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Role of Phosphorus Source and Biochar Levels on Some Fertility and Productivity Characteristics of Barley Crop Grow in Gypsiferous Soils

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Citation: Hilal N. A, Khalaf. A. I & Alwan, A. A. K. H. Role of Phosphorus Source and Biochar Levels on Some Fertility and Productivity Characteristics of Barley Crop Grow in Gypsiferous Soils. American Journal Of Botany And Bioengineering 2026, 3(2), 34-44.

Received: 10th Nov 2025

Revised: 21th Dec 2025

Accepted: 14th Jan 2026

Published: 06th Feb 2026



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Abstract: A Factorial Field experiment was conducted in Kirkuk governorate / plastic house of follower for the plant production department in technical institute – Hawija during the winter season to study the effect of phosphate source and biochar level in some fertility and productivity characteristics of barley crop planted in three gypsoferous soils. The experiment included three factors: the first factor is phosphorus source (Triple super phosphate and Rock phosphate) and at the level (120) Kg P ha⁻¹ for both, the second factor is biochar (0, 0.5, 1)% , the third factor is gypsum content of soils (5.12, 11.76, 17.9) %. The experiment was designed according to RCBD and with three repetitions. The results showed The phosphorus source, soil content of gypsum and biochar level significantly affected the productivity and fertility features, The highest average concentration of nitrogen, phosphorus, organic matter, grain yield came from the interaction of triple super phosphate fertilizer (120) Kg P ha⁻¹, 1% level of biochar and soil with 5.12 % gypsum content and reached (33.08) mg Kg⁻¹, (40.12) mg Kg⁻¹, (10.73) g Kg⁻¹, (38.19) g pot⁻¹ respectively.

Keywords: Phosphorus, Biochar, Barley, Gypsiferous Soil.

Introduction

Gypsiferous soils suffer from many problems due to the presence of gypsum salts in them, There are factors that limit production in these soils, including those related to physical, chemical or fertility properties, and it is related to its soil and water management, the decrease in soil fertility, productivity and rapid degradation due to high levels of gypsum, gypsum affects the ionic balance of nutrients in the soil solution resulting from the saturation of its solution with calcium and sulfate ions, When irrigating crops planted in these soils, gypsum forms a solid layer that prevents the growth and spread of roots, thus hindering the development of the plant [1]. In addition to the low content of organic matter and clay in these soils.

Phosphorus is an important essential element for plants [2], which suffer from a deficiency in gypsiferous soils because it undergoes many transformations in these soils due to its association with the calcium element, which is present in large quantities and concentrations in gypsiferous soils, Therefore most added phosphate fertilizers exposed to adsorption and precipitation reactions [3],

the research indicated that the plant absorbs about (15 -20) % from added fertilizer and rest is either chemically fixed with soil colloids or converted into organic forms within microorganisms (biological fixation). Explained [4] it is often overlooked fact is that the rate at which plant phosphorus is converted into unavailable forms tends to decrease with time .

Biochar is an organic amendment that plays a major role in improving most physical soil properties such as porosity, bulk density, moisture content, and hydrolic conductivity, in addition to chemical and biological properties Which is reflected in providing suitable conditions for plant growth and increasing its production and decrease Soil penetration resistance [5].

Biochar significantly decreases nutrient and pollutant leaching in soils [6]. While [7] and [8] mentioned that biochar improves chemical and physical properties in particular, including porosity, soil resistance to penetration, and hydraulic conductivity. concluded that biochar amended in soil can increase the availability of phosphate. Several studies have explained that biochar applied to the soil could enhance P availability in soils and decrease P fixation [9]; [10]; [11]. biochar application could somewhat P loss from applied P fertilisers due to leaching; as a result, reducing the pollution risk from P in water and soils [12]; [13].

The aim of this study is to know which source of phosphorus and which level of biochar increases the availability of elements in the soil, in addition to knowing the extent the impact of percentage of gypsum on nutrients.

Materials and Methods

A plastic pots experiment was carried out in the plastic house of the Plant Production Department Polytechnic college / Hawija - Northern Technical University during the winter season. Soil sampling were collected from surface layer (0-30) cm of different sites in from different locations in Salah al-Din Governorate. The soil was grinded, air-dried and passed through a sieve with 4 mm holes for planting purposes, and Then it was filled into pot with a capacity of (14) kg In addition other samples were taken from the same sites and grinding drying and sieving processes in order to estimate some chemical and physical properties table (1) for these soil. The experiment included three factors: the first factor is phosphorus source they are Phosphate Rock (Its properties in a table 2) it symbolized (P1) and Triple super phosphate it symbolized (P2) and both are at the same level (120) Kg P ha⁻¹ in addition phosphorus without treatment (Po), the second factor is biochar level (0 , 0.5 , 1) % and Its source is from sugarcane waste of Iranian origin)(table 3) and levels symbolized (S0 , S1 , S2) respectively and the third factor is soil with different gypsum percentage (5.12 , 11.76 , 17.09) % it symbolized (G1 , G2 , G3). Designed according to Random completely block design (RCBD) and with three replicated. Barley seeds were planted in pots at a rate of 20 seeds on the date 10 /11/2024. Fertilizer recommendation added for all from nitrogen fertilizer and potassium fertilizer at rate 200 Kg N ha⁻¹ (Equivalent 100 mg N Kg⁻¹ soil) as urea (46%N) and 160 Kg K ha⁻¹ as potassium sulfate (43%K) and both in two doses, the first at the beginning of the planting, The recommendation was mixed with phosphorus, biochar and soil treatments and placed in the pots, the second at the branching stage. It was irrigated with tap water based on field capacity by the gravimetric method and soil moisture was maintained by weighting the pots with the soil daily and adding water to bring the moisture to field capacity. After the plants germinated reduced them to (10) plants per pot. The experiment was harvested on the date 20/5/2025.

Studied characteristics

1. Available Nitrogen (mg Kg⁻¹) :- Estimate by the soil extracted with using potassium chloride solution (2M KCL) According to the method [14] by using microkeldahl.
2. Available phosphorus (mg Kg⁻¹) :- Estimate by the soil extracted with using sodium bicarbonate (NaHCO₃ 0.5M) at pH 8.5 by method [15], using aluminum molybdate and ascorbic acid , measured using a Spectrophotometer at wave length 882 nm as mentioned in [16].
3. Organic matter (g Kg⁻¹) :- determined by wet oxidation method [17].

4. Grain yield (g pot⁻¹) :- Taked the spikes without plant, The grain yield was calculated for each pot and averages were taken for three pots.

Table 1. Some Chemical And Physical Parameters For Soils Befor Planting

Parameters	Unit	G1	G2	G3	The method used in the analysis
Sand		501.01	544.07	577.11	
Clay	g Kg ⁻¹	273.55	239.14	218.12	
Silt		225.44	216.79	204.77	Pipette method [17]
Texture Class			SCL		
CEC	cmol Kg ⁻¹	16.09	12.11	9.11	Simplified methylene blue method [17]
pH (1:1)	—	7.74	7.33	7.11	Using device pH-meter [16]
EC (1:1)	ds m ⁻¹	2.33	2.58	3.00	Using device EC [16]
CaSO ₄		5.12	11.76	17.09	Dilution method [16]
CaCO ₃		211	181	153	gravimetric method [16]
O.M	g Kg ⁻¹	8.22	6.01	5.13	Wet oxidation [17]
Av. N		22.09	13.76	9.12	KCL 2M [17]
Av. P	mg Kg ⁻¹	7.09	3.89	3.00	NaHCO ₃ 0.5 M [15]
Av. K		133	110	98	NH ₄ CH ₃ COOH (1N) [18]
			Dissolved ions		
Ca ⁺²		5.34	10.09	14.06	Ca and Mg were determined by the Fresnet titration method (0.01 N) [19].
Mg ⁺²		2.08	1.21	1.04	
K ⁺¹		0.71	0.51	0.36	
Na ⁺¹		1.39	1.32	1.14	K and Na using a flame photometer [19].
SO ₄ ⁻²		3.74	8.80	12.00	Estimated by precipitation as BaSO ₄ [19].
HCO ₃ ⁻¹	mm L ⁻¹	0.19	0.29	0.33	estimated by titration with H ₂ SO ₄ [19].
CO ₃ ⁻²			Nil		
Cl ⁻¹		0.94	0.77	0.51	titration with silver nitrate solution (1N) [19].

Table 2. Some Chemical Properties Of The Phosphate Rock Used In The Study

Parameters	P ₂ O ₅ %	P %	Ca%	% CO ₂
Value	33	14.38	39	2.9

Table 3. Some Chemical Properties Of The Biochar Used In The Study

Parameters	% K	% P	% N	EC (ds m ⁻¹)	pH
Value	22	2.2	0	2.79	7.07

Statistical analysis :- Data were analyzed statistically using the statistical program (SAS) using analysis of variance (ANOVA) according to the randomized complete block design (RCBD) and the differences between the arithmetic means were tested at a significance level (5%) using Duncan's multiple range test [20].

Results and Discussion

Available Nitrogen (mg Kg⁻¹)

Table (2) show effect of phosphorus source ,the addition of phosphorus had a significant effect, and the average of both PR and TSP (24.99 , 27.71) mg Kg-1 while the treatment rate without adding phosphorus was (22.46) mg Kg-1 respectively. through the results TSP superior to the PR was observed due phosphorus role in decomposed microorganisms activating for organic matter therefore nitrogen released,this is reflected in availability increasing, these results correspond with [21]. Biochar levels significant affected nitrogen concentration increased with increased levels of addition and the level gave (1)% highest average was (28.45) mg Kg-1 while the levels (0 , 0.5) % gave a rate (21.63 , 25.07) mg Kg-1 respectively, the reason for this is due biochar has improvement soil physical properties such as porosity , water holding capacity reduce bulk density this led to encourage non symbiotic N2 microorganisms therefore the soil content from available nitrogen increased.

Table 4. Effect Of Phosphorus Source , Biochar Levels And Gypsum Content Of Soil And The Interaction Between Them In The Concentration Of Nitrogen In The Soil After Harvest (Mg Kg-1)

Soil gypsum content G	Biochar S	Added phosphorus source Kg ha ⁻¹			G X S
		P0	P1	P2	
	S0	21.11 g	23.07 f	24.92 ef	23.03 de
G1	S1	24.32 ef	27.33 cd	29.40 b	27.02 bc
	S2	28.00 c	29.57 b	33.08 a	30.22 a
	S0	18.09 hi	20.87 gh	24.92 e	21.29 e
G2	S1	21.45 g	25.14 e	26.66 d	24.42 d
	S2	25.09 e	28.77 bc	31.00 ab	28.29 ab
	S0	17.60 i	21.00 g	23.11 f	20.57 e
G3	S1	21.09 g	23.14 f	27.14 cd	23.79 de
	S2	25.37 e	26.00 de	29.18 b	26.85 c
	Average S				
S X P	S0	18.93 e	21.65 d	24.32 c	21.63 c
	S1	22.29 d	25.20 c	27.73 b	25.07 b
	S2	26.15 bc	28.11 b	31.09 a	28.45 a
Average G					
G X P	G1	24.48 c	26.66 ab	29.13 a	26.76 a
	G2	21.54 d	24.93 bc	27.53 a	24.67 b
	G3	21.35 d	23.38 cd	26.48 b	23.74 b
Average P		22.46 c	24.99 b	27.71 c	
P0 = without phosphorus		S0 = without biochar		G1 = gypsum 5.12 %	
P1= phosphate rock (120) Kg ha ⁻¹		S1= 0.5 % biochar		G2 = gypsum 11.76 %	
P2 = TSP (120) Kg ha ⁻¹		S2 = 1 % biochar		G3 = gypsum 17.09 %	

The results of the table (4) indicate that increasing gypsum has a negative effect on the soil content of available nitrogen. The soil with gypsum content 5.12% gave the highest concentration of (26.76) mg Kg-1 and with significantly superiority compared to the two soils (11.76 , 17.09) % Which gave a concentration of (24.67 , 23.74) mg Kg-1 respectively. This is due to the fact that organic matter is the only store of nitrogen in the soil and that the release of nitrogen from organic matter to the soil solution depends on the state of decomposition of organic matter, as the decomposition of organic

matter decreases with the increase of gypsum in the soil [22]. On the other hand there are organisms that fix nitrogen in symbiosis, such as Azotobacter and Azospirillum bacteria, and these microorganisms may have been affected by the increase of gypsum on their activity, which was reflected in the soil content of available nitrogen. These results were consistent with what was found by [23].

The interactions appeared between the treatments visible significant differences The interaction between the soil gypsum content and the biochar level a superiority in favor of the interaction treatment G1S2 and gave the highest rate was (30.22) mg Kg-1 while the lowest average for treatment G3S0 was (20.57) mg Kg-1 .

The interaction between gypsum content and phosphorus source also showed differences between treatments, Whereas treatment G1P2 gave the highest average of (29.13) mg kg-1 There is no significant difference between the previous value and the treatment value G2P2 (27.53) mg kg-1 , while treatment G3P0 gave the lowest average of (21.35) mg kg-1, This result is consistent with the result of [24] which stated that by increasing the level of gypsum in the soil leads to available nitrogen in the soil decreased.

The results of the table showed that the interaction between the phosphorus source and the biochar level gave significant differences between the treatments. Treatment S2P2 recorded the highest average for this interaction, reaching (31.09) mg kg-1, while the interaction treatment S0P0 gave the lowest average, reaching (18.93) mg kg-1, Perhaps it may be due to the role of biochar in providing the soil with carbon or helping it to stabilize its carbon reserves, which makes microbial activity more efficient within the soil and thus converts organic nitrogen into nitrogen compounds ready for absorption by plants.

The triple interactions between treatments gave differences between treatments and treatments G1S2P2 recorded the highest average of (33.08) mg kg-1 while treatment G3S0P0 gave the lowest average of (17.60) mg kg-1.

Available Phosphorus (mg Kg-1)

Table (5) shows that available phosphorus decreased with increasing soil gypsum content. The soil with a gypsum content of 5.12% gave an average of (22.57) mg kg-1 with a significant superiority compared to the two soils with a gypsum content of (11.76 and 17.09) % which gave an average of (16.17 and 12.89) mg kg-1 respectively. This is due to the fact that gypsum is a salt with a solubility of (2.6) g L-1 and when it dissolves calcium ions are released into the solution which leads to the precipitation of calcium phosphate and this form is considered unavailable and soluble for the plant. These results were consistent with what was found by [24].

The results indicate the role played by biochar as the available phosphorus increased with increasing the level of biochar addition as the level (1.0) % gave the highest average of (23.78) mg kg-1 while the addition levels (0 , 0.5) % gave an average of (10.48 ,17.37) mg kg-1 respectively. This is attributed to the fact that biochar has a high surface area which led to protecting phosphorus from adsorption and precipitation reactions. thus increasing its availability These results are compatible with [25].

The results of the interaction between the biochar and the soil gypsum content show that the G1S2 treatment gave the highest concentration of (31.69) mg kg-1 and the G3S0 treatment gave the lowest average for this characteristic of (7.68) mg kg-1.

The results of the same table indicate that the interaction between gypsum and the phosphorus source gave significant differences between the treatments, as treatment G1P2 gave the highest average in this interaction reaching (30.00) mg kg-1 while treatment G3P0 gave the lowest average reaching (7.29) g Kg-1.

The interaction between phosphorus source and biochar level showed significant differences between treatments, as treatment S2P2 gave the highest concentration of (31.29) mg kg-1 which

significantly outperformed all treatments in this interaction in addition treatment S0P0 also gave the lowest average in this reaching an average of (2.70) g Kg-1.

The results also indicate that the interaction between gypsum content, biochar level and phosphorus source was superior for treatment G1S2P2 which gave the highest average of (40.12) mg kg-1 while treatment G1S0P0 gave the lowest average of (3.17) mg kg-1.

Table 5. Effect Of Phosphorus Source , Biochar Levels And Gypsum Content Of Soil And The Interaction Between Them In The Concentration Of Phosphorus In The Soil After Harvest (Mg Kg-1)

Soil gypsum content G	Biochar S	Added phosphorus source Kg ha ⁻¹			G X S
		P0	P	P2	
		P1			
G1	S0	3.17 o	17.34 ij	20.15 fg	13.55 e
	S1	13.26 lm	24.47 d	29.72 c	22.48 b
	S2	19.75 gh	35.19 b	40.12 a	31.69 a
G2	S0	2.82 o	12.21 lm	15.61 jk	10.21 f
	S1	9.54 n	17.54 ij	22.83 de	16.64 d
	S2	14.08 kl	21.80 ef	29.08 c	21.65 b
G3	S0	2.11 o	9.21 n	11.73 m	7.68 g
	S1	7.75 n	13.22 lm	18.00 hi	12.99 e
	S2	12.00 m	17.32 ij	24.67 d	18.00 c
Average S					
S X P	S0	2.70 h	12.92 f	15.83 e	10.48 c
	S1	10.18 g	18.41 d	23.52 c	17.37 b
	S2	15.28 e	24.77 b	31.29 a	23.78 a
Average G					
G X P	G1	12.06 f	25.67 b	30.00 a	22.57 a
	G2	8.81 g	17.18 d	22.51 c	16.17 b
	G3	7.29 h	13.25 e	18.13 d	12.89 c
Average P		24.18 a	19.68 b	24.18 a	
P0 = without phosphorus		S0 = without biochar		G1 = gypsum 5.12 %	
P1= phosphate rock (120) Kg ha ⁻¹		S1= 0.5 % biochar		G2 = gypsum 11.76 %	
P2 = TSP (120) Kg ha ⁻¹		S2 = 1 % biochar		G3 = gypsum 17.09 %	

Organic Matter (g Kg-1)

The results of Table (6) showed that the concentration of gypsum in the soil had a significant effect on the decrease in the soil organic matter content, as the soil with a gypsum content of (5.12) % gave the highest average of (9.69) g kg-1 while the soils with gypsum ratios (11.76 and 17.09) it reached (8.93 , 7.83) g kg-1 % respectively. The reason for this is that perhaps the increase in gypsum hinders the growth of the roots and thus produces less organic matter. On the other hand the percentage of clay is low with the increase in gypsum (Table 1), which resulted in the association of organic carbon with the cations adsorbed on the clay surfaces [26].

Table 6. Effect Of Phosphorus Source , Biochar Levels And Gypsum Content Of Soil And The Interaction Between Them In Soil Organic Matter Content After Harvest (G Kg-1)

Soil gypsum content G	Biochar S	Added phosphorus source Kg ha ⁻¹			G X S
		P0	P	P2	
		P1			
G1	S0	9.07 c-g	9.23 b-f	9.51 b-e	9.27 c
	S1	9.44 b-e	9.69 b-d	9.86 b	9.66 b

	S2	9.74 bc	9.91 b	10.73 a	10.13 a
G2	S0	8.41 g-i	8.71 f-h	8.90 e-g	8.67 d
	S1	8.87 e-g	9.01 c-g	9.14 c-f	9.01 cd
	S2	8.98 d-g	9.12 c-f	9.27 b-f	9.12 c
G3	S0	7.11 k	7.47 jk	7.74 i-k	7.44 f
	S1	7.62 jk	7.95 ij	8.13 h-j	7.90 e
	S2	7.89 ij	8.15 h-j	8.37 g-i	8.14 e
				Average S	
S X P	S0	8.20 e	8.47 de	8.72 b-d	8.46 c
	S1	8.64 cd	8.88 bc	9.04 b	8.86 b
	S2	8.87 bc	9.06 b	9.46 a	9.13 a
				Average G	
G X P	G1	9.42 bc	9.61 b	10.03 a	9.69 a
	G2	8.75 d	8.95 d	9.10 cd	8.93 b
	G3	7.54 f	7.86 ef	8.08 e	7.83 c
	Average P	8.58 c	8.80 b	9.07 a	
	P0 = without phosphorus	S0 = without biochar	G1 = gypsum 5.12 %		
	P1= phosphate rock (120) Kg ha ⁻¹	S1= 0.5 % biochar	G2 = gypsum 11.76 %		
	P2 = TSP (120) Kg ha ⁻¹	S2 = 1 % biochar	G3 = gypsum 17.09 %		

While the source of phosphorus has a significant effect on the soil organic matter content, triple superphosphate fertilizer (TSP) gave the highest average of (9.07) g kg⁻¹ with a significant superiority compared to phosphate rock which reached (8.80) g kg⁻¹ and the treatment without addition recorded the lowest average of (8.58) g kg⁻¹. The reason is due to the major role played by phosphorus in the vital processes inside the plant, in addition to the role of phosphorus in increasing the growth and yield of the plant after encouraging root growth and helping to absorb other nutrients. Increasing plant growth results in increasing dry matter and then increasing organic matter [27].

The results of the table also show that the biochar level had a significant effect on the concentration of organic matter, and the addition level (1.0) g kg⁻¹ gave the highest average of (9.13) g kg⁻¹ significantly superior to the addition levels (0, 0.5) % which gave an average of (8.46 and 8.86) respectively. This is due to the fact that biochar may have improved root growth and thus accumulated more dry matter which was reflected in its concentration in the soil. On the other hand biochar encouraged the activity of microorganisms and the bodies and waste of these organisms worked to increase the organic matter. This result was consistent with [25].

The results of the binary interaction between the phosphorus source and the soil gypsum content show a significant superiority in favor of treatment G1P2 which gave the highest average of (10.03) g kg⁻¹ while treatment G3P0 gave the lowest average in this interaction of (7.54) g kg⁻¹.

The interaction between the phosphorus source and the biochar level also led to significant differences between the treatments as treatment P2S2 gave the highest average in this interaction (9.46) g kg⁻¹ and treatment P0S0 recorded the lowest average in this interaction reaching (8.20) g kg⁻¹.

The effect of biochar and gypsum was in favor of treatment G1S2 which gave the highest average of (10.13) g kg⁻¹ significantly superior to all treatments in this interaction and treatment G3S0 gave the lowest average of (7.44) g kg⁻¹.

The combinations between the three study factors were significant in some treatments as the combination treatment G1P2S2 gave the highest average of (10.73) g kg⁻¹ significantly superior to all treatments in these combinations. The comparison treatment G3P0S0 gave the lowest average in this interaction reaching (7.11) g kg⁻¹.

Grain Yield (g pot⁻¹)

The results of Table (7) show that the soil gypsum content had a significant effect on the grain yield as the soil with a gypsum content of (5.12) % gave the highest yield of (29.89) g pot-1 and with a significant superiority compared to the two soils with a gypsum content of (11.76 , 17.09) % which gave a yield of (27.18 , 24.18) g pot-1 respectively. The reason for the decrease is due to the increase in calcium ions which affect the growth and penetration of roots which negatively affected the grain yield These results are Compatible with [24].

The addition of phosphorus had a significant effect on the grain yield and the superiority of superphosphate over phosphate rock, and their rates reached (31.22 , 27.54) g pot-1 respectively compared to the treatment without addition which recorded the lowest yield of (22.50) g pot-1. The values also indicate that triple superphosphate fertilizer was superior to phosphate rock, This increase may be due to the important role of phosphorus in the growth and development of the plant as the appropriate concentration of this element in the root area will increase the division of root cells and the formation of a large root system and thus the development of the plant in the early stages of growth, which makes the plant able to absorb the largest possible amount of water and nutrients that help develop and increase the number of branches and then early maturity and increase the yield in addition to the contribution of phosphorus to the elongation of the roots as it works to increase the activity of many enzymes [28] as the increase in added phosphorus will increase the dry matter of the plant and thus the demand for nutrients will increase, as indicated by [29] and [30].

Biochar levels achieved a significant increase as the grain yield increased with increasing the addition level and level (1.0) % gave the highest yield of (32.00) g pot-1, while levels (0 , 0.5) % gave an average of (22.50 , 26.75) g pot-1 respectively. This is due to its role in providing the plant with nitrogen, phosphorus and potassium elements and improving the physical properties of the soil which is reflected nutritionally especially in increasing the vegetative growth of the plant and thus increasing the total grain yield [31].

The interaction between the soil gypsum content and the biochar level gave significant differences as the interaction treatment G1S2 was found to have the highest average for this trait reaching (34.26) g pot-1 while the interaction treatment G3S0 gave the lowest average reaching (20.29) g kg-1. The combination of gypsum content and phosphorus source showed significant differences between

Table 7. Effect Of Phosphorus Source , Biochar Levels And Gypsum Content Of Soil And The Interaction Between Them In Grain Yield (G Pot-1)

Soil gypsum content G	Biochar S	Added phosphorus source Kg ha ⁻¹			G X S
		P0	P1	P2	
G1	S0	19.98 m	25.00 ij	30.17 de	25.05 f
	S1	24.37 jk	31.14 d	35.55 b	30.35 c
	S2	27.94 fg	36.66 b	38.19 a	34.26 a
G2	S0	18.21 n	22.21 l	26.09 hi	22.17 h
	S1	23.11 kl	26.77 gh	29.59 e	26.49 e
	S2	28.74 ef	33.20 c	36.69 b	32.88 b
G3	S0	16.00 o	19.86 m	25.00 ij	20.29 i
	S1	20.15 m	23.87 jk	26.22 hi	23.41 g
	S2	24.00 jk	29.12 ef	33.45 c	28.86 d
S X P	S0	18.06 f	22.36 e	27.09 d	22.50 c
	S1	22.54 e	27.26 d	30.45 c	26.75 b
	S2	26.89 d	32.99 b	36.11 a	32.00 a
G X P	G1	24.10 ef	30.93 b	34.64 a	29.89 a
	G2	23.35 f	27.39 d	30.79 b	27.18 b
					Average S
					Average G

	G3	20.05 g	24.28 e	28.22 c	24.18 c
Average P		22.50 c	27.54 b	31.22 a	
P0 = without phosphorus			S0 = without biochar		G1 = gypsum 5.12 %
P1= phosphate rock (120) Kg ha ⁻¹			S1= 0.5 % biochar		G2 = gypsum 11.76 %
P2 = TSP (120) Kg ha ⁻¹			S2 = 1 % biochar		G3 = gypsum 17.09 %

treatments, as treatment G1P2 gave the highest average of (34.64) g pot-1 while treatment G3P0 gave the lowest average of (20.05) g pot-1.

As for the combination between the phosphorus source and the biochar level it gave significant differences between the treatments. Treatment S2P2 recorded the highest average for this interaction reaching (36.11) g pot-1 while the interaction treatment S0P0 gave the lowest average reaching (18.06) g pot-1.

The triple interactions between treatments gave differences between treatments and treatments G1S2P2 recorded the highest average of (38.19) g pot-1 while the two treatments G3S0P0 gave an average of (16.00) g pot-1.

The interaction between the soil gypsum content and the biochar level gave significant differences as the interaction treatment G1S2 was found to have the highest average for this trait reaching (34.26) g pot-1 while the interaction treatment G3S0 gave the lowest average reaching (20.29) g kg-1.

The combination of gypsum content and phosphorus source showed significant differences between treatments, as treatment G1P2 gave the highest average of (34.64) g pot-1 while treatment G3P0 gave the lowest average of (20.05) g pot-1.

As for the combination between the phosphorus source and the biochar level it gave significant differences between the treatments. Treatment S2P2 recorded the highest average for this interaction reaching (36.11) g pot-1 while the interaction treatment S0P0 gave the lowest average reaching (18.06) g pot-1.

The triple interactions between treatments gave differences between treatments and treatments G1S2P2 recorded the highest average of (38.19) g pot-1 while the two treatments G3S0P0 gave an average of (16.00) g pot-1.

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