted on maize plants to study effect of mineral fertilizers on growth and soil N, P, K availability [8] found that NPK fertilizer gave highest soil nitrogen and potassium content, highest plant height as compared with unfertilized plants. [9] Also found in his study on response of ‘Sumer’ maize cultivar to three levels of potassium (0, 80 and 160 kg K ha-1) that addition of this fertilizer, especially at 160 kg ha-1 showed a significant superiority in plant height, leaf area and leaf chlorophyll index as compared with control treatment.

Foliar spraying is a crucial practice for advancement of modern agriculture, as research and experiments have shown that it is possible to supply plants with a range of nutrients by spraying solutions of these nutrients, which plants can then efficiently absorb from their leaves and other parts that emerge above soil's surface. When soil conditions make it difficult for plants to absorb nutrients, foliar fertilization is very helpful. This is especially true for micronutrients like manganese, zinc, iron, and copper, which are typically fixed in the soil by soil particle deposition and are therefore not readily available to plants. Instead, they are added as salts or in a coated state, and since plants only require small amounts of these minor mineral elements, spraying them on the soil at the right time is a good way to meet their needs[10, 11]. Zinc-containing foliar fertilizers are advised because they supply nutrients, particularly micronutrients, that aerial plant parts cannot produce on their own. Additionally, mechanism of nutrient absorption by leaf cells is similar to that of nutrient absorption by root cells because primary step in absorption is transport through cellular membranes. In some situations, foliar feeding with zinc is helpful, particularly when nutrient absorption through soil is challenging [12, 13]. Plants require a very small amount of zinc to function properly in their enzymatic, physiological, and metabolic processes. For

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agricultural plants to thrive and reproduce regularly, zinc is a crucial and important nutrient. Many enzymes and proteins involved in many metabolic pathways, such as pollen generation, cell membranes, photosynthesis, protein metabolism, carbohydrate synthesis, and resistance to pathogen infection, depend on zinc as a structural element and regulatory cofactor [12, 14]. Numerous research were conducted to find out how zinc spraying affected mineral content of soil and growth of maize, in a study carried out by [15] effects of zinc sulfate ($ZnSO_4.H_2O$) and zinc-EDTA were linked to zinc (Zn) applied spraying at (0.75 $g.L^{-1}$) and in soil on maize plants. The results indicated that, in comparison with control treatment, plant height and soil nitrogen and potassium availability significantly increased at zinc spraying. In another experiment it included soil application and four level of foliar spray (control, 0.5% $ZnSO_4$ ha^{-1}, 0.5% $FeSO_4$ ha^{-1} and 0.5% $ZnSO_4$ ha^{-1} + 0.5% $FeSO_4$ ha^{-1}) in nutrient content in soil after harvest of maize [16] found spraying of zinc significantly affected soil nitrogen, phosphorus, potassium, zinc and iron concentration after harvest, while foliar spray of $ZnSO_4$ and $FeSO_4$ could not significantly affect soil manganese and copper concentration after harvest.

Copper is essential for plants since it is a powerful fungicide in addition to a nutrient. It is one among eight elements that plants require in trace amounts in order to grow and perform their important functions, soil rocks contain huge amounts of copper. Only a minor portion of it dissolves in soil solution, it plays a number of significant roles in plants, most significant of which is that it is an enzymatic partner for essential plant functions like oxidation and reduction reactions. In addition to using copper compounds to fight fungi that cause root rot, bacterial wilt, downy mildew, and bacterial spots, it is involved in oxidation of ascorbic acid, which is responsible for processes of vegetative, fruitful, and root growth. It is also involved in photosynthesis, and it has a role in building chlorophyll, it is responsible for raising plant immune system efficiency against many diseases, it is also used as an enzymatic accompaniment to build lignin layer responsible for shine and hardness of fruit peel, especially in pomegranates, oranges, and onions, it is involved in synthesis of some proteins and amino acids [17, 18]. Several studies have demonstrated that giving plants a copper spray promotes their growth. In a study [19], copper was sprayed at concentrations of 0, 10, and 20 $mg.L^{-1}$alone or interaction with zinc spray, resulted in a considerable increase in plant height and leaf chlorophyll content in Vicia faba L, particularly when the copper concentration was 20 $mg.L^{-1}$. In a further experiment, numerous bread wheat types [20], were grown with four concentrations (0, 5, 10, 15) mg L^{-1} of water copper sulphate ($Cuso_4.5H_2o$) added in two batches. Results showed that spraying copper at a concentration of 15 mg Cu L^{-1} significantly affected area of flag leaf .

Maize (Zea mays L.) is third most important cereal grain after wheat and rice in world. It is one of most versatile crops and can be grown in a variety of environmental conditions. It has many uses in human diet, animal feed, and raw materials for a large number of industrial products [21]. Goal of study is to ascertain how potassium fertilizer, zinc spray, and copper spray affect parameters that govern maize plant growth and mineral content of soil.

MATERIALS AND METHODS

The study was carried out in Experiment Station, which is situated at latitude 34.4057 N

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and longitude 43.3856 E, and is a part of Department of Soil Sciences and Water Resources, College of Agriculture, Tikrit University, Saladin Governorate. In 2023, in fall, maize plants of Gloria variety—a Serbian type from ZP Company and widely grown throughout the nation—were planted in gypsiferous soil. On 7 august, 2023, seeds were sown in holes at a rate of two to three seeds per hole in shape of lines of maize (Zea mays L). A hole is separated from another by 25 centimeters, and a line is separated from another by 75 centimeters. As a result, each experimental unit has four lines, and each line contains eight plants, with a plant density of 53,333 plants per hectare. A drip irrigation system was installed so that plants may be watered as needed. Urea fertilizer (46% N) was delivered in two batches, one at planting and the second forty days later, to provide 200 kg N ha-1 of nitrogen to all experimental treatments. DAP fertilizer was added as a source of phosphorous at a level of (50) kg P ha-1 for all treatments at planting. To get rid of weeds growing alongside crops, weeds were physically pulled twice in a uniform manner throughout all experimental units. After 20 or 40 days after germination, corn stem borer Sesmia gilica L was controlled by feeding it on rising top of the stem while applying 10% granular Diazinon pesticide at a rate of (6) kg ha-1. 110 days after planting, 27 November, 2023, plants were harvested. Irrigation and service operations continued until the conclusion of the season. An analysis of some chemical and physical properties of the experimental soil was also conducted (table 1 .(

Study included addition of Potassium sulphate as main plot at a concentration of (41.5% K) as a source of potassium at three levels (0, 100, 200) kg K ha-1 as (K0, K1, K2), respectively in two batches, half quantity first at planting and second after 40 days of planting, second factor was copper sulphate ($CuSo4.5H2o$) sprayed with three concentrations (0, 15, 35) mg Cu L-1 as (C0, C1, C2) respectively as sub-plot and with three sprays. Third factor was Spraying zinc sulphate fertilizer ($ZnSo4.7H2o$) at three concentrations (0, 50, 100) mg Zn L-1 as (Z0, Z1, Z2), respectively as sub-plot. Spraying was done during vegetative growth stage with three sprays. A randomized complete block design was used to conduct the experiment using a split-plot design (RCBD).three replicates of every treatment, for a total of 81 experimental units. The study's findings were statistically examined, and averages were compared using the (L.S.D.) at 0.05 in accordance with [22]. The study's parameters were as follows: plant height (cm) measured with a tape measure, leaf area (cm2) ten plants were randomly selected from midlines of each experimental unit and leaf area under ear was measured according to equation: Maximum length of leaf under ear × Maximum width × 0.75 [23], soil potassium availability (mg kg-1 soil) according to [24] and soil zinc and copper availability (mg kg-1 soil) according to [25.[

Table (1) Some Physical and Chemical Properties of Study Soil Before Planting.

Adjective	Unit	Value
Sand		36.6
Clay	%	28.2
Silt		35.2

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Texture	Clay loam	
Bulk density	$Cm^3.g$	1.49
pH	-	7.58
$CaSO_4$	%	4.78
$CaCO_3$	%	26.51
O.M		0.90
N		20.00
P		7.20
K	$mg.kg^{-1}$	127.00
Zn		0.71
Cu		0.46

RESULTS AND DISCUSSIONS

Effect of potassium fertilizer and copper and zinc spraying on plant height and leaf area: Tables (2 and 3) showed that experimental factors had a significant impact on plant height and leaf area, as treatment of adding potassium at 200 kg K ha-1 (K2) excelled in giving it highest plant height and leaf area of 193.98 cm and 618.11 cm2, respectively compared to control treatment (K0). Zinc spray treatment at 100 mg Zn L-1 (Z2) also excelled in giving highest significantly increase in plant height and leaf area of 189.54 cm and 605.94 cm2 respectively, compared to control treatment (Z0). Copper spraying at 35 mg Cu L-1 (C2) also excelled it gave highest values for studied traits of 190.78 cm and 601.50 cm2 for plant height and leaf area, respectively, compared to control treatment (C0). Interactions between potassium fertilizer and copper spray had a major impact, particularly when interaction treatment (K2C2) was given 199.35 cm and 628.45 cm2 as plant height and leaf area, respectively. Interaction between zinc spray and potassium fertilizer treatments, in particular the interaction treatment (K2Z2), as it produced the highest plant height of 198.11 cm and highest leaf area of 641.31 cm2. Interactions between zinc spray and copper spray especially interaction treatment (Z0C2) significantly affected in plant height of 198.38 cm and interaction treatment (Z2C2) gave highest leaf area of 614.83 cm2. These traits were significantly impacted by triple interactions between research factors, especially interaction treatment K2Z2C2, while a lowest value of these traits was in interaction treatment K0Z0C0. This increase in vegetative growth characteristics of maize plants could be due to addition of potassium to soil, Potassium increases uptake of nitrogen and synthesis of proteins. It also promotes division of live plant cells, which is a crucial aspect of cell division thus encouraging growth of meristematic tissues, it also helps in carbohydrates formation , also actively participates in controlling mechanism that opens and closes stomata due to its effect on plant water absorption and thus helps to increase osmotic potential of cell and allow water to enter plant cell, which leads to cell swelling or increased turgor pressure, which is necessary for cell expansion, all of these roles subsequently led to an increase in vegetative growth characteristics [4, 26]. Also, spraying

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Zinc has a major impact on maize plant height and leaf area because it is a necessary and significant nutrient for crop plants' healthy growth and reproduction. It also functions as a structural element and regulatory cofactor of a number of enzymes and proteins involved in various biochemical pathways, including the synthesis of carbohydrates, photosynthesis, protein metabolism, and cell membranes, all of these activities had a positive impact on improving vegetative growth characteristics [11, 27 .[

Table 2. Effect of potassium application and copper and zinc spray on plant height (cm) of maize

potassium (K)	$CuSo_4$ (C)	$ZnSo_4$ (Z)			K × C
		Z_0	Z_1	Z_2	
	C_0	168.17	187.50	189.49	181.72
K_0	C_1	179.05	187.47	182.06	182.86
	C_2	187.66	184.77	183.56	185.33
	C_0	189.30	184.71	184.88	186.29
K_1	C_1	191.43	186.55	183.22	187.06
	C_2	185.86	188.90	188.31	187.69
	C_0	192.21	195.10	188.85	192.05
K_2	C_1	187.96	189.56	194.13	190.55
	C_2	194.63	192.06	211.37	199.35
L.S.D 5 %		11.069			9.293
K × Z					K
K_0		178.29	186.58	185.03	183.30
K_1		188.86	186.72	185.47	187.01
K_2		191.60	192.24	198.11	193.98
L.S.D 5 %		9.293			8.984
C × Z					C
C_0		183.22	189.10	187.74	186.68
C_1		186.14	187.86	186.47	186.82
C_2		198.38	188.57	194.41	190.78
L.S.D 5 %		4.802			2.772
Z		186.24	188.51	189.54	
L.S.D 5 %		2.772			

This is also case when spraying copper, as it led to a significant increase in vegetative growth characteristics of maize plants, reason for this is due to role of this element in plants, most important of which is that it is an enzymatic companion for vital processes within plant, such as oxidation and reduction reactions. It is involved in oxidation of ascorbic acid, which is responsible for processes of vegetative and root growth. It is

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involved in photosynthesis, and it has a role in building chlorophyll, it is also used as an enzymatic accompaniment to build lignin layer, it is involved in synthesis of some proteins and amino acids, consequently this is reflected in improvement plant height and leaf area [27, 28.[

Table 3. Effect of potassium application and copper and zinc spray on leaf area (cm2) of maize..

potassium (K)	$CuSo_4$ (C)	$ZnSo_4$ (Z)			K × C
		Z_0	Z_1	Z_2	
	C_0	486.96	566.76	603.50	552.40
K_0	C_1	551.70	605.91	610.26	589.29
	C_2	606.29	527.85	554.25	562.79
	C_0	574.57	570.59	597.59	580.91
K_1	C_1	550.75	616.06	550.61	572.47
	C_2	638.72	587.64	613.43	613.26
	C_0	592.55	631.16	622.09	615.26
K_2	C_1	588.50	618.41	625.02	610.64
	C_2	598.66	609.88	676.83	628.45
L.S.D 5 %		53.55			41.50
K × Z					K
K_0		548.31	566.84	589.33	568.16
K_1		588.01	591.43	587.21	588.88
K_2		593.23	619.81	641.31	618.11
L.S.D 5 %		41.50			38.94
C × Z					C
C_0		551.36	589.50	607.72	582.86
C_1		563.65	613.46	595.29	590.80
C_2		614.55	575.12	614.83	601.50
L.S.D 5 %		25.79			14.89
Z		576.52	592.69	605.94	
L.S.D 5 %		14.89			

Effect of potassium fertilizer and copper and zinc spraying on soil potassium, zinc and copper availability :

It was shown from Tables (4, 5 and 6) that soil potassium, zinc and copper availability were significantly impacted by addition of potassium, as 200 kg K ha-1 (K2) treatment gave highest soil potassium availability of 154.69 (mg kg-1 soil) and lowest soil zinc availability of 0.384 (mg kg-1 soil), also lowest soil copper availability of 0.210 (mg kg-1 soil), zinc spraying treatment (Z2) at 100 mg Zn L-1 gave highest values of 0.548 (mg kg-1 soil), for soil zinc availability unsprayed (Z0) gave highest soil potassium and copper availability as 126.33 and 0.264 (mg kg-1 soil), respectively . The spraying of copper at 35 mg Cu L-1 (C2) gave highest values of

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0.446 and 0.274 (mg kg-1 soil), for soil zinc and copper availability respectively, while control treatment (C0) gave highest soil potassium availability of 127.84 (mg kg-1 soil). Interactions between potassium fertilizer and copper spray greatly impacted, particularly when interaction (K2C0) was administered 161.33 (mg kg-1 soil) as soil potassium availability, while interaction treatment (K0C2) gave highest soil zinc and copper availability of 0.496 and 0.308 (mg kg-1 soil), respectively. Interaction between zinc spray and potassium fertilizer treatments, it had a moral impact, interaction treatment (K2Z0) it excelled in soil potassium availability of 158.55(mg kg-1 soil), while interaction treatment (K1Z2) it excelled in soil zinc availability of 0.589 (mg kg-1 soil), while interaction treatment (K0Z0) it excelled in soil copper availability of 0.302 (mg kg-1 soil). Interactions between zinc spray and copper spray it had a moral impact, interaction treatment (C0Z0) it excelled in soil potassium availability of 123.00 (mg kg-1 soil), while interaction treatment (C2Z2) it excelled in soil zinc availability of 0.568 (mg kg-1 soil), while interaction treatment (C2Z0) it excelled in soil copper availability of 0.295 (mg kg-1 soil).These attributes were significantly impacted by triple interactions between the research factors.

Table 4. Effect of potassium application and copper and zinc spray on soil potassium availability (mg kg-1 soil.(

potassium (K)	$CuSo_4$ (C)	$ZnSo_4$ (Z)			K × C
		Z_0	Z_1	Z_2	
K_0	C_0	97.00	94.00	89.66	93.55
	C_1	94.00	99.00	85.66	92.88
	C_2	88.66	88.66	80.66	85.99
K_1	C_0	131.00	126.66	128.33	128.66
	C_1	133.00	118.33	122.00	124.44
	C_2	117.66	114.33	111.00	114.33
K_2	C_0	168.00	160.66	155.33	161.33
	C_1	158.00	153.66	154.00	155.22
	C_2	149.66	148.00	145.00	147.55
L.S.D 5 %		3.784			3.451
K × Z					K
K_0		93.22	93.88	85.32	90.80
K_1		127.22	119.77	120.44	122.47
K_2		158.55	154.10	151.44	154.69
L.S.D 5 %		3.451			3.405
C × Z					C
C_0		132.00	127.10	124.44	127.84
C_1		128.33	123.66	120.55	124.18
C_2		118.66	116.99	112.22	115.95
L.S.D 5 %		1.362			0.787
Z		126.33	122.58	119.07	
L.S.D 5 %		0.787			

This increase in potassium availability may be attributed to availability of these elements in added fertilizer as a result of addition with decomposition of organic matter, which led to an increase in availability of this element in soil. The increase in concentration of available potassium in soil is attributed to fertilizer addition in addition to acidic effect of potassium fertilizer (potassium sulfate), which leads to an increase in potassium availability in soil. Also, increase in soil content of zinc and copper as a result of spraying these two elements is that plant did not consume these elements present in soil as a result of spraying them to leaves, and therefore concentration in soil whose plant were sprayed with these elements was higher than soils whose plants were not sprayed with these two elements area [8].These results are consistent with area [16, 29.[

Table 5. Effect of potassium application and copper and zinc spray on soil zinc availability (mg kg-1 soil.(

potassium (K)	$CuSo_4$ (C)	$ZnSo_4$ (Z)			K × C
		Z_0	Z_1	Z_2	
	C_0	0.330	0.496	0.530	0.452
K_0	C_1	0.340	0.453	0.553	0.448
	C_2	0.323	0.473	0.613	0.496
	C_0	0.293	0.453	0.563	0.436
K_1	C_1	0.316	0.480	0.610	0.468
	C_2	0.343	0.493	0.596	0.477
	C_0	0.266	0.343	0.450	0.353
K_2	C_1	0.270	0.426	0.526	0.407
	C_2	0.280	0.403	0.496	0.393
L.S.D 5 %		0.027			0.025
K × Z					K
K_0		0.331	0.474	0.565	0.456
K_1		0.317	0.475	0.589	0.460
K_2		0.272	0.390	0.490	0.384
L.S.D 5 %		0.025			0.019
C × Z					C
C_0		0.296	0.430	0.514	0.413
C_1		0.308	0.453	0.563	0.441
C_2		0.315	0.456	0.568	0.446
L.S.D 5 %		0.009			0.005
Z		0.306	0.446	0.548	
L.S.D 5 %		0.005			

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Conclusion

We conclude from this study that levels of addition of spraying at highest level are significantly superior to no addition in their effect on soil content and some growth characteristics of maize plant, and thus this will be positively reflected in improving plant quantitative and qualitative yield .

Table 6. Effect of potassium application and copper and zinc spray on soil copper availability (mg kg-1 soil.(

potassium (K)	$CuSo_4$ (C)	$ZnSo_4$ (Z)			K × C
		Z_0	Z_1	Z_2	
	C_0	0.230	0.246	0.200	0.225
K_0	C_1	0.336	0.276	0.253	0.288
	C_2	0.340	0.286	0.300	0.308
	C_0	0.213	0.246	0.216	0.225
K_1	C_1	0.293	0.293	0.246	0.277
	C_2	0.313	0.320	0.253	0.295
	C_0	0.196	0.183	0.223	0.200
K_2	C_1	0.230	0.213	0.193	0.212
	C_2	0.233	0.246	0.176	0.218
L.S.D 5 %		0.027			0.025
K × Z					K
K_0		0.302	0.269	0.251	0.274
K_1		0.273	0.286	0.238	0.265
K_2		0.219	0.214	0.197	0.210
L.S.D 5 %		0.025			0.024
C × Z					C
C_0		0.213	0.225	0.213	0.217
C_1		0.286	0.260	0.230	0.258
C_2		0.295	0.284	0.243	0.274
L.S.D 5 %		0.009			0.005
Z		0.264	0.256	0.228	
L.S.D 5 %		0.005			

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