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Effect of biochar of temperature and time differences on some chemical properties and available nutrients in Mosul city soil

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A B S T R A C T

Wheat straws were pyrolyzed at 200°C, 400°C, and 600°C to create biochar. Experiments on biochar incubation with calcareous soil were carried out at 1, 2, 4, 6, and 8 g kg^{-1} for a maximum of 60 and 90 days at rates to silty loam. The soil's pH, EC, and CEC values were measured, in addition to its accessible N, P, and K. The availability of pH, EC, CEC, N, P, and K increased with the usage of biochar. The pH values ranged from 7.35 at 200°C for 60 days to 7.94 at 600°C for 90 days, while the electrical conductivity increased from 2.42($dS.m^{-1}$) at 200°C for 60 days to 4.65(dS.m-1) at 600°C for 90 days, and the cation exchange capacity values increased from 14.35 (Cmol. Kg^{-1})at 200°C for 60 days to 22.37 (Cmol. Kg^{-1})at 600°C for 90 days. Moreover, a significant increase in the availability of nutrients (N, P, and K) was observed, reaching 83($mg.Kg^{-1}$) at 200°C for 60 days to 107 ($mg.Kg^{-1}$) at 600°C for 90 days, 34 ($mg.Kg^{-1}$) at 200°C for 60 days to 54 ($mg.Kg^{-1}$)at 600°C for 90 days,113 ($mg.Kg^{-1}$) at 200°C for 60 days to 135 ($mg.Kg^{-1}$)at 600°C for 90 day respectively. It was found that the correlation coefficient between soil properties with biochar levels ,temperature and Incubation period time for all soils was high and positive.

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Introduction

Calcareous soil contains 5% or more by weight, which affects some of the chemical, physical, and fertility properties of the soil responsible for plant growth (Naz et al,2023). Calcium carbonate is widespread in soils of dry and semi-dry areas where precipitation is less than 500 mm including Iraq ranging percentages of calcium carbonate between 15-35% (Mawlood,2018). Since calcareous soils often include calcium carbonate, it will function to coat the clay particles in many layers, increasing the thickness of positive ions surrounding the clay particles (Aljumaily et al,2022). Because the clay particles are coated with positive ions, this causes them to repel one another, also repulsion between ions that are identical to one another prevents the process from happening(Chen et al,2018).The type of ions that the clay is saturated with largely determines how stable the soil particles are; in particular, calcium ions work to encapsulate the clay particles, lowering the impact of clay on aggregate formation and stability and thickening the electrical double layer(Liu et al,2023).

Iraq's wheat cultivation produces a significant each year (Noori and Al-Hiyali,2018). The majority wheat residue seethes remnants of as waste and they are sometimes stacked and left in the fields or burned (Memon et al,2018). Burning crop leftovers causes a significant loss of nutrients, including sulfur and nitrogen, and can also cause air pollution and health issues for people (Tipayarom and Oanh 2007). Reusing crop residues is one way to overcome the limitations on soil fertility in calcareous soils (Dadhich et al. 2021). Recycled wheat wastes can be added straight to the soil or composted, crop leftovers added in this way to the soil may decompose quickly and release nutrients, to keep the soil fertile with this method, significant amounts of organic materials must be added each year(Shanmugam et al,2024). Applying crop remains to soil as biochar is an alternate strategy, because it is high in carbon, biochar the solid byproduct of pyrolyzing plant biomass has potential benefits for soil. Over the last ten years, biochar has gained popularity as a useful substance that may be used to enhance the qualities of soil (Sohi et al,2010).

The chemical characteristics of soil are significantly influenced by biochar, which raises carbon storage, balances soil ecosystems, and increases CEC and pH enhancing the structure of the soil even more. As a nutrient sink that and affects nutrients' bioavailability and mobility, biochar can affect the nutrients in the soil. As a source, it can provide nutrients like potassium (K), phosphorus (P), nitrogen (N), and other nutritional components. Simultaneously, the temperature and length of pyrolysis are related to the values of both relevant biochar parameters (pH, CEC, C contents, and nutritional contents) (Elkhlifiet al, 2023). Longer pyrolysis times at the same temperature have been shown to produce more alkaline materials (Sun et al., 2017). In high-pH alkaline soils, temperatures and biochar are raising pH (Qayyum et al,2021). The purpose of this study was to examine how applying biochar made from wheat waste harvest .

MATERIALS AND METHODS

Study area and sample collection

The experimental soil sample was collected from the agricultural fields in Mosul, Nineveh Governorate, Iraq (43.194889° E 36.455241° N). Studded soil is classified as typic Torrifluvents as claimed by soil survey Staff (1999). The soil sample was collected from 0 - 30 cm and air-dried, crushed, and passed through 2 mm sieve, and physical and chemical analyses were carried out based on soil analysis methods (Page et al., 1982)(Table 1).

Table1. Physical and chemical properties of the study soil

Soil characteristic	Value
EC ($dS.m^{-1}$)	1.95
pH	7.3
OM ($g.Kg^{-1}$)	20.91
CEC ($Cmol.\ Kg^{-1}$)	15.35
carbonate $g.Kg^{-1}$	218.35
N ($mg.Kg^{-1}$)	65
P ($mg.Kg^{-1}$)	15
K ($mg.Kg^{-1}$)	85
Texture	Silty Loam
Sand	252
silt	511
clay	237

Biochar production and incubation incubation

Anexperiment was conducted in a completely randomized design with three replications. One type of biochar (wheat straw) was used in each treatment at three distinct temperatures (200°C, 400°C, and 600°C). five different rates of biochar (1, 2, 4, 6, and 8% w/w). Table 2 lists the properties of the biochar produced at various pyrolysis temperatures. The raw wheat straws were first crushed to fit through a 2-mm filter and allowed to air dry. After that, two hours of slow pyrolysis heating were used to create wheat straw biochars. To reduce the amount of oxygen in the stainless steel cylinder, the raw feedstocks were wrapped in aluminum foil. Placed within the muffle furnace, it was progressively heated to the desired temperatures. Using the previously mentioned methods, biochar subsamples were obtained in order to examine the material's physical and chemical properties (Cantrell et al., 2012; Enders et al., 2012; Khadem et al., 2017). To prepare for the incubation experiment, the biochars were crushed and sieved through a 1 mm sieve.One hundred grams of soil sample was weighed into polypropylene pots, and one, two, four, and eight grams of the biochar samples were then properly mixed in. No changes were made to the soil control methods. The soil samples and soil-biochar mixes were mixed with distilled water to maintain a moisture level of 60%. For eight weeks, the incubation was conducted in an aerobically controlled, non-leached environment at 25 °C in a controlled incubation chamber. Following a 60-day incubation period, samples of the control and biochar-amended soils were taken, and the same methodologies as before were used for testing (Naeem et al. 2017). the samples were dried and soil pH and electrical conductivity (EC) were determined in 1:5 soil-to-water extracts. Also, to determine mineral N, the soil samples with biochar were extracted with 2 M KCl. Organic matter was determined by dichromate oxidation. Soil extractable P and K were extracted with 0.5 M NaHCO3 (ratio 1:10) (Olsen-P) and 1 N NH4Ac (1:20) (NH4Ac-EK), respectively.

Table2. Properties of wheat biochar produced at varying pyrolysis temperatures (200°C, 400°C, and 600°C).

Parameters	200°C	400°C	600°C
pH	7.3	7.5	7.6
EC (dS.m^{-1})	2.31	1.95	1.54
CEC (Cmol. Kg $^{-1}$ soil)	18.52	19.27	20.86
N (mg.Kg^{-1})	17.36	18.64	21.45
P (mg.Kg^{-1})	4.16	3.57	3.26
K (mg.Kg^{-1})	39.65	31.56	26.36

Statistical analysis

The experiments were conducted in a completely randomized design. The data were analyzed by three-way (ANOVA) for the incubation study. The significance of different treatments (Biochar levels × temperature × Incubation period time) . Means comparison was done by the Duncan's test at 1% and 5% probability levels, out using SPSS 17 software.

RESULTS AND DISCUSSION

Changes in Soil Chemical properties

Figure (1a and Table 3). Show an increase in soil pH increasing both addition levels, temperature, and incubation duration, With a significant positive ranging between (7.35-785) at 200°C for 60 days and 600°C for 90 days respectively. Because biochar is a very basic product because it contains organic ions and inorganic carbonates, an increase in soil pH was found. This is because the interaction between pH and biochar has the ability to change the pH of the soil (Yuan and Xu 2011; Liu and Zhang 2012).

Due to the fact that ash contains mineral components in the form of oxides or carbonates, which dissolve in water to generate an alkaline solution, numerous investigations have demonstrated that soil pH increases biochar. (Yuan & Xu 2011; Dume et al. 2016). The moisture and volatile matter contents of feedstocks will steadily decrease as the pyrolysis temperature rises, and the intramolecular and intermolecular chemical bonds will break , as a result, biochars' ash concentrations per unit mass steadily increased, raising the material's pH also, demonstrated when the temperature of pyrolysis rises, so does the contribution of total carbonates to the overall alkali concentration in biochar.(Yuan et al. 2011). Nonetheless, as the temperature of pyrolysis rises, organic acids become more dehydrated and break down (Novak et al. 2009).

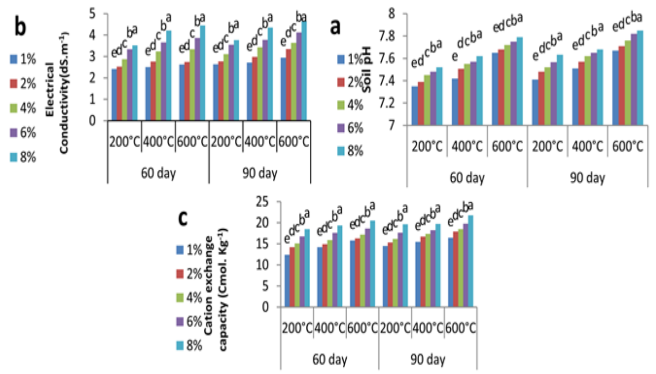

Figure 1. Effects of biochar levels, temperature, and Incubation period time on both (a) pH values (b) Electrical conductivity values (c)Cation exchange capacity values. Different letters show a significant difference according to Duncan's test at 1% and 5% probability.

These results suggested that levels of biochar, time, and temperature application increase were proportional to the amount of biochar applied and led to an increase in a significant positive2.42 (dS.m^{-1}) at 200°C for 60 days and 4.65 (dS.m^{-1}) at 600°C for 90 days (Figure 1b and Table 3), and the cause is said to be the higher EC values after applying biochar, which were most likely brought on by the biochars' high ash contents and the soluble alkaline components they released (Song et al. 2018). Could also be linked to higher levels of alkaline cations, particularly K+, in this treatment. Al, it is possible that the salt content of the biochar is the cause of the rise in soil EC following biochar amendments. These findings concur with those of (Beheshti et al. 2018; Song et al. 2018), who found that applying various kinds of biochar raised the electrical conductivity (EC) of the soil.

The results obtained on cation exchange capacity as influenced by different levels of biochar, time, and temperature are presented in (Figure 1c and Table 3). Increased with a significant positive at 14.35 (C.molc kg^{-1}) at 200°C for 60 days and 17.37 (C.molc kg^{-1})at 600°C for 90 days , and the explanation for this is that the release of low-molecular-weight humic-like chemicals and the presence of surface functional groups in biochar are likely what contribute to the soil's increased CEC after the addition of biochar. Additionally, Yuan et al. (2011) discovered that adding biochar made from various crop residues to the soil significantly increased the CEC of the soil. According to reports by (Khadem and Raiesi 2017; Amin and Eissa, 2017), the organic carbon added to the biochar treatments may have contributed to the rise in soil SOC.

These results are consistent with earlier research showing that adding biochar raised the soil's CEC, demonstrating the soil's strong buffering ability (Cheng et al. 2008; Naeem et al. 2017). Fresh biochar usually has a low CEC, but as it ages in the presence of oxygen and water, it eventually rises also, another possible explanation for the rise in CEC could be the slow oxidation of biochar in soil (Cheng et al. 2008). The higher CEC of biochar treatment could potentially be attributed to a characteristic of biochar feedstock. According to Glaser et al. (2002), the higher surface area and high porosity of biochar retain organic materials with varying charges, which raises the CEC of soil and base saturation in addition to soil.

Changes in Soil Nutrient availability

The soil available N was increased with the application of biochar levels, temperature, and Incubation period time. Activity was further demonstrated by a significant positive up to 83(mg.Kg^{-1}) at 200°C for 60 days to 107 (mg.Kg^{-1}) at 600°C for 90 days (Figure 2a and Table 3).The biochar's release of accessible nitrogen into the soil and subsequent increase in soil N could be the cause of the increased N content and increased soil N mineralization and microbial activity (bacterial biomass) may be responsible for the beneficial effects(Zhang et al,2021). Moreover, most likely included a large proportion of hydrolyzable N and unpyrolyzed carbohydrates, which had an impact on the soil's N mineralization (Wang et al,2012). Our findings concur with those of (Aon et al,2023), who discovered that adding wheat straw biochar heated to 300 °C considerably raised the inorganic N content in calcareous soil.

The soil P availability increased with the application of biochar levels, temperature, and Incubation period time. With a significant positive 34 (mg.Kg^{-1}) at 200°C for 60 days and 54 (mg.Kg^{-1})at 600°C for 90 days (Figure 2b and Table 4). The increased microbial activity following biochar application may be the cause of the increased soil P availability, it is changes in the surface area of the biochar and soil exchangeable site, and the avoidance of P fixation with cations and carbonates in the soil are some possible explanations for the rise in soil accessible P with increasing pyrolysis temperature(Glaser and Lehr,2019). Furthermore, a decrease in Ca^{+2} and Mg^{+2} release as a result of these cations becoming immobile at higher pyrolysis temperatures could account for the increased P availability. These results can also be explained by the fact that N, P, and K concentrations in biochars rose as the pyrolysis temperature rose(Purkaystha et al,2022). Our findings concur with (Naeem et al. 2017) of who demonstrated that adding biochar from rice and wheat straw that had been pyrolyzed at various temperatures (300, 400, and 500 °C) enhanced the availability of P in calcareous soil.

Figure 2 Effects of biochar levels, temperature, and Incubation period time on both (a) The values of availability N (mg.Kg^{-1}) (b) The values of availability P (mg.Kg^{-1}) (c) The values of availability K (mg.Kg^{-1}). Different letters show a significant difference according to Duncan's test at 1% and 5% probability.

In this study, as shown in (Figure 2c and Table 3), was observed the biochar levels produced from wheat straw, temperature, and Incubation period time increased the effect of the potassium content available in the soil. With a significant positive 113 (mg.Kg-1) at 200°C for 60 days and135 (mg.Kg-1)at 600°C for 90 days (Figure 2c and Table 3). The availability of nutrients, particularly K, is significantly influenced by the amount of ash in biochars. Soil K content was enhanced more by high-temperature biochars with a high mineral ash component than by low-temperature biochars. Because high-temperature biochars have a high K content—up to 1.57% in the ash fraction the direct release of K from them is a significant factor in boosting K availability in the soil (Qayyum et al,2020).

Table 3. Correlation coefficients between soil properties and the availability of nutrients

Variables	pH	EC	CEC	N	P	K
pH	--					
EC	88.59*	--				
CEC	85.14**	88.35**	--			
N	91.49**	90.45**	91.78**	--		
P	91.59**	91.75**	91.94**	92.35**	--	
K	91.75**	91.85**	92.11**	92.57**	93.12**	--

(*)and (**)significant at 0.01 ,0.05 probability level, respectively.

Conclusions

The current study's findings lead us to the conclusion that biochar positively alters soil pH, EC, CEC, N, P, and K availability. These changes are influenced by the kind of raw material used as well as the temperature and length of the pyrolysis process. In dry, calcareous soils, the biochar made from wheat straw would significantly raise the availability of N, P, and K as well as the SOC content and stability potential of the soil. In summary, the use of biochars in these arid soils can be advantageous for chemical indicators of soil quality and could be a significant soil amendment to offset the loss and depletion of organic matter in these regions. It can also help to mitigate the main issue that is typically linked to the deterioration of soil fertility and quality as well as the ability of agricultural soils to maintain ecosystem services and goods.

CONFLICT OF INTEREST

The author declare no conflicts of interest associated with this manuscript.

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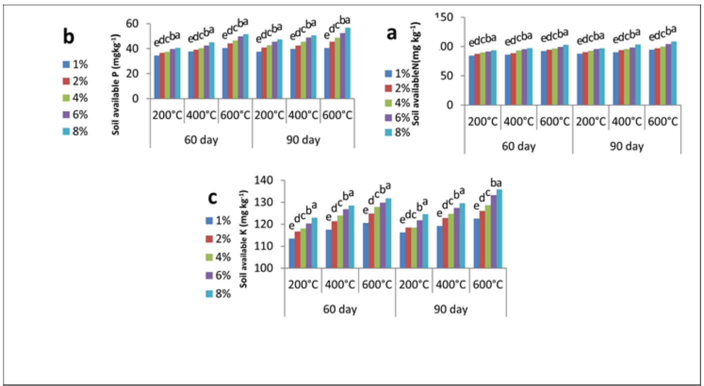

Figure 2. Effects of biochar levels, temperature, and Incubation period time on both (a) The values of availability N (mg.Kg^{-1}) (b) The values of availability P (mg.Kg^{-1}) (c) The values of availability K (mg.Kg^{-1}). Different letters show a significant difference according to Duncan's test at 1% and 5% probability.

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