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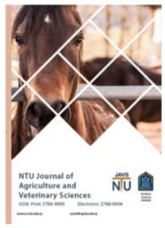

Effect of Copper Levels and Types of Coal on The Growth and Yield of Wheat

1st Mustafa A. Hussain[1], 2nd Yasir H. Ijrish[2]
1,2. Department of Soils and Water Resources, College of Agriculture, Tikrit University, Tikrit, Iraq,

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Corresponding author:
Mustafa A. Hussain
Tikrit University, College of Agriculture, Tikrit, Iraq
Email: mus.a.h519@st.tu.edu.iq

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ABSTRACT

Samples were selected from Tikrit University fields from gypsum soils of different gypsum content, the first low gypsum (65 g.Kg-1), and symbolized by G1, second medium gypsum (141 g.Kg-1), and symbolized by G2, and third high gypsum (309 g.Kg-1), and symbolized by G3. Three types of charcoal were selected: wheat residue charcoal, symbolized by W, rice residue charcoal, symbolized by R, and corn cobs charcoal Z. Charcoal was added at a rate of 1% and the soil was incubated for 100 days, taking into account stirring and moisturizing by spraying it with a solution rich in urea fertilizer, to which urea fertilizer was added at a rate 2% to help activate the charcoal particles and stimulate the organisms in its analysis. Three concentrations of copper were used (0 ppm), symbolized by cu0, (5 ppm) and symbolized by cu1, and (10 ppm), symbolized by cu2. The number of treatments is 27 in three repeats the number of experimental treatments becomes (81) experimental units in plastic pots with a capacity of (5 kg). the seeds were planted on 11/7/2023 and were subjected to service, irrigation, and thinning operations. Then the number of plants in each experimental unit was reduced to eight plants. After the plants matured, the harvesting process was carried out on 29/4/2024. The most important results obtained were that the treatments (G1Zcu2) outperformed the rest of the treatments in the characteristic of plant length, as it reached 90 cm, and outperformed in the characteristic of the flag leaf area, as it reached 49.33 cm2. As for the number of branches, the highest average number of branches was 25 branches. The copper percentage was also examined, as the highest percentage was 45.1941 ppm. As for the number of spikes, the highest average was 14 spikes. The seed weight was also measured, as the highest weight obtained was 14.55 g.spike-1, and the highest weight for 100 grains was 4.3 g. grains-1. The above results show that the superiority of the sample (G1Zcu2) is noted.

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Introduction

Gypsiferous soils is a type of soil that contains a high percentage of gypsum, a mineral consisting of hydrated calcium sulfate [1]. These soils are mainly found in arid and semi-arid regions, where the climatic conditions are suitable for the formation of gypsum. These soils have characteristics that distinguish them from other types of soil. They are usually white or gray and these soils are fragile and easily eroded when exposed to water, making them a challenge in agriculture. Gypsum soils suffer from low organic matter content, so different types of organic matter are added, including biochar. Biochar is a type of coal that is produced from organic waste through a process of thermal decomposition in the absence of oxygen. Biochar is used as a soil conditioner to modify the soil properties and increase its ability to retain nutrients and water. Biochar is a sustainable source of carbon which helps reduce greenhouse gas emissions. In addition, biochar improves soil structure and increases nutrient availability to plants. Biochar can help improve soil aeration and increase microbial activity which enhances plant growth and increases crop yields,[2].

Which enhances plant growth. Organic matter also improves soil structure and increases the activity of microorganisms, which leads to improving soil fertility in general. In addition, organic matter contributes to reducing soil erosion and increasing its ability to resist drought [2].

Gypsum soils also suffer from low nutrient content, including copper, so it must be added to improve plant growth and increase its productivity. Copper is a micronutrient essential for plant growth as it plays an important role in many vital processes such as photosynthesis and cellular respiration. Copper is an essential component of many enzymes and proteins that participate in plant metabolism. However, increased copper concentration in the soil can be toxic to plants, negatively affecting their growth and productivity. The availability of copper in the soil depends on several factors, including acidity, organic matter content, and soil type. It's important to monitor copper levels in the soil to ensure that it is available in appropriate proportions for plant growth without causing poisoning [3]. Wheat is one the most important food crops in the world as it is a major source of carbohydrates and proteins. Wheat productivity depends on many factors including soil properties and nutrient availability. Improving soil fertility and increasing nutrient availability can increase wheat productivity and improve crop quality. Wheat is grown in different regions around the world and is used in the production of many food products such as bread, pasta, and cereals. Our study aims to identify the interaction between gypsum levels, biochar types, and copper nutrition on wheat growth, yield, and copper content.

MATERIALS AND METHODS

Soil samples were collected from the fields of the College of Agriculture, Tikrit University. Three different soils were selected in their gypsum content: low (65%) (G1), medium (141%) (G2), and high (309%) (G3)/ then the samples were sieved using a 4mm sieve and three types of biochar were added to samples: wheat residue charcoal (W), rice shell charcoal (R), and high corn cob charcoal (Z). this resulted in nine treatments (G1W, G1R, G1W, G2W, G2R, G2W, G3W, G3R, G3W) from which samples were taken and sieved using a 2mm sieve to conduct physical and chemical analyses on them, such as soil texture, apparent density, pH, electrical conductivity (EC), organic matter percentage, and cation exchange capacity (CEC) [4]. The percentage of dissolved, available, and total copper was estimated according to the method of [5]. The biochar samples were examined according to [6].

Table 1. Some characteristics of the study soils and coal

Samples	Units	G1	G2	G3
Reaction rate	ppm	7.61	7.81	7.66
Electrical conductivity	$g.kg^{-1}$	2.55	2.32	2.34
Gypsum	$g.kg^{-1}$	65	141	309
Organic matter	$mg.kg^{-1}$	10.12	9.10	8.89
Dissolved copper	$mg.kg^{-1}$	0.013331	0.012171	0.011885
Exchangeable copper	$mg.kg^{-1}$	0.017817	0.01788	0.01675
Total copper	$mm.L^{-1}$	1.6123	1.33312	1.3143
Sodium	$mm.L^{-1}$	1.24	1.56	2.13
Potassium	$mm.L^{-1}$	0.88	0.74	0.55
Calcium	$mm.L^{-1}$	5.33	10.11	12.5
Magnesium	$mm.L^{-1}$	5.45	9.43	11.12
Chloride	$mm.L^{-1}$	1.11	1.71	1.20
Carbonate	$mm.L^{-1}$	Nil	Nil	Nil

Bicarbonate	$mm.L^{-1}$	1.32	1.65	1.25
Calcium carbonate	$mm.L^{-1}$	232	209	220
Sulfate	$mm.L^{-1}$	10.11	13.77	16.30
Cation exchange capacity	$Centimole.kg^{-1}$	12.76	12.11	11.96
Sand	$g.kg^{-1}$	373	368	478
Silt	$g.kg^{-1}$	432	465	421
Clay	$g.kg^{-1}$	195	167	101
Texture		Loam	Loam	Loam
Apparent density	$g.cm^{-3}$	1.477	1.591	1.619
pH	pH 1:1	7.59	7.60	7.88
Electrical conductivity	ppm	4.45	4.32	4.26
Organic matter	$g.kg^{-1}$	58.2	66.7	61.2
Nitrogen %	%	2.8	2.7	2.5
Carbon %	%	35.13	34.00	44.05
C/N ratio %	%	12.54	12.59	17.62
Hydrogen %	%	65.96	72.25	63.99
Exchange capacity	$Centimole.kg^{-1}$	22.43	24.32	27.87
Surface area	$m^2.g^{-1}$	21.53	19.28	20.92

Table 2. Effect of adding biochar on some properties of the nine soils

Samples	units	G3Z	G3R	G3W	G2Z	G2R	G2W	G1Z	G1R	G1W
degree of interaction		7.64	7.16	7.63	7.52	7. 13	7.61	7.35	7.61	7.65
Electrical conductivity	$Ds.m^{-1}$	2.47	2.34	2.41	2.39	2.32	2.67	2.77	2.55	2.59
Organic matter	$g.kg^{-1}$	10.21	8.89	10.38	10.23	9.10	11.21	12.39	10.12	12.21
Sodium	$mm.L^{-1}$	2.32	2.13	2.44	1.65	1.51	1.81	1.60	1.24	1.28
Potassium	$mm.L^{-1}$	0.61	0.55	0.67	0.88	0.74	0.82	0.97	0.88	0.95
Calcium	$mm.L^{-1}$	12.66	12.55	12.73	10.84	10.11	10.21	5.51	5.33	6.5
Magnesium	$mm.L^{-1}$	11.76	11.13	11.87	10.56	9.43	10.54	5.98	5.45	6.65
Chloride	$mm.L^{-1}$	1.61	1.21	1.28	1.96	1.71	1.87	1.30	1.11	1.24
Carbonate	$mm.L^{-1}$	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Bicarbonate	$mm.L^{-1}$	2.54	1.95	2.55	2.24	1.65	2.27	2.11	1.32	2.81
Calcium carbonate	$mm.L^{-1}$	15.75	16.51	16.43	15.25	13.71	15.05	15.12	10.11	15.85
Exchange capacity	$Centimole.kg^{-1}$	12.55	11.96	12.21	11.87	12.11	12.26	12.79	12.76	12.25
Surface area	$m^2.g^{-1}$	1.412	1.509	1.421	1.389	1.591	1.395	1.339	1.477	1.343

Agricultural experiment: was carried out in Tikrit city on 11/7/2023, where wheat was planted in plastic pots with a capacity of five kilograms of soil.

Soil preparation: the previously sifted soil was placed on 2mm in plastic pots with a capacity of (5 kg.soil-1).

Statistical design of the experiment: was carried out in pots for three soils three levels of biochar and three levels of copper sulfate and with three replicates. They were distributed according to the randomized complete block design (RCBD) [7]. The number of experimental units was 81 units.

Fertilization: fertilizer (N, P, K) was added according to the fertilizer recommendation for the wheat crop and mixed well with the soil before planting the wheat, and nitrogen fertilizer was added in two batches.

Seeding process: 10-12 wheat grains were placed in each pot.

Irrigation: the plants were watered weekly with tap water.

Plant thinning: the experimental units were thinned to eight plants after four weeks of germination.

Copper nutrition: copper fertilizer was added to the soil after dissolving it in water at three levels (0, 10, 5) ppm, on 19/1/2023 as in the summary.

Harvesting: the plants were harvested on 29/4/2024, as the plants were harvested from all experimental units.

Studied attributes: the physiological characteristics of the plant were studied, such as plant height according to [8]. And the area of the flag leaf according to [9]. And the calculation of the number of branches, spike length, grain weight, number of grains, and measuring the concentration of copper in the grains according to [31].

Statistical analysis: the studied characteristics were analyzed by computer using the statistical analysis system program [23] and the last significant difference (LSD) for the treatments was calculated
at a probability of 5%. The arithmetic means between the soil and fertilizer treatments were compared using the T-test.

RESULTS AND DISCUSSION

Wheat plant height

Table (3) shows that the level of gypsum in the soil greatly affected the height of the wheat plant, as the soil with a low gypsum content G1 gave the highest average wheat plant height of 62.6 cm, and in the soil with a high gypsum content G3 gave the lowest average of 48.3 cm, the reason may be due to the low percentage of gypsum that is within the nutrient ratios in addition to the role of organic matter in improving the structure of the soil and its ability to retain water, which increases in readiness.

Adding different types of biochar gave a significant difference in favor of treatment (Mz), as the highest average was 78 cm, and the lowest average was for treatment (Mw), as it reached 68.3 cm.

The result showed a significant difference in the average copper level, as the treatments (Cu1, Cu2) gave a significant difference that averaged (64.466, and 60) ppm compared to the treatment (Cu0) without adding copper, which averaged (52.66ppm). this increase may be attributed to the positive role of copper in the formation of wheat plant cells, their division, and then their elongation, 1

as well as through the role of building (RNA) and manufacturing the basic protein in building plant cells [24].

As for the bilateral interaction between the gypsum content in the soil and biochar, it gave a significant difference between the treatments, as the treatment (G1Mz) gave the highest average, reaching 89 cm, and the lowest average was for the treatment (G2Mw), reaching 32 cm. the height of gypsum led to restricting potassium absorption, which reduced the efficiency of water absorption and metabolism, following [21].

The bilateral interaction of the type of biochar and copper levels the addition to the presence of a significant difference in the height of the wheat plant, and the highest average was in favor of the MzCu2 treatment, which reached 90cm, while the lowest values in the treatment MwCu0 reached an average of 52cm. The interaction between the soil content of gypsum and added copper levels gave a significant difference, as the highest average was in treatment G1Cu2, which reached 74cm, and the lowest values were in treatment G3Cu0, which reached 43cm. the reason may be the role of organic matter and biochar in the formation of humic acids, which may have a role in increasing the division and elongation activities of plant cells due to their influence on many vital processes within the plant [10]. In addition, organic acids reduce the washing and sedimentation processes that work to increase root and vegetative growth and plant resistance to high temperatures and drought [11]. These results were consistent with [12] on barley and with [25] and with [14] and [15]. The triple interaction of the soil content of gypsum, biochar levels, and added copper levels gave the significant difference between most of the treatments, as the treatment G1ZCu2 gave the highest value in this interaction, which amounted to 96cm, and the treatment G2WCuo gave the lowest value, which amounted to 23. The superiority of the treatment G1ZCu2 may be due to its high potassium content compared to other soils, which helped in increasing its permeability and photosynthesis and increasing the nutrients inside the plant, which contributed to increasing the length, and this is in agreement with [29].

Table 3. Effect of biochar levels and copper levels on the height of wheat plants grown in soils with different gypsum content (cm)

M*G	Added copper levels (mg.kg^{-1})			Types of copper (M)	Levels gypsum G
	cu_2	cu_1	cu_0		
38	54	30ij	30 nop	w	G1
85.3	85	85klm	86nom	r	
89	96	90fe	81ih	z	
32	32	23nom	41rs	w	G2
42	41	40klm	45rs	r	
48.6	47	51nom	48rq	z	
53.6	59	58t	44t	w	G3
53	51	61t	47t	r	
61	64	68qp	51t	z	
(M)					
68.3b	79c	74e	52f	w	M*Cu
73b	84d	78e	57f	r	
78a	90b	81d	63e	z	
(G)					
62.6a	74b	60c	54d	G1	G*Cu
52.6ab	58c	52e	48g	G2	
48.3ed	53f	49h	43i	G3	
	64.466a	60 c	52.66d	Average levels of Cu	
G_1: low gypsum soils 6.5%, G_2: medium gypsum soils 14.1%, G_3: high gypsum soils 35%, while Cu: (0.5-10)%, and copper levels (mg.kg^{-1}), M: (Z, R, W)%					

Flag leaf area

Table (4) indicates that the gypsum content in the soil has a significant effect in increasing the flag leaf area of wheat plants, as the soils with low gypsum content G1 gave the highest significant difference, reaching 37.39cm^2.leaf^{-1}, respectively, compared to the high gypsum soil G3, which gave the lowest significant difference, reaching 33.89 cm^2.leaf^{-1}. This is attributed to the fact that the soil gypsum content is important as a source of sulfates and calcium, but when it is abundantly available in the form of deposits, it affects plant growth and also causes problems in soil properties [16]. Adding different types of biochar gave slight differences, but they don't reach the significant level due to the lack of a significant difference between the values. The highest average for corn cob coal MZ reached 37.52 cm2.leaf-1, and the lowest average for wheat waste coal MW reached 35.4 cm2.leaf-1. The effect of potassium enhanced the regulation of stomatal opening, which increased the efficiency of the photosynthesis process, which is consistent with the study presented by (Dorjee et al., 2024). The increase in copper addition levels had a significant effect on increasing the area of the flag leaf of the wheat plant, as the treatments (Cu1, Cu2) gave significant differences with average copper levels reaching (38.01,41.94)ppm, respectively, compared to the treatment without addition, which reached average copper levels 36.57ppm. this increase may be attributed to the vital role of copper in increasing the efficiency of the photosynthesis process through the active cycle in the process of transferring electrons from water (Nicotine amide adenine phosphate) to participate in the process of cell division and elongation [25], [29].

The dual interaction of the soil content of gypsum and types of biochar gave a significant difference between the treatments, as treatment G1Mz recorded the highest average reaching 45.42cm2.leaf-1, and treatment G3Mw the lowest average, reaching 35.18cm2.leaf-1. The reason for this is that the decrease in calcium and potassium affected cell division, which limited leaf growth [3]. As for the binary interaction between the types of biochar and the levels of added copper, there was a significant difference between the treatments of this interaction, as the treatment MzCu2 gave the highest value of 39.53 cm2.leaf-1 and the treatment MwCu0 gave the lowest value of 32.12 cm2.leaf-1.

The results of the binary interaction between the gypsum content in the soil and the levels of added copper also showed a significant difference, as the treatment G1Cu2 gave the highest value of 41.06 cm2.leaf-1, while the lowest value was for the treatment G3Cu0, which reached 32.1 cm2.leaf-1. This increase is attributed to the fact that copper is involved in the photosynthesis process. The triple interaction of soil gypsum content, biochar types, and added copper levels gave significant differences between treatments. Treatment G1ZCu2 recorded the highest value in this interaction, reaching 49.33 cm2.leaf-1. The reason for the superiority of this treatment may be attributed to its high content of organic matter and potassium, in addition to its low content of calcium sulfate, which reduces competition between elements, so it gave the best values in the leaf area.

Table 4. Effect of biochar levels and copper levels on the flag leaf area of wheat plants grown in soils with different gypsum content (cm^2.leaf^{-1})

M*G	Added copper levels (mg.kg^{-1})			Types of copper (M)	Levels gypsum G
	cu 2	cu 1	cu 0		
43.24b	48.09bc	41.47bc	40.17c	w	G1
43.84b	48.71bc	42.12bc	40.69c	r	
45.42b	49.33bac	42.64c	44.31c	z	
42.26ba	45.64 Bac	41.05bac	40.09c	w	G2
42.08b	45.93bac	41.31bc	39.02c	r	
41.94a	46.32a	40.65 Bac	38.87bc	z	
35.18ba	38.27bc	34.07bc	33.21c	w	G3
35.38ba	38.40bac	34.24bac	33.51c	r	
36.25ba	38.96bac	35.09bac	34.71bc	z	
(M)					
35. 40ebdac	37.84ba	36.26ebdac	32.12ed	w	M*Cu
36.60bdac	38.25ebdac	37.05ebdc	34.51e	r	
37.52bac	39.53a	37.72ebdac	35.33edc	z	
(G)					
37.93bdec	41.06bdec	37.07bdac	35.67e	G1	G*Cu
35.69a	37.30bac	35.47de	34.32dec	G2	
33.89bdac	35.61ba	33.97bdac	32.10de	G3	
	41.94a	38.01a	36.77b	Average levels of Cu	

G_1: low gypsum soils 6.5%, G_2: medium gypsum soils 14.1%, G_3: high gypsum soils 35%, while Cu: (0.5-10)%, and copper levels ($mg.kg^{-1}$), M: (Z, R, W)%

Number of branches

Table (5) indicates that the gypsum content in the soil affects the number of wheat branches, as the soil with a low gypsum content (G1) gave a significant difference, as it recorded the highest average, which amounted to (16.66), while the lowest average was in the soil with a high gypsum content, which amounted to (13.66), which may be because the high gypsum content works to deteriorate the physical properties of the soil, such as aeration and porosity, which hinders the growth and spread of roots in it, in addition to its competition with calcium for nutrients [27]. The types of biochar significantly affected the number of wheat branches, as it gave the treatment (MW), which amounted to (14) branches. Also, adding levels of copper had a significant effect on the number of wheat branches, as the treatment (Cu2) gave the highest value for the average copper levels, which amounted to (17.73) ppm, and the treatment(Cu0) without adding copper gave the lowest average copper levels, which amounted to (13.53) ppm. These results agree with [17], in the effect of the types ofbiochar, it recorded significant differences between the treatments, as the treatment (G1Z) recorded the highest average, which amounted to (20.66), while the treatment(G3W) recorded the lowest average value, which amounted to (13). The reason may be due to the addition of any organic waste, including biochar, to the soil, which works to prepare the plant with its needed nutrients that are considered a moral enhancer in plant and soil characteristics [18].

As for the binary interaction between biochar levels and copper levels, there is a significant difference between the treatments, as the treatment MzCu2 recorded the highest value of (18) and the treatment MwCu0 gave the lowest value of (13). The interaction between the soil gypsum content and copper levels gave a significant difference and was in favor of the treatment G1Cu2, which gave the highest value of(19) and the treatment G2Cu0 gave the lowest value in this interaction, which was(12).

In the triple interaction, the results showed significant differences between the treatments, as the treatment G1ZCu2 gave the highest average number of wheat branches in this interaction, reaching(25) branches, and the treatment(G3WCu0) gave the lowest value, reaching(11) branches. The reason may be attributed to the high percentage of gypsum, which led to a reduction in the ability of the roots to absorb copper, which weakened the structure of the plant, as indicated by [21].

Table 5. Effect of biochar levels and copper levels on the number of branches of wheat plants grown in soils with different gypsum content

M*G	Added copper levels ($mg.kg^{-1}$)			Types of copper (M)	Levels gypsum G
	cu 2	cu 1	cu 0		
17.33c	21 gdfjieh	16gdfcieh	15gkfjih	w	G1
19b	22ba	18dfce	17gkfjieh	r	
20.66a	25a	19 de	18 gkfjieh	z	
14 def	16gdfceh	14 mjilh	12nmo	w	G2
13.33de	16dfce	13nkmlo	11no	r	
14.66dc	18bc	14gdfceh	12 nkmlo	z	
13f	15gkfjleh	13nkmjlo	11o	w	G3
14.33 f	17gdfjieh	14nkmjlo	12nmlo	r	
15.33 ef	18gkfjieh	15kmjilh	13nmlo	z	
(M)					
14dc	15 dc	14df	13f	%0	M*Cu
15ba	16dc	15de	14f	%1	
16.33a	18b	16d	15fe	%2	
(G)					
16.66a	19ab	16c	15de	G1	G*Cu
14bc	16dc	14 f	12g	G2	
13.66de	14fe	14f	13g	G3	
	17.73a	15c	13.53d	Average levels of Cu	

G_1: low gypsum soils 6.5%, G_2: medium gypsum soils 14.1%, G_3: high gypsum soils 35%, while Cu: (0.5-10)%, and copper levels ($mg.kg^{-1}$), M: (Z, R, W)%

Number of spikes in each anvil

Table (6) shows the effect of soil gypsum content on the number of spikes of wheat plant per anvil, as the soil with low gypsum content (G1) gave the highest average value, reaching (11) spikes.pot^{-1}, while the lowest average value was in soil with high gypsum content (G3), reaching (8.66) spikes.pot^{-1}. The reason may be due to the high gypsum content, which leads to a reduction in the soil's ability to retain positive ions [22]. The addition of types of biochar gave a significant difference in favor of the treatment to which charcoal from corn cobs (MZ) was added. The highest value and average reached (12.33) spikes.pot^{-1} and the lowest average value was in the treatment (MW) which reached (9.66). increasing the levels of added copper gave positive results in the number of spikes, as the treatments (Cu1, Cu2) gave the highest values for the average levels of copper, respectively, which reached (9.4, 11.8) ppm, respectively, while the lowest average value was with the treatment without adding (Cu0), which reached an average of (8.7) ppm.

This may be attributed to the fact that copper enhances plant growth and increases crop productivity, as potassium enhances the development of inflorescences and contributes to improving the flowering process, [29]. The binary interaction between the soil gypsum content and the types of biochar gave a significant difference between the treatments, as the treatment (G1R) gave the highest average value in this interaction, reaching (11.66) spikes.pot^{-1}, and the treatment (G3W) gave the lowest average value, reaching (8.33) spikes.pot^{-1}, as these results are consistent with [28] and [30], while the binary interaction between the treatments, as the treatment (MzCu2) recorded the highest value, reaching (14) spikes.pot^{-1}, and the treatment (MwCu0) the lowest value, reaching (8) spikes.pot^{-1}. The interaction between the soil gypsum content and the added copper levels gave a significant difference in favor of the treatment (G1Cu2), which reached a value of (14) spikes.pot^{-1},and the treatment(G3Cu0) gave the lowest value in this interaction, which reached(7) spikes.pot^{-1}. The triple interaction of the soil gypsum content, biochar levels, and added copper levels led to significant differences between the treatments, as the treatment (G1ZCu2) gave the highest value, which reached (14) spikes.pot^{-1}, while the treatment (G3ZCu0) gave the lowest value in this interaction, which reached (7) spikes.pot^{-1}, and this is attributed to the high concentration of gypsum affecting the absorption of calcium and potassium, which reduced the number of spikes, as indicated by [21].

Table 6. Effect of biochar levels and copper levels on copper concentration of wheat seeds grown in soils with different gypsum content (mg.kg^{-1})

M*G	Added copper levels (mg.kg^{-1})			Types of copper (M)	Levels gypsum G
	cu 2	cu 1	cu 0		
9.33 cb	11 bc	8 gfecd	9gfeidh	w	G1
11.66b	13bc	11bcd	11gfeijh	r	
11a	14a	10bcd	9becd	z	
9.33ed	13gfeidh	8h	7j	w	G2
8c	8becd	9gfecdh	7gfijh	r	
9.66cb	13bcd	7becd	9gfeijh	z	
11.33e	11gijh	11ijh	12ijh	w	G3
9ed	10gfeijh	8 ij	9ij	r	
8.33d	10gfecd	8gijh	7ij	z	
(M)					
9.66dc	12ed	9e	8e	w	M*Cu
11bac	13bdc	11ed	9e	r	
12.33a	14ba	13bdc	10ed	z	
(G)					
11a	14b	10cb	9cd	G1	G*Cu
9.66cb	11	10cde	8gf	G2	
8.66fde	10fge	9g	7g	G3	
	11.8a	9.4c	8.7d	Average levels of Cu	
G_1: low gypsum soils 6.5%, G_2: medium gypsum soils 14.1%, G_3: high gypsum soils 35%, while Cu: (0.5-10)%, and copper levels (mg.kg^{-1}), M: (Z, R, W)%					

Weight of seeds in each pot

The results of Table (7) show that the weight of seeds is affected by the soil gypsum content, as the soil with high gypsum content G3 gave the highest average weight of wheat seeds in the pot, which averaged (9.42) g.pot^{-1}, while the lowest weight was in the soil with low gypsum content G1, which amounted to (5.54) g.pot^{-1}. As for adding types of biochar, it led to a significant increase in the weight of the ear grains, as the soil to which corn residue charcoal (MZ) was added gave the highest average value in this treatment, which amounted to (8.86) g.pot^{-1}, and the lowest

the average value was in the soil to which wheat residue charcoal (MW) was added, which amounted to (5.79) g.pot-1.

Also, adding different levels of copper gave significant differences between the treatments, as treatment (Cu2) gave the highest values, as the average copper levels in it reached(9.09) ppm, while the treatment without adding copper (Cu0) gave the lowest value, reaching (6.50) ppm. The binary interaction of soil gypsum content and biochar types gave a significant difference between treatments, as treatment (G1Z) gave the highest average by adding corn residue charcoal, which reached (11.82) g.pot-1, while treatment(G1W) by adding wheat residue charcoal gave the lowest average value, which reached (3.4) g.pot-1. The binary interaction of biochar types and added copper levels gave the highest significant difference for treatment (MzCu2), which reached (9.4) g.poit-1, while the lowest value was fortreatment (MwCu0), which reached (5.24) g.pot-1, and treatment (G1Cu0) gave the lowest value in this interaction, which reached (4.35) g.pot-1.

The triple interaction of soil gypsum content, biochar types, and added copper levels led to significant differences between treatments, as treatment(G1ZCu2) gave the highest value in this interaction, which amounted to (14.55) g.pot-1, and treatment (G3WCu0) gave the lowest value, which amounted to (5.30) g.pot-1, because high gypsum led to reduced absorption of calcium and potassium, which affected seed development following [3]. Low gypsum soil showed the highest response to treatments, especially with biochar and copper, while high gypsum soil showed a decrease in most traits due to its effect on absorption and plant growth. Increasing potassium and calcium levels positively affected plant growth, while high gypsum reduced their availability, which was reflected in decreased productivity [8].

Table 7. Effect of biochar levels and added copper levels on the number of spikes in each anvil of wheat plants grown in soils with different gypsum

M*G	Added copper levels (mg.kg^{-1})			Types of copper (M)	Levels gypsum G
	cu 2	cu 1	cu 0		
3.43b	3.2ebdac	3.4ebdhgcf	3.7eidhgcf	w	G1
6.46b	9bdac	6.3ebdacf	4.1ebdhgcf	r	
11.82a	14.55a	11.53a	9.40ba	z	
8.72de	9.81eikhgjf	8.22ikhjf	8.13kj	w	G2
7.96c	10.04eidhgcf	7.80eidkhgjf	6.04ikhgj	r	
8.78dc	11.09ebdhgcf	8.06eikhgjf	7.2ikhgj	z	
9. 03e	11.1ikj	10.7kj	5.30kj	w	G3
9.49 e	12.18ikhj	10.07kj	6.23kj	r	
9.12 e	10.12ikhj	8.46kj	8.8kj	z	
(M)					
5.79bac	6.42bc	5.72c	5.24c	w	M*Cu
6.93 ba	7.06bac	6.95bac	6.78bc	r	
8.86a	9.4bac	9.11ba	8.07bac	z	
(G)					
5.54a	6.76a	5.51a	4.35ba	G1	G*Cu
7.11bc	6.93dc	6.04dce	5.38dfe	G2	
9.42dfe	10.46fe	9.01f	8.8f	G3	
	9.09a	7.38b	6.50b	Average levels of Cu	
G_1: low gypsum soils 6.5%, G_2: medium gypsum soils 14.1%, G_3: high gypsum soils 35%, while Cu: (0.5-10)%, and copper levels (mg.kg^{-1}), M: (Z, R, W)%					

Weight of 100 grains

The results of Table (8) show that the soil content of gypsum and the types of added biochar gave differences, but they did not reach a significant level in the weight of 100 grains due to the lack of a significant difference between the values, as the high gypsum soils (G3) gave the highest values, as their average reached (2.8 g.grains-1), and the lowest average was in the medium gypsum soils, as their average reached (2.3 g.grains-1), and the addition of the types of biochar gave the highest value in the charcoal of corn cobs (MZ), as its average reached(2.7 g.grains-1), and the lowest average value was in the charcoal of wheat residues, as it reached (2.26 g.grains-1). The same is the case with the levels of added copper, which did not give a significant difference due to the lack of a significant difference between the values, as the highest average was recorded in the treatment (Cu2), which reached (2.95) ppm, and the lowest average for the treatment (Cu0). The average of which was (2.55) ppm. The binary interaction between the soil gypsum content and the types of biochar gave a significant difference between the treatments, as the treatment (G1Z) recorded the highest average value in this interaction, which amounted to (3.83 g.grains-1), and the treatment(G2R) gave the lowest value, which amounted to (2.4 g.grains-1). In the binary interaction between the types of biochar and the levels of added copper, there were no significant differences due to the lack of a significant difference between the values, as the treatment (MzCu2) gave the highest value, which amounted to (3 g.grains-1), and the treatment(MwCu0) gave the lowest value, which amounted to (2.1 g.grains-1). The same is the case with the binary interaction of the soil gypsum content and the levels of added copper, which did not give significant differences due to the lack of a significant difference between the values, but the highest value in this interaction amounted to (3 g.grains-1) for the treatment (G3Cu2) and the lowest value was (2.1 g.grains-1) for the treatment (G2Cu0). The triple interaction of the study factors gave a significant difference between the treatments, as the treatment (G1ZCu2) recorded the highest value in this interaction, as it reached (4.3 g.grains-1), and the treatment (G2RCu1) gave the lowest value, which reached(2.1 g.grains-1). These results are consistent with what was obtained by [15].

Table 8. Effect of biochar levels and added copper levels on seed weight in each pot planted in soil with different gypsum (g.spike^{-1})

M*G	Added copper levels (mg.kg^{-1})			Types of copper (M)	Levels gypsum G
	cu 2	cu 1	cu 0		
2.72b	3.6b	2.4b	2.3b	w	G1
3.56b	3.9b	3.3b	3.5b	r	
3.83b	4.3b	3.8b	3.4b	z	
2.53ba	2.4b	2.7b	2.5b	w	G2
2.40b	2.5b	2.1b	2.6b	r	
2.43b	2.6b	2.3b	2.4b	z	
2.73b	2.8b	2.8b	2.6b	w	G3
2.53b	2.9b	2.5b	2.3b	r	
2.7 a	3.1a	2.6b	2.4b	z	
(M)					
2.26a	2.4a	2.3a	2.1a	w	M*Cu
2.5a	2.7a	2.5a	2.3a	r	
2.7a	3.0a	2.6a	2.5a	z	
(G)					
2.5a	2.6a	2.4a	2.5a	G1	G*Cu
2.3a	2.5a	2.3a	2.1a	G2	
2.8a	3.0a	2.8a	2.6a	G3	
	2.95a	2.62a	2.55a	Average levels of Cu	
G_1: low gypsum soils 6.5%, G_2: medium gypsum soils 14.1%, G_3: high gypsum soils 35%, while Cu: (0.5-10)%, and copper levels (mg.kg^{-1}), M: (Z, R, W)%					

Copper concertation in wheat seeds

Table (9) indicates that the gypsum content in the soil affects the copper concertation in wheat, as the soil with low gypsum content G1 gave a significant difference, as it reached the highest average in low gypsum soils (47.7427 mg.kg-1) and the lowest average value reached (47.72702 mg.kg-1) in high gypsum soils G3. The addition of biochar showed the superiority of the MZ treatment, and its average reached (42.4778) and the lowest average in the MW treatment, it reached 38.5514. the results showed that the copper concertation in wheat grains increased with the increase in added copper, as the Cu2 treatments gave the highest average copper levels, and it reached 43.1673 ppm, with a significant difference compared to the treatment without adding copper, which gave the lowest average 39.1644ppm. this may be attributed to the positive role of copper in activating many enzymes that contribute to reducing oxygen from the aerobic respiration process helps in the production of the energy needed by the plant to perform many vital activities within the plant in addition to the role of copper in increasing the plant's absorption of many nutrients [26].

The dual interaction between the gypsum content in the soil and the types of added biochar gave the highest significant difference for the treatment G1MZ which averaged 41.4361 mg.kg-1 and the treatment G3MZ gave the lowest value in this interaction as its average reached 36.8918 mg.kg-1 may be due to the biochar-containing groups capable of chelating the copper element which reduces its deposition [20]. The dual interaction between the types of biochar and the levels of copper added to the soil gave a significant difference between the treatments in the concertation of the copper in wheat grains as the treatment (MzCu2) gave the highest value in this interaction which amounted to 45.9851 mg.kg-1. The treatment MWCu0 gave the lowest value of 34.4064 mg.kg-1. This may be due to the dissolution of gypsum and copper on the absorption sites, which causes ionic opposition between calcium ions, and thus may be reflected in its concertation in the grains [15]. These results are consistent with [21]. As for the interaction between the gypsum content in the soil and the added copper levels, the treatment G1Cu2 gave the highest value, reaching 57.4321 mg.kg-1, while the lowest value was for the treatment G3Cu0, reaching 39.2455 mg.kg-1. The triple interaction of the study factors gave the highest significant difference in favor of treatment G1ZCu2, as its value reached 45.1941 mg.kg-1, and the treatment G3wCu0 gave the lowest value in this interaction, which reached 31.4664 mg.kg-1. This may be attributed to the low gypsum content and the addition of biochar and copper to the soil, which gave positive results in the concentration of copper in wheat grains.

Table 9. Effect of biochar levels and added copper levels on the weight of 100 wheat grains planted in soil with different gypsum (g.100grains^{-1})

M*G	Added copper levels (mg.kg^{-1})			Types of copper (M)	Levels gypsum G
	cu 2	cu 1	cu 0		
40.5043 bc	42.1231 ebdagcf	43.871 ebdagcf	35.519 ejdihgcf	w	G1
37.5871 a	32.1764 bdac	44.4064 Bac	36.1787 Bdac	r	
41.4361 ba	45.1941 ba	43.1764 Ebdac	35.9379 ejdihgcf	z	
37.5008 f	33.4409 jlihgkf	40.7127 Jlihk	38.3488 Lk	w	G2
39.2455 de	39.2455 jlihgk	41. 3144 ejdihgkf	39.2455 Jlik	r	
39.5774 fe	36.3239 ejihgkf	40.0462 Jlk	42.3622 F	z	
36.8918 fe	39.8471 jlihgk	39.3621 Jlihk	31.4664 Lk	w	G3
39.0706 dc	36.6626 ebdhgcf	39.3552 Jlihgkf	41.1941 jlihgk	r	
37.8605 d	37.5638 ebdhgcf	36.6626 Jlihgk	39.3552 jlihgk	z	
(M)					
38.5514 bdec	44.5432 fde	36.7042 Fde	34.4064 F	w	M*Cu
40.5804 bac	44.3712 a	36.176 Bdac	41.1941 Dec	r	
42.4778 Ba	45.9851 bdac	35.5743 Fdec	45.874 Fe	z	
(G)					
47.7427a	57.4321a	43.1229a	42.6732ba	G1	G*Cu
47.5083ecd	55.4064ed	42.6521ef	44.4664f	G2	
47.2702bc	57.1941bcd	45.3712ed	39.2455ef	G3	
	43.1673a	40.5138b	39.1644c	Average levels of Cu	

G1: low gypsum soils 6.5%, G2: medium gypsum soils 14.1%, G3: high gypsum soils 35%, while Cu: (0.5-10)%, and copper levels (mg.kg^{-1}), M: (Z, R, W)%

Conclusions

1. adding the three types of coal copper levels increased most grow traits, seed weight, and seed copper content.
2. There was a variation between the types of coal with the studied traits, as the superiority was between corn cob coal and rice shell coal.

CONFLICT OF INTEREST

There is no conflict of interest.

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