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# Effect of Sheep Manure and Biochar on Phosphorus Availability in Calcareous and Non-Calcareous Soils in Sulaimani Governorate, Iraqi Kurdistan Region

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## ABSTRACT

This study conducted the influence of sheep manure and biochar on soil phosphorus retention in both calcareous and non-calcareous soils. Soil samples were taken from the plowing depth (0–30 cm) of agricultural areas at two locations: Bakrajo (calcareous soil) (35°32'03.9" N, 45°21'57.1" E) and Arbat (non-calcareous soil) (35°23'40" N, 45°39'27" E) in the Sulaimani Governorate, Kurdistan Region, Iraq. A soil incubation experiment was performed using 200 g of soil which mixed with four levels of biochar (0, 0.25, 0.5, 0.75%) and four level of sheep manure (0, 0.5, 1, 2%) in glass jars at 28±2°C at 60% of its available water, the samples were incubated for 2,4 and 6 months and soil available phosphorous was measured after 2,4 and 6 months, Phosphorus availability was influenced by different levels of manure and biochar across the incubation periods of 2, 4, and 6 months. Manure P mineralization increased over time, leading to a substantial rise in soil phosphorus levels after 2 months, with the highest value 13.565 mg kg<sup>-1</sup> observed at the 1% manure application in non-calcareous soil, and decreased significantly afterwards. At similar soil test P values, non-calcareous soils with high buffering capacities had larger P reserves than calcareous soils with low buffering capacities and 14.15 mg kg<sup>-1</sup> in calcareous soil at manure level 2% after 6month. The findings indicate that the impact of biochar and sheep manure increased with increasing application rates. Biochar at a 0.75% application rate and sheep manure at 2% had the greatest impact.

**Keywords:** available phosphorus, biochar, calcareous soil, non-calcareous soil, sheep manure.

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## INTRODUCTION

Phosphorus (P) is an important determinant of plant growth and productivity. P is rarely available in sufficient amounts for plants to grow and develop to their full potential due to its fixation in calcareous soils in form of Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub> or adsorption at the surface of CaCO<sub>3</sub> [1]. According to [2,3], Phosphorus is essential for controlling physiological responses and strengthening plants' defenses against abiotic stressors such as high CO<sub>2</sub>, heat, salinity, drought, waterlogging, and heavy metal toxicity, to detect and respond to changes in the phosphorus supply, plants alter their stomatal morphology, root architecture, and specific signaling pathways [4,5].

Enough P can be hard to give plants, especially in alkaline and calcareous soils, as it acts as a sink for calcium phosphate precipitation that is surface-adsorbed in alkaline soil. A soil is deemed alkaline if its pH is higher than neutral, usually between 7.5 and 8.5. If soil CaCO<sub>3</sub> is more than 2.0% the soil is regarded as a calcareous soil. While lime dissolves readily in soil with a pH of neutral to acidic [6].

The soil's pH has a direct correlation with P bioavailability, because iron and aluminum phosphate minerals are formed, P becomes less soluble in extremely acidic soil; this improves as pH approaches neutral. As pH increases into the alkaline range, P's maximum solubility and plant availability once again decline to 6.5. Since these calcium phosphate minerals are least soluble at pH values around 8, the decline in P availability in alkaline soil is caused by the reaction between P and calcium. In alkaline soil, the presence of carbonate minerals in the state of lime exacerbates the problem of P availability. In calcareous soil, the lime forms a solid calcium phosphate bond with the soil solution P. These calcareous, in regions with little precipitation that are arid or semi-arid, alkaline soils are prevalent, because calcium and other bases are leached and replaced by hydrogen ions found in water and low fertilizer, the pH of the soil is low in places with a long history of excessive rainfall. In calcareous and alkaline soil, low P solubility leads to low P effectiveness. Under these conditions, plants may be stunted, with weak root systems and shortened internodes, due to a P deficit. While yield reduction without any visible symptoms is more common, occasionally a darkening of the leaf tissue indicates a deficiency. [7].

At comparable soil test P levels, non-calcareous soils with greater buffering capacities displayed larger P reserves than

calcareous soils with smaller buffering capacities. [8].

Low levels of OM and nutrient availability, especially for micronutrients (Fe, Mn, Zn, and Cu) and phosphorus, are frequent issues in calcareous soils in arid regions [9-12]. Microbial activity is negatively impacted by decreased soil organic matter [13] and the availability of nutrients in the soil [14]. The main problem with calcareous soil is that, even though its overall P and micronutrient concentration is extremely high, its high pH, high calcium carbonate content, and low level of soil organic matter (SOM) limit their availability. [10].

In calcareous soil, microbial activity and soil fertility are greatly influenced by soil organic matter (SOM) [15]. Thus, adding soil organic amendments, such as biochar, to calcareous soil, semi-arid regions with very low OM content may enhance their nutritional status and soil microbial function [16]. A beneficial soil organic amendment, biochar is the carbonaceous byproduct of pyrolyzing feedstocks in the complete or partial lack of oxygen. By modifying a number of the soil's biological, chemical, and physical characteristics, it can improve soil fertility and quality. [15,17]. The circumstances of pyrolysis and the kind of biochar feedstock affect the nutrients' availability and composition [18]. According to [19], a number of variables also impact the nutrient status in soils treated with biochar, such as the type of soil, feedstock kinds, pyrolysis temperature, and using amount used.

Animal manures are useful P fertilizers that can be added back into soils by a variety of farming methods. Mineral P fertilizer use can be reduced, which lowers pollution in the environment, by replenishing animal manure through agricultural techniques. According to earlier research, adding animal manure to soil might raise P levels. According to certain reports, manures specifically increase microbial activities, such as microbial biomass and the entire microbial community. which will influence the transformation of different P forms either directly or indirectly through immobilization and microbial mineralization [20].

#### The following are the study's objectives:

- To assess how biochar and sheep manure affect the retention of phosphorus in the soil.
- To compare the impact of varying dosages of biochar and sheep manure on phosphorus availability.

#### Materials and methods

The experimental soil sample was taken from the plowing depth (0 -30 cm) from the agricultural fields in two locations, Bakrajo (calcareous soil) (35° 32' 03.9" N, 045° 21' 57.1" E), and Arbat (non-calcareous soil) (35° 23' 40" N, 45° 39' 27" E) in Sulaimani Governorate. Iraq Kurdistan region. as shown in (Fig.1)

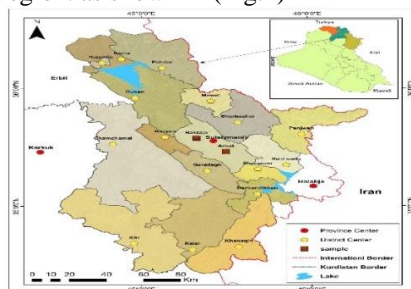


Fig. 1. The location of the studied area

Following the random assignment of sampling locations, the samples were collected from the field, brought to the lab, allowed to air dry, then sieved through a 2 mm sieve for chemical analysis and a 4 mm sieve for experiments and kept at room temperature. Some fundamental physicochemical characteristics of the studied soil including particle size distribution, pH, EC, organic matter  $\text{g kg}^{-1}$  and calcium carbonate  $\text{g kg}^{-1}$  determined according to the technique of soil analysis as described by [21,22] and CEC was calculated according to equation provided by [23]. Soil available P was extracted with  $0.5N \text{NaHCO}_3$  and measured spectrophotometry at 880nm wavelength by using Olsen procedure as described in [21]. Some physicochemical characteristics of the soils are presented in Table 1.

Table 1 lists some of the soil's physicochemical characteristics that were used in the experiment

Property	Unit	Bakrajo	Arbat
Particle size distribution			
Sand	(g kg <sup>-1</sup> )	64.100	22.400
Silt	(g kg <sup>-1</sup> )	472.7	438.5
Clay	(g kg <sup>-1</sup> )	463.2	539.1
Texture class		silty clay	silty clay
pH (1:5 water)		7.780	7.210
ECe (dS m <sup>-1</sup> ) at 25 Co		0.292	0.200
Calcium carbonate content	(g kg <sup>-1</sup> )	293.2	18.900
Organic matter	(g kg <sup>-1</sup> )	14.1	21.2
Cation exchange capacity	(cmolc kg <sup>-1</sup> )	39.216	43.747
Available phosphorous	( mg kg <sup>-1</sup> )	5.040	6.200

The chemical content of sheep manures and biochar is presented in Tables 2 and 3.

Table (2) Chemical composition of biochar from pomegranate and orange tree wood

Parameter	Typical Range
Carbon (C)	70 - 85 wt. %
Oxygen (O)	10 - 20 wt. %
Hydrogen (H)	1 - 3 wt. %
Nitrogen (N)	<1 wt. %
Ash content	2 -7 wt. %
PH (in 1:5 water)	8 - 10

Table (3): Basic physical and chemical properties of the sheep manure in this experiment

Parameters	Unit	Value
Total N	%	0.837
Total P	%	1.208
Total K	%	3.253
OM	%	39.448
PH(1:5)		8.3

### Design of the Experiment and Incubation Study

An experiment in incubation was carried out using a complete randomized design, as a factorial study that has 3 replications. Four levels of biochar (0, 0.25, 0.5, 0.75%) and four levels of sheep manure (0, 0.5, 1, 2%) were used. The air-dried soil 200g was mixed with biochar and sheep manure in glass jars. After being incubated for (2, 4, and 6) months at  $28 \pm 2^\circ\text{C}$ . Throughout the incubation phase, by adding distilled water to make up for the water loss, the soil moisture content of the samples was maintained at 60% of the available water, have been estimated according to the model prepared by [24] as following equation  $F.C. = 13.20 + 0.397 \times \text{Clay}\%$ ,  $W.P. = 4.57 + 0.35 \times \text{Clay}\%$ . and soil available phosphorus was measured after 2, 4, and 6 months.

### Statistical Analysis

Analysis of Variance (ANOVA) software was utilized to examine the gathered data (Version, 2019). To compare means, the Duncan Multiple Range Test (DMRT) was used at the 1% significance level.

### Results and discussion

#### Effect of sheep manure on phosphorus availability in calcareous and non-calcareous soils

Phosphorus availability was influenced by different levels of sheep manure and biochar across the incubation periods of 2, 4, and 6 months. Table 4 displays the time dependence of P mineralization in soil across levels of biochar and sheep manure. Manure P mineralization increased over time, leading to a substantial rise in soil phosphorus levels after 2 months, with the highest value  $13.565 \text{ mg kg}^{-1}$  observed at the 1% manure application in non-calcareous soil, and decreased significantly afterwards. At similar soil test P values, non-calcareous soils with high buffering capacities had larger P reserves than calcareous soils with low buffering capacities [8] and  $14.15 \text{ mg kg}^{-1}$  in calcareous soil at manure level 2% after 6 month.

Table (4) Change in mean value of available phosphorus  $\text{mg kg}^{-1}$  as a function of manure application rates and biochar application rates during incubation periods in the studied soil.

Time Incubated(months)	Arbat soil (non-calcareous soil)				Biochar application( $\text{g } 100\text{g}^{-1}\text{soil}$ )			
	Sheep manure application ( $\text{g } 100\text{g}^{-1}\text{soil}$ )				0	0.25	0.5	0.75
2	6.835 c	10.450 b	13.565 a	12.060 ab	11.170a	11.285a	10.245ab	10.210ab
4	7.205c	10.890abc	12.475ab	10.720abc	8.560 a	11.825a	9.100 a	11.805a
6	5.825d	7.105cd	10.288bc	10.875b	8.380a	7.830a	9.005a	8.428a
	Bakrajo Soil (calcareous soil)							
2	5.040c	6.690c	6.325c	10.025 b	7.820 a	6.765c	7.070 c	6.425c
4	10.888 abc	14.243a	8.905bc	8.805 bc	10.178 a	10.453a	10.510a	11.700a
6	6.938 cd	5.900d	8.425bcd	14.150a	7.888 a	8.875a	9.075a	9.575a

In contrast, the lowest phosphorus availability,  $5.040 \text{ mg kg}^{-1}$ , appeared in the control treatment after 2 months in calcareous soil (Bakrajo soil). According to Table 4's data, all types of manure considerably increased soil P compared to the control in terms of manure level between two and four months, and the majority of the P that the manures released did not fix by soil

colloids. After four months, this finding became more apparent than it had been during the two-month period. Thus, the quantity of available phosphorus (P) in the soil is raised by adding manure, The organic ligands in the manures may have sealed the P sorption sites, resulting in this improvement and it's possible that the influence of manure on soil P availability outweighed that of colloidal fixation, comparable outcomes were reported by [25] and [26]. After 6 months, the high value in calcareous soil was recorded as 14.15 mg kg<sup>-1</sup> with the application of 2% of sheep manure, but in non-calcareous soil at the same manure level was 10.875 mg kg<sup>-1</sup>. These results align with prior research indicating that organic amendments, including sheep manure, can improve phosphorus availability in both calcareous and non-calcareous soils. The effect is more pronounced in calcareous soils due to the interaction with calcium carbonate and microbial activity [27]. And the lowest (P) availability was recorded after 6 months in non-calcareous soil under control treatment (without manure application), recording a value of 5.825 mg kg<sup>-1</sup>, followed by the calcareous soil treated with 0.5 % of sheep manure, which was 5.9 mg kg<sup>-1</sup>.

The results in Fig. 2 show that after two months, the non-calcareous soil had higher P concentrations than the calcareous soil at the same amount of sheep manure. In contrast to non-calcareous soils, where phosphorus is more soluble and accessible, calcareous soils have a high calcium carbonate content, which encourages phosphorus fixation and lowers its availability. This discrepancy is mostly explained by variations in the chemical characteristics of the soil [28,5]. However, after 4 and 6 months of incubation, no discernible difference in phosphorus availability was found between calcareous and non-calcareous soils. This might be because the initial variations brought on by soil type are lessened over time by the slow mineralization of organic matter and stabilization of phosphorus forms [29].

After six months, both soil types showed an increase in phosphorus fixation, which could be explained by chemical processes like the creation of stable phosphorus compounds, especially in calcareous soils. The initial phosphorus content of the applied manures may also be the cause of this trend. After six months, available phosphorus levels decreased, despite the fact that the phosphorus balance in manure-treated soils stayed positive during the incubation period. This could be because of a gradual increase in fixation and a decrease in microbial activity; it could be assumed that the microorganism had died, stopped growing, or stopped metabolizing [30].

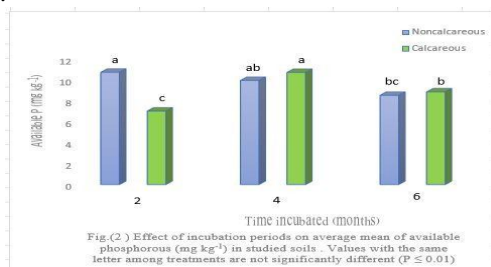


Fig. (2) Effect of incubation periods on average mean of available phosphorus (mg kg<sup>-1</sup>) in studied soils. Values with the same letter among treatments are not significantly different ( $P \leq 0.01$ )

Fig. 3 demonstrate that, when the control soil was compared to other treatment levels, larger negative values in soil P were observed at the 1% and 2% manure levels in month 4, and at the 0.5% level in 6 months, this result showed that change between the four and six months, the effects of each colloidal fixation describe the process by which phosphorus is chemically bonded to soil constituents and immobilization were stronger. In six months, soil P fixation was more noticeable in both soils at a level of 0.5%. The immobilization of P by the microbes in the manures may have been caused by the manures' original C:P ratios; fixation of P by colloids may also have exacerbated this P problem. The availability of P decreases after 4 to 6 months because it could be assumed that the microorganism had died, stopped growing, or stopped metabolizing. The observed trend might have also been a reflection of the initial P contents of the manures. Throughout the incubation period, the P balance of manure-treated soil remained positive; however, after 6 months, the P levels increased with increasing manure rate from 0.5 to 2% [30].

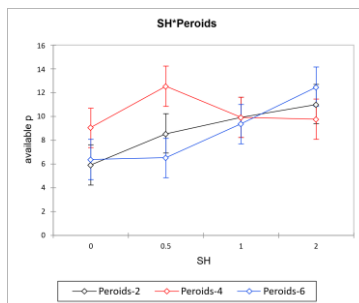


Fig. (3). Effect of sheep manure application rates g 100g<sup>-1</sup> soil on the average mean of available phosphorus mg kg<sup>-1</sup> during incubation periods in the studied soils.

These soil types may react very differently to organic amendments, whereas non-calcareous soils usually have moderate P availability and lower fixation, calcareous soils are known to have high P fixation capacity and frequently low available phosphorus [31].

### Effect of biochar on phosphorus availability in calcareous and non-calcareous soils

Low-rate biochar application had a smaller impact on soil P availability Table 4. After four months in calcareous soil, a 0.75% biochar level revealed a moderate phosphorus value ( $11.700\text{mg kg}^{-1}$ ) and ( $11.825\text{ mg kg}^{-1}$ ) in non-calcareous soil at a 0.25% level, suggesting an improvement over the control. According to certain research, adding biochar to both calcareous and non-calcareous soil may increase [14,32,33] or decrease [34] P availability. While according to other researchers, adding biochar to calcareous soils had no discernible effect on the availability of soil P [35,36], in general, the impact of biochar applications on the nutrient status in calcareous soils of arid regions is not well understood [14].

Fig. 4 shows that the application of biochar increased P availability after 4 months of incubation, particularly at the 2% level, but after 6 months, P availability decreased.

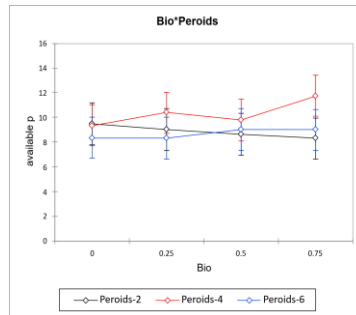


Fig. (4). Effect of biochar application rates g 100 g<sup>-1</sup> soil on the average mean of available phosphorus mg kg<sup>-1</sup> during incubation periods in the studied soils.

The sheep manure and biochar application rate altered considerably ( $p < 0.001$ ) in all treatments, as shown in Table 4. Available P concentration was observed in treatment calcareous soil and non-calcareous soil; the highest available P was recorded at the biochar level of 0.75% and sheep manure level 2% compared to the other treatments. Utilizing sheep manure and biochar, the increased microbial activity may be the cause of the increased soil P availability, Fig. 2 according to [38]. Also, it's possible that the increased P availability in calcareous soil results from the immobilization of  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  cations as the pyrolysis temperature rises [37]. According to these disparate results, depending on characteristics of the biochar and the soil, adding biochar to calcareous soils may either increase or decrease P availability [38].

### Conclusions

The current study's results clearly showed how the application rate of sheep manure and biochar affected the amount of phosphorus in the soil. We found that the application rate of biochar and sheep manure increased by 0.75% and 2%, respectively. The application of sheep manure at a level of 1% after 2 months in non-calcareous soil, and after 4 months at 0.5% in calcareous soil showed high available P observed. After 6 months, the highest phosphorus availability in calcareous soil was observed with the application of 2% sheep manure. In contrast, non-calcareous soil at the same manure level had a lower value than calcareous soil. Application of biochar has no significant effect on the availability of P.

### Conflict of interest

The author declares that there are no conflicts of interest associated with this manuscript.

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## تأثير روث الأغنام والفحم الحيوي على جاهزية الفوسفور في الترب الكلسية وغير الكلسية في محافظة السليمانية- إقليم كردستان العراق

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### الخلاصة

اجريت هذه الدراسة بهدف تقييم تأثير روث الأغنام والفحم الحيوي على جاهزية الفوسفور في كل من التربة الكلسية وغير الكلسية. أخذت عينات تربة من الطبقات السطحية (0-30 سم) من المناطق الزراعية في موقعين: بكر جو (تربة كلسية) (35°32'03 شمالاً، 45°21'57 شرقاً) وعربت (تربة غير كلسية) (35°23'40 شمالاً، 45°39'27 شرقاً) في محافظة السليمانية، إقليم كردستان، العراق. تم إجراء تجربة حضانة التربة باستخدام (200 غرام) من التربة تم خلطها مع الفحم الحيوي بأربعة مستويات (0، 0.25، 0.5، 0.75%) وأربعة مستويات من روث الأغنام (0، 0.5، 1، 2%) في أوعية زجاجية عند درجة حرارة 28 ± 2 درجة مئوية و60% من الماء الجاهز لها، تم حضن العينات لمدة (2 و4 و6 أشهر) وتم قياس الفوسفور الجاهز في التربة بعد (2، 4 و6) أشهر، تأثر جاهزية الفوسفور بمستويات مختلفة من السماد والفحم الحيوي خلال فترات الحضانة التي استمرت لمدة 2 و4 و6 أشهر. زادت تمعدن الفوسفور في السماد بمرور الوقت، مما أدى إلى ارتفاع كبير في مستوى الفوسفور في التربة خلال شهرين، حيث لوحظ (13.565 ملغ/كجم-1) عند أقصى مستوى للسماد (1%) في التربة غير الكلسية، وانخفضت قيمته بشكل كبير بعد ذلك. في اختبار التربة المتشابهة قيم *P*، الترب غير الكلسية ذات القدرات التخزينية العالية كانت لديها احتياطات فسفور أكبر من الترب الكلسية ذات القدرات التخزينية المنخفضة و(14.15 ملغ/كجم-1) في الترب الكلسية عند مستوى السماد (2%) بعد 6 أشهر. كما تشير النتائج إلى أن تأثير الفحم الحيوي وروث الأغنام زاد مع زيادة معدلات الاستخدام، وكان للفحم الحيوي بمعدل إضافة 0.75% و مخلفات روث الأغنام بمعدل 2% التأثير الأكبر.

الكلمات المفتاحية: الفوسفور الجاهز، الفحم الحيوي، التربة الكلسية، التربة غير الكلسية، روث الأغنام.