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(Original Article)

Effects of Co-applied Farmyard Manure (FYM) and Date Palm Biochar (BC) on Saturated Hydraulic Conductivity and Nutrient Availability to Wheat Plants in a Calcareous Sandy Soil

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Abstract

This study conducted in column and greenhouse pot experiments with wheat plants (*Triticum Aestivum* L.) to investigate the effects of co-applied farmyard manure (FYM) and biochar (BC) with different particle sizes on hydraulic conductivity (K_{sat}) and nutrient availability in a calcareous sandy soil. The amendments of FYM and BC were added at 1.5% w/w. The treatments consisting of T1: control soil, T2: FYM, T3: BC (≤2 mm), T4: BC (0.8-2 mm), T5: BC (0.4-0.8 mm), T6: BC (≤0.4), T7: BC (≤2 mm) +FYM, T8: BC (0.8-2 mm) + FYM, T9: BC (0.4-0.8 mm) +FYM, and T10: BC (≤0.4) +FYM. The results showed that the K_{sat} for soils amended with different sizes of biochar decreased by 15.5-42.0% compared to the control. The soil available P and K concentrations exhibited higher increases in all investigated treatments than in the control soil. The highest increases in the soil available P were observed in soil treated with FYM and the high content of soil available K was pronounced for BC≤0.4 mm. Adding most treatments significantly increased the dry matter of the aboveground biomass and nutrients (NPK) uptake. The highest increases in PK uptake were observed in wheat plants treated with T2 (FYM) followed by T9 (FYM with BC at 0.4-0.8 mm) and T7 (FYM with BC at ≤2mm). The highest increase in the shoot N uptake was pronounced for co-applied FYM and BC (0.4-0.8 mm). It could be concluded that FYM alone or co-applying with BC can improve nutrient uptake and plant growth.

Keywords: *Bioavailability, Charcoal, Soil amendments, Waste recycling.*

Introduction

Billions of people no longer have access to enough food, and a large portion of the global population suffers from moderate to severe food insecurity (Paslakis *et al.,* 2021). Therefore, the world is moving toward horizontal expansion and soil reclamation. Sandy calcareous soils, which make up about 30% of the earth's surface, are soils with a high calcium carbonate content (Singare *et al.,* 2022). The area of sandy calcareous soils is between 25-30% of Egypt's area (Taalab *et al.*, 2019). These soils have many problems affecting negatively its physical and chemical properties. The addition of organic amendments has been utilized to

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improve sandy calcareous soils characteristics (Bolan *et al.*,2023). Applying organic manure has a positive impact on the physical characteristics of such soils and it serves as the main supply of nitrogen for the majority of plants and a key source of other plant nutrients (Khan *et al.,* 2010; Singh *et al.,* 2020*;* Bashir *et al*., 2021). improving nutrients availability in sandy calcareous soils directly or indirectly influences crop growth and yield (Hussain *et al.,* 2023)

Biochar is the solid product of the pyrolysis of biomass under conditions of limited or no oxygen (Lehmann *et al.,* 2015). Biochar has many distinctive properties, such as its rich carbon content, high cation exchange capacity, large surface area, and stable structure (Rizwan *et al.,* 2016). Biochar is made up of stable black colour condensed aromatic moieties that can perform a variety of tasks, making it an intriguing molecule for carbon sequestration (Zhang *et al*., 2021). Biochar can be produced from many organic materials and under different conditions, resulting in products with different properties (Weber and Quicker, 2018). It can be produced from a wide range of biomass sources, for example, wood and straw, agricultural waste such as olive peels, corn and tea plants, green waste, animal manure and other waste products (Carpenter *et al.,* 2014). It is worth noting that palm waste is exploited to produce biochar (Usman *et al.,* 2015). Biochar production from palm waste affects many physical and chemical soil properties, as well as stabilizing carbon in the soil and reducing greenhouse gas emissions (Lehmann., 2007; Sohi *et al*., 2010; Liu *et al*., 2016). However, these physical and chemical effects of biochar vary depending on raw materials and pyrolysis temperature (Sohi *et al.,* 2010). Therefore, biochar was produced from palm waste with different particle sizes to study its effect on the sandy calcareous soils and the growth of wheat.

Hydrological and physical characteristics like bulk density, porosity, accessible water content, and water retention can all be enhanced by biochar addition to soils, which is essential to the creation of (black soil). Simultaneously, the addition of biochar to soil has been demonstrated to improve soil's ability to hold plant nutrients, reduce leaching of nutrients, and raise pH, soil organic matter (SOM), and soil water-holding capacity (Lusiba *et al*., 2017). Applying biochar to soil is thought to be a win-win way to enhance soil fertility and improve the physical conditions of the soil that affect water retention and soil hydraulic properties (Grau-Andrés *et al.,* 2021). Comprehending the size of biochar particles is crucial as it influences its interaction with the soil matrix. The chemical, physical, and hydrological qualities of the soil may directly change depending on how much or how little biochar interacts with the soil matrix. According to Alghamdi *et al.* (2020), adding biochar with particles smaller than 1 mm can improve the hydrological and physical characteristics of light-textured soils. It can also improve water conservation in the soil, which will assist lowering the quantity of water needed for irrigation. Furthermore, biochar added at smaller particle sizes (< 1 mm) in the study by Ibrahim *et al.* (2016) had better impacts than that of 1-2 mm on decreasing cumulative water infiltration and saturated hydraulic conductivity and enhancing water saved of course-textured soil. However, little is known about the effect of the size of biochar particles in combination with farmyard manure on the physical and chemical properties of soils as well as nutrient uptake. Thus, the objective of this research was to investigate the potential effects of co-applied farmyard manure with different particle sizes of date palm biochar on hydraulic conductivity and nutrient availability in a calcareous sandy soil.

Materials and Methods

1-Production and characteristics of biochar

In this study, biochar (BC) was produced from the pyrolysis of date palm waste (branches) brought from the farm of the Faculty of Agriculture, Assiut University, Egypt, and prepared by cutting it into small pieces and placing it in charcoal kilns at 365±10 °C under limited oxygen conditions. After the carbonization process is completed, the biochar is crushed and ground, then sieved through a set of sieves to obtain the required sizes. A range of sieves with different diameters of 2, 0.8, and 0.4 mm were used for the following sizes: BC (≤2mm), BC (0.8-2 mm), BC (0.4-0.8 mm), BC (≤0.4mm). As for farmyard manure, it was collected from the animal production farm at the Faculty of Agriculture, Assiut University, Egypt, sifted with a 2 mm sieve to obtain the required size (≤2 mm). Some analyses were performed on different sizes of BC and FYM. The following parameters were measured: pH, EC, and the content of C, H, N, and S. The EC and pH of BC and FYM were determined using an EC meter and a pH meter, respectively, at a BC or FYM to water ratio of 1:20. Samples were analyzed using a CHNS device to measure their carbon, hydrogen, nitrogen, and sulphur content.

Table 1. Properties of different sizes of biochar (BC) and farmyard manure (FYM) samples

Sample Name	pH	EC, dS/m	N %	C %	S %	H %
FYM	8.13	4.44	1.26	34.2	2.97	2.17
BC (≤2mm)	7.07	7.64	0.565	53.83	1.242	1.924
BC (0.8-2 mm)	6.94	6.01	0.572	52.25	0.138	1.797
BC (0.4-0.8mm)	6.97	6.88	0.376	53.40	1.264	1.469
BC (≤0.4)	7.03	8.33	0.501	51.30	1.701	1.371

2-Greenhouse pot experiment

Sandy calcareous soil samples were collected from Al-Gharib Farm, Assiut, Egypt. The samples were air-dried then sieved using a 2 mm sieve. The mechanical analysis of soil was performed using the pipette method (Day, 1965). Some chemical properties (pH, EC, $CaCO_3$, and OM) were measured (Sparks (1996) and Nelson and Sommers (1996). The measured physical and chemical properties of the soil sample are listed in Table 2.

A greenhouse experiment was conducted in pots to study the potential effects of co-applied farmyard manure with different particle sizes of date palm biochar on saturated hydraulic conductivity and nutrient availability in a calcareous sandy soil planted with wheat. In this experiment, each plastic pot (14.8 cm diameter and

14.8 cm height) was filled with 2 kg of soil. Different sizes of BC and FYM were added at 1.5% w/w (1.5 g of BC or FYM: 100 g of soil). These additives are added to the soil and mixed with the soil before being packed into plastic pots.

Table 2. Physical and chemical properties of soil samples

Soil property	Values
Particle size distribution	
Silt, %	8.00 %
Clay, %	1.60 %
Sand, %	90.4 %
Texture	Sandy
EC (1:1) dS/m	0.83
pH (1:1)	7.99
Calcium carbonate, %	16.0%

Separately or in combination with farmyard manure. The ten treatments that were applied in three replicates in the current study included the following: (T1) CK, (T2) FYM, (T3) BC (≤2 mm), (T4) BC (0.8-2 mm), (T5) BC (0.4-0.8 mm), (T6) BC (≤0.4), (T7) BC (≤2 mm) +FYM, (T8) BC (0.8-2 mm) +FYM, (T9) BC (0.4-0.8 mm) +FYM, and (T10) BC (≤0.4) +FYM. In this experiment, wheat plants (*Triticum aestivum* L.; Sids 12) were tested. Eight seeds were sown in each pot and thinned to five plants per pot. Tap water was used to irrigate the growing plants, and the soil's water content was kept at field capacity during the experiment period. The plants were harvested after six weeks of germination. At the end of the experiment, the height of the plants was measured, then the plant branches were collected, their fresh weight Wheat was taken, they were dried at 70°C, ground, and then digested by wet digestion (H_2SO_4-H_2O_2) (Jones *et al*.,1991). To conduct nutrient content analysis, nitrogen in plants was measured using the Kjeldahl method. Additionally, the concentration of P was measured colorimetrically using a spectrophotometer, and the concentration of K in the plant digests was measured using a flame photometer. After wheat plants harvesting, soil samples were taken from the pots and sieved through a sieve with 2 mm holes. Soil pH was measured using a pH meter in 1:1 soil-to-water suspensions, and electrical conductivity was measured in 1:1 soil-to-water extracts using an electrical conductivity meter. The available soil K was also measured using a flame photometer after soil extraction with 1 M NH_4AOC (Jackson, 1973). Soil available phosphorus was determined by extracting soil containing 0.5 M $NaHCO_3$ at pH 8.5 for neutral alkaline soil and determining P from the filtrate by a spectrophotometric method (Olsen *et al*., 1954).

3-Column experiment

For the soil column experiment (diameter 6.055 cm and height 20 cm) to estimate the saturated hydraulic conductivity, the column was filled with 921 grams of soil based on a total soil bulk density of 1.6 grams/cm^3 and a soil height in the column of 20 cm. The previously indicated soil amendments were applied at a 1.5% (w/w) rate in the first 10 cm of the soil column and each column was completely saturated from the bottom. Then they were left to reach their field capacity. Specifically, to quantify the field capacity, all the columns were brought to saturation, allowed to drain any excess water, and then the field capacity was estimated gravimetrically 48 hours later. After any excess water was drained, the columns were placed directly under normal weather conditions. Each column was irrigated once a week by weighing the soil column and bringing its water content to the field capacity. The experiment lasted for 5 months. The saturated hydraulic conductivity (K_{sat}) was measured after the incubation period. The constant head method was used to K_s according to Klute *et al.* (1986). Darcy's law was applied to calculate hydraulic conductivity as follows:

$$K_S = \frac{QL}{AHT}$$

Ks (m/s) Saturated hydraulic conductivity.

Q (m^3) is the volume of the percolating head.

L(m) Is the height of the soil mixture column and the treatments inside the core.

A (m^2) is the cross-sectional area of the soil colure sample.

H (m) is total head (water and soil) in column.

T (s) is the time of collecting percolates.

4-Statistical analysis

The statistical program Statistix 8.1.1 was used to examine the different between the experimental treatments and to perform correlation study among different parameters. On the data, analysis of variance (ANOVA) was done. To compare the effects of the treatments, the Tukey HSD (Honestly Significant Difference) test was utilized at the 0.05 level.

Results and Discussions

1-Amendments effect on saturated hydraulic conductivity

The saturated hydraulic conductivity (K_{sat}) was significantly affected by the farmyard manure (FYM) and different particle sizes of date palm biochar (Fig. 1). Compared to the K_{sat} of the control (21.1 cm·h^{-1}), the FYM treatment increased the K_{sat} to 29.2 cm h^{-1}. The increase of K_{sat} with the addition of FYM may be associated with the increase of soil macro porosity. Contrary to our results, previous studies demonstrated that the incorporation of organic amendments into light soils decreases saturated hydraulic conductivity (Lipiec *et al.*, 2021). Dong *et al.* (2022) study, however, supports our findings by showing that the addition of organic amendments increased saturated hydraulic conductivity because of the soil's porosity—particularly its macro-porosity. Yazdanpanah *et al.* (2016) also found that the organic materials-treated soils resulted in higher levels of water stable aggregates and more macro-pore fraction, leading to greater hydraulic conductivity. This is mainly attributed to improvement in soil structure was associated with improvement in water movement. The biochar application significantly increased the amount of macroaggregates and decreased soil bulk density, which results in significantly higher Ks values. The current study's results showed that, in contrast to the effect of FYM, the K_{sat} of soils amended with different sizes of biochars decreased the K_{sat} by 15.5-42.0% compared to the control soil. Due to its high surface area and high porosity, the applied biochar could increase soil microporosity, causing decreased hydraulic conductivity in sandy soil (Igalavithana *et al.,* 2017; Chen *et al.,* 2018). In a sandy loam and a silt soil, Gelardi *et al.* (2021) found that biochar reduced K_{sat} by 64 %–80 % compared to control. In the biochar–soil mixtures, applied biochar with high porosity could reduce the interpore size, creating potential capillary flow paths, which are responsible for the decreasing water infiltration and saturated hydraulic conductivity of the soil (Igalavithana *et al.,* 2017). Biochar can also clog parts of the pores by the filling of the macropores in sandy soils with fine biochar particles, reducing porosity, water flow and hydraulic conductivity in mixing biochar particles with coarse-textured soils (Igalavithana *et al.,* 2017; Blanco-Canqui *et al*., 2017; Bhat *et al*., 2022). In this context, our result shows that the highest decrease in the saturated hydraulic conductivity was observed in sandy soil amended with the smallest fraction of applied biochar (≤0.4 mm) (Fig. 1). Our finding confirmed previous studies, showing decreased saturated hydraulic conductivity in sandy soil due biochar addition and observed that lower values of saturated hydraulic conductivity in smaller biochar particles treatments than in larger ones (Alghamdi *et al*., 2020). Additionally, biochar with hydrophobic properties can induce water repellence and reduce infiltration and hydraulic conductivity (Blanco-Canqui *et al*., 2017).

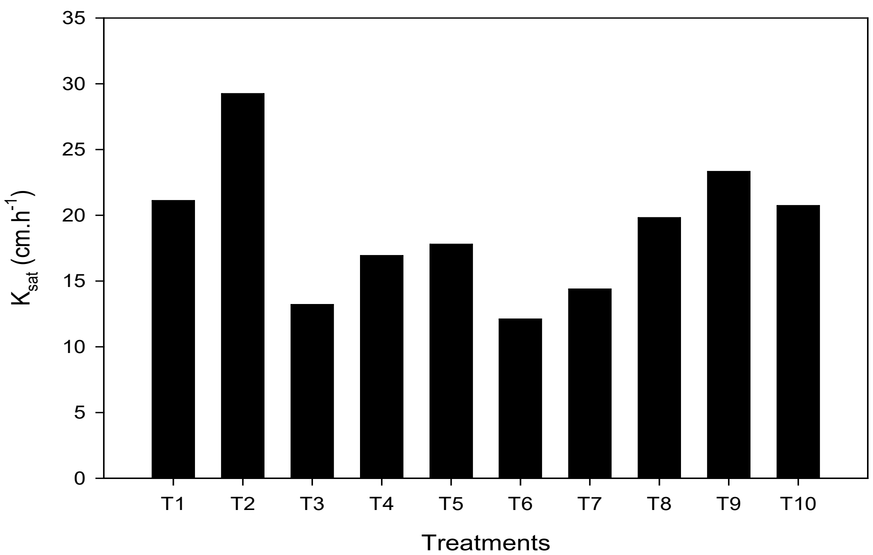

Fig. 1. Treatments effect on saturated hydraulic conductivity (K_{sat}) (T1: CK, T2: FYM, T3: BC (≤2mm), T4: BC (0.8-2 mm), T5: BC (0.4-0.8 mm), T6: BC (≤0.4), T7: BC (≤2mm)+FYM , T8: BC (0.8-2 mm) + FYM, T9: BC (0.4-0.8 mm)+FYM, and T10: BC (≤0.4)+FYM.

2-Amendments effect on soil pH, EC and nutrients availability

The results showed that the pH of the soil in different treatments ranged from 7.65 to 8.32 (Table 3). The addition of FYM increased soil pH from 8.02 to 8.32, mainly because of the release of basic cations from FYM.

Date palm BCs decreased sandy soil pH from 8.05 to 8.02, 7.65, 7.86, 7.70, and 7.96 for T3: BC (≤2mm), T4: BC (0.8-2 mm), T5: BC (0.4-0.8 mm), and T6: BC (≤0.4), respectively (Table 3). Though applying BC increases soil pH as indicated in the literature, our results suggest that the soil pH was significantly decreased after biochar application using different particle sizes. It is possible that the lower pH of the applied BC compared to the soil pH may explain the lower soil pH found in our investigation because of its application.

In this study, the EC values for control soils were 1.85 dS/m (CK) (Table 3). These EC values increased to 2.08-3.78 dS m^{-1} among various treatments. The highest levels of salinity were pronounced for T3 (BC ≤2mm) followed by T6 (BC ≤0.4). It has previously been documented that the significant concentrations of soluble ions induced by BC ash after BC treatment resulted in a high level of salinity (Singh *et al.,* 2022).

Table 3. Treatment effect on pH, and EC

Treatments	pH	EC dS/m
T1	8.05_{BC}	1.85_{E}
T2	8.32_{A}	2.08_{E}
T3	8.02_{CD}	3.78_{A}
T4	7.65_{F}	2.79_{C}
T5	7.86_{DE}	3.18_{B}
T6	7.70EF	3.66_{A}
T7	7.96_{CD}	2.85_{C}
T8	8.05_{BC}	2.40_{D}
T9	8.21_{AB}	2.80_{C}
T10	8.05_{BC}	3.17_{B}
Tukey test (p < 0.05) critical value	0.17	0.27

T1: CK, T2: FYM, T3: BC (≤2mm), T4: BC (0.8-2 mm), T5: BC (0.4-0.8 mm), T6: BC (≤0.4), T7: BC (≤2mm) +FYM , T8: BC (0.8-2 mm) + FYM, T9: BC (0.4-0.8 mm)+FYM, and T10: BC (≤0.4)+FYM; Different letters represent significant difference at p < 0.05 among various treatments.

The addition of organic amendments to soils can have an impact on soil properties, affecting the available form of soil nutrients (Angelova *et al.,* 2013). The results showed that the soil Olsen-extractable P concentrations (available form) exhibited higher increases in all investigated treatments compared to that of the control soil (Fig. 2). The highest increases in soil available P were observed in soil treated with FYM followed by co-applied farmyard manure with BCs (particularly at particle size of 0.8-2 mm, 0.4-0.8 mm, and ≤0.4) +FYM). For example, increase in soil available P was 169% in soil receiving FYM alone than control. Additionally, increases in soil available P was 101%, 139%,139%, and

134% in soil receiving co-applied FYM with BC (($\leq$ 2mm), BC (0.8-2 mm), BC (0.8-0.4 mm), and BC ($\leq$0.4 mm) treatments than control, respectively. However, the lowest increases were observed by sole application of BCs with different particle sizes. The sole application of BCs increased soil available P by 21-58%. In organic amendments, organic chemical structures contain phosphorus, which is converted into inorganic forms through mineralization. Subsequently, P might be released into the mineral nutrient pool found in the soil (Diacono *et al.,* 2011). Additionally, biochar contains abundant nutrients and, hence, can directly increase soil available P levels. According to review article published by Shi *et al.* (2023), the incorporated biochar may alter the chemical and physical characteristics of soil, including its pH, adsorption potential for P, cation exchange capacity, and porous structure. These varied properties are related to the availability of soil P. Additionally, the addition of biochar increased the amount of soil biota and phosphatase, which helped to solubilize insoluble inorganic P and mineralize organic P, increasing P availability. According to reports, biochar made at temperatures lower than 450 °C increased the amount of P that was available for plant uptake in amended soils (Glaser and Lehr, 2019). Additionally, the effect of biochar on P availability considerably diminishes with increasing pyrolysis temperature (Bruun *et al.,* 2017). In this context, the low pyrolysis temperature biochar produced in the current study result in decreasing soil pH, enhancing the availability of soil P. Consequently, to increase the amounts of P that are available to plants in alkaline soils with P restrictions, low pyrolysis temperature biochar—which has a low pH—should be applied. According to a prior study on alkaline soil, biochar with low pyrolysis temperatures may accelerate organic matter mineralization and the conversion of non-labile Ca-associated P forms into labile P forms (Alotaibi *et al*., 2021).

Soil available K enhanced significantly by FYM and BC application to the soil (Fig. 2). In soil treated with FYM, the soil exchangeable content of K significantly increased from 35.6 to 230 mg kg^{-1}. However, the application of BCs significantly increased the values of soil available K from 35.6 (CK) to 372 mg kg^{-1} (BC $\leq$2mm), 281 mg kg^{-1} (BC = 2-0.8 mm), 321 mg kg^{-1} (BC = 0.8-0.4), and 398 mg kg^{-1} (BC$\leq$0.4 mm). Additionally, in mixed FYM-BC treatments, the values of soil available K content significantly increased from 35.6 to 304 mg kg^{-1} (FYM+BC$\leq$2 mm), 253 mg kg^{-1} (FYM+BC 2-0.8), 290 mg kg^{-1} (FYM+BC 0.8-0.4 mm), and 325 mg kg^{-1} (FYM+BC $\leq$0.4 mm). Our results suggested that BCs itself might be a K source, and thus, it enhanced its bioavailability in soils. The high content of soil exchangeable K in the soil was pronounced for the application of fine fraction of biochar (BC$\leq$0.4 mm). Several other researchers showed that the application of biochar could increase the potassium content and availability in soil (Rasuli *et al.,* 2022; Khadem *et al*., 2021; Sg *et al.,* 2021). After applying biochar to soil, inorganic form of potassium in organic residues and derived biochar can be readily liberated into soluble and exchangeable fractions.

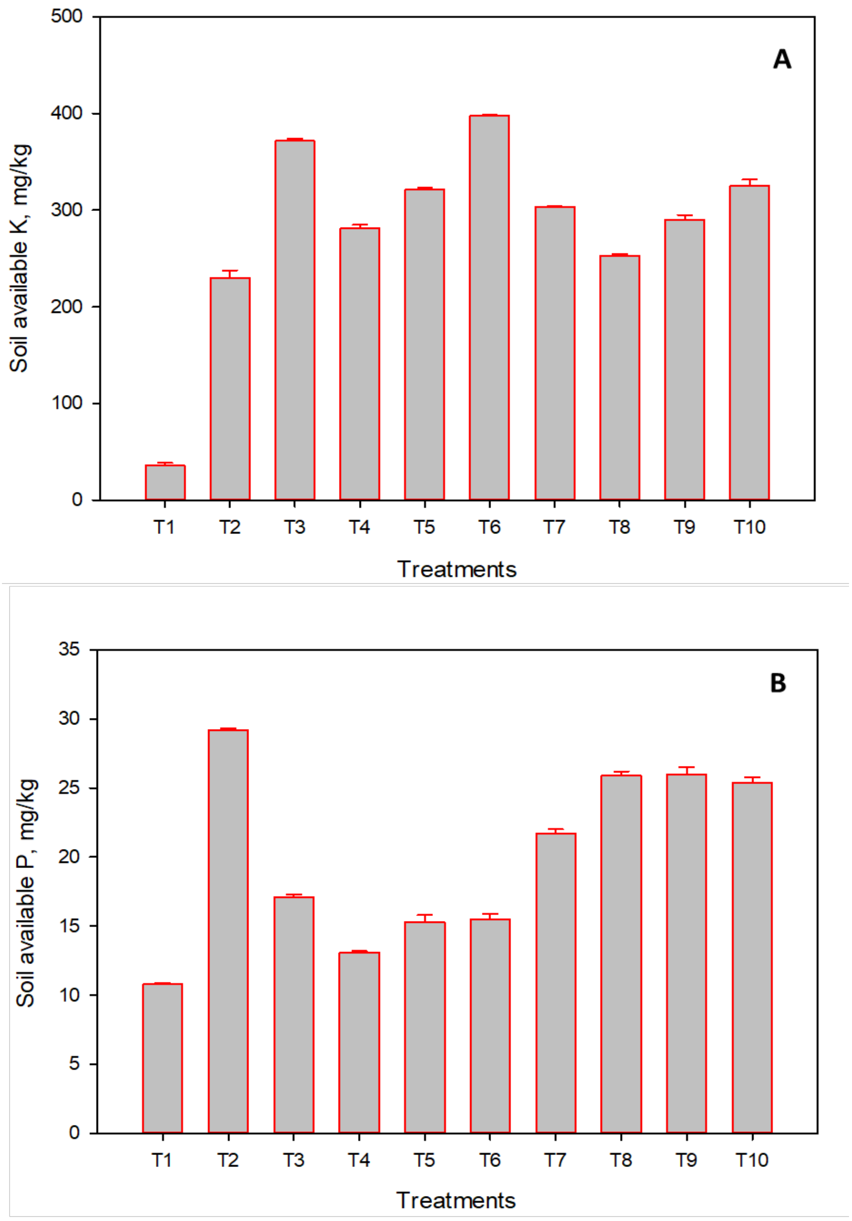

Fig.2. Treatments effect on soil available K (A) and P (B) (T1: CK, T2: FYM, T3: BC (≤2mm), T4: BC (0.8-2 mm), T5: BC (0.4-0.8 mm), T6: BC (≤0.4), T7: BC (≤2mm)+FYM , T8: BC (0.8-2 mm) + FYM, T9: BC (0.4-0.8 mm)+FYM, and T10: BC (≤0.4)+FYM).

3-Amendments effect on aboveground biomass and mineral content of wheat plants

Applied biochar was reported to enhance crop growth, particularly in acidic soils, by increasing soil pH, and by enhancing nutrient retention, bioavailability, and uptake (Tusar *et al.,* 2023; Syuhada *et al.,* 2016; Singh *et al.,* 2022). However, in the literature, the effect of biochar on the productivity of alkaline soils is inconsistent. The results of current studies found that the sole and combined applications of FYM and BCs with variable particle sizes significantly affect the growth of wheat plants grown in calcareous soil. The combined application of FYM with BCs (T7, T8, and T9) increased significantly the plant height (Table 4).

The addition of all treatments (except for T3, T6 and T10) also increased significantly the fresh weight of the aboveground biomass. Moreover, adding T2, T5, T7, T8, and T9 significantly increased the aboveground biomass's dry matter. Among all treatments, the addition of T2 (application sole of FYM) and T9 (BC (0.4-0.8 mm) +FYM) performed significantly better for enhancement in the aboveground biomass than other treatments. Soil with T2 (sole application of FYM) and T9 (combined application of BC (0.4-0.8 mm) and FYM) respectively showed 36% and 44% higher shoot fresh weight and 42.9% and 42.6% higher shoot dry weight against un-amended soil. Our findings imply that improved NPK absorption in wheat was the cause of the improvements in wheat growth parameters. As indicated by our results, the manure could improve nutrient availability to the plants and may improve edaphic factors, which resulted in higher vegetative growth parameters. Similarly, other studies reported that organic fertilizer improved soil productivity and fertility, which improved yield and quality of crops (Liu *et al*., 2024). In this context, it has been reported that using organic material as a fertilizer can also improve soil quality, water retention, porosity, nutrient availability, and soil moisture, leading to improvements in the growth attributes of plants (Dawar *et al.,* 2022; Amzad and Yukio, 2007). In a study conducted by Meena *et al*. (2018) to investigate the influence of FYM on soil properties and yield and nutrient uptake of wheat plants, the grain yield of wheat was significantly higher (by 62.74%) in FYM than in control soil.

In addition to the enhancement effect by FYM, a significant rise in plant growth parameters was noted in the sole application of BCs (T4 and T5 for enhancing fresh weight and T5 for enhancing dry weight). Biochar, as a soil conditioner, has been widely utilized to stimulate the development of plants (Tusar *et al.,* 2023; Singh *et al.,* 2022; El-Bassi *et al*., 2021). For example, Cong *et al.* (2023) found that the application of biochar results in a significant impact on maize yield by altering soil properties and maize physiological characteristics. However, other studies have also found that biochar can have no effects on plant growth and yield in alkaline soils, depending on biochar characteristics and its application rates as well as soil type (Lentz and Ippolito, 2012; Alazzaz *et al.,* 2020; Farrell *et al.,* 2014).

Table 4. Treatment effect on plant growth and nutrient content

Treatments	Plant height	FW	DW	Nutrients concentration			Nutrients uptake		
				N	P	K	N	P	K
	cm	g/plant			g/kg			mg/plant	
T1	31.6_{B}	2.16_{EF}	0.65_{DE}	20.7_{ABC}	3.97_{H}	12.3_{F}	13.4_{DE}	2.57_{C}	7.99_{F}
T2	36.8_{AB}	2.94_{AB}	0.93_{A}	20.93_{AB}	5.42_{C}	15.1_{BCD}	19.4_{AB}	5.03_{A}	14.01_{A}
T3	34.4_{AB}	2.38_{DE}	0.58_{E}	20.62_{ABC}	6.34_{B}	15.2_{BC}	11.9_{EF}	3.67_{BC}	8.79_{EF}
T4	35.0_{AB}	2.73_{BC}	0.72_{BCD}	18.9_{D}	5.08_{E}	14.7_{D}	13.6_{DE}	3.66_{BC}	10.58_{D}
T5	36.7_{AB}	2.88_{ABC}	0.75_{BC}	19.18_{CD}	4.90_{F}	15.1_{BCD}	14.4_{D}	3.68_{BC}	11.34_{CD}
T6	33.8_{AB}	1.90_{F}	0.47_{F}	22.19_{A}	7.28_{A}	16.3_{A}	10.4_{F}	3.42_{BC}	7.65_{F}
T7	37.9_{A}	2.82_{BC}	0.80_{B}	21.7_{A}	5.41_{C}	15.5_{B}	17.3_{BC}	4.31_{AB}	12.34_{BC}
T8	37.2_{A}	2.63_{CD}	0.76_{BC}	19.88_{BCD}	5.17_{D}	13.9_{E}	15.2_{CD}	3.94_{AB}	10.58_{D}
T9	38.2_{A}	3.11_{A}	0.93_{A}	21.42AB	4.84_{G}	14.8_{CD}	19.9_{A}	4.48_{AB}	13.67_{AB}
T10	34.2_{AB}	2.32_{E}	0.68_{CD}	21.0_{AB}	5.13_{D}	15.0_{CD}	14.2_{DE}	3.47_{BC}	10.10_{DE}
Tukey test ($p < 0.05$) critical value	0.27	0.10	1.72	0.05	0.49	2.31	1.23	1.39	0.27

T1: CK, T2: FYM, T3: BC (≤2mm), T4: BC (0.8-2 mm), T5: BC (0.4-0.8 mm), T6: BC (≤0.4), T7: BC (≤2mm)+FYM , T8: BC (0.8-2 mm) + FYM, T9: BC (0.4-0.8 mm)+FYM, T10: BC (≤0.4)+FYM; *:Fresh weight, **: Dry weight; Different letters represent significant difference at $p < 0.05$ among various treatments. The same letter/letters represent no significant difference.

Table 5. Pearson correlation between different investigated parameters

Parameters	pH	EC	Soil av.	Soil av.	FW	DW	Plant N	Plant P	Plant K	N uptake	P uptake	K uptake
pH	1.0000											
EC	-0.4595*	1.0000										
Soil av. K	-0.3412	0.8868*	1.0000									
Soil av. P	0.7019*	-0.1824	0.1687	1.0000								
FW	0.3995*	-0.2854	-0.0121	0.4760*	1.0000							
DW	0.6221*	-0.5547*	-0.2592	0.6267*	0.9159*	1.0000						
Plant N conc.	0.2240	0.1421	0.1505	0.2595	-0.2779	-0.1239	1.0000					
Plant P conc.	-0.3321	0.7297*	0.7754*	0.0102	-0.4048*	-0.5299*	0.3941*	1.0000				
Plant K conc.	-0.2698	0.7298*	0.9027*	0.2166	0.0341	-0.1447	0.3097	0.7972*	1.0000			
N uptake	0.6840*	-0.5138*	-0.2221	0.6918*	0.8408*	0.9631*	0.1453	-0.4321*	-0.0699	1.0000		
P uptake	0.4315*	-0.0731	0.2471	0.6664*	0.7079*	0.7073*	0.1142	0.1205	0.3789*	0.7300*	1.0000	
K uptake	0.5374*	-0.3310	0.0129	0.6852*	0.9277*	0.9535*	-0.0347	-0.2953	0.1577	0.9389*	0.8152*	1.0000

*Significant correlation

It is worth noting that in our study, the dry matter of aboveground biomass was inhibited by T3: BC (≤2mm) and/or T6: BC (≤0.4) in sandy soil (Table 4). The highest salinity levels produced by these treatments may be the cause of this inhibition, as indicated by the high EC values, which also suggest that these treatments reduce plant growth characteristics. Conversely, the results of this study demonstrated an increase in plant growth parameters when BCs alone (at particle sizes of 0.8-2 mm and 0.4-0.8 mm) or in combination of BCs (at particle sizes of ≤2 mm, 0.8-2 mm, or 0.4-0.8 mm) with FYM were applied. This may be because of the negative effects of sandy calcareous soil were more effectively mitigated by adding soil amendments. Generally, co-applied of BC (with particle size of 0.4-0.8) and FYM observed higher plant height and fresh weight than the sole application of FYM. These findings revealed that combined biochar with FYM proved to be an effective reclamation strategy to improve low fertile sandy calcareous soils under arid conditions than the applied farmyard manure alone. Additionally, co-applied FYM with BCs prevents the occurred negative impact of sole application of BCs (T3: BC≤2mm and T6: BC ≤0.4) on plant growth parameters. The incorporation of biochar combined with organic fertilizer also can prevent nutrient losses and enhance physical soil properties (i.e. soil water holding capacity), further increasing nutrient uptake by plants and thus improving plant growth (Hu *et al.,* 2024). According to Mensah and Frimpong (2018), applying biochar in addition to organic amendments may slow down the breakdown and mineralization of the organic materials, resulting in a delayed release of nutrients into the soil and thus, a reduction in nutrient leaching. According to Chen *et al.* (2022), combined application of biochar and organic fertiliser was more beneficial to improving soil characteristics, and plant yield than applying them separately. It has been reported that applying biochar along with organic fertilizer may stimulate plant growth and improve fertilizer use efficiency (Liu *et al.,* 2022; El-Syed *et al*., 2023).

The results of the current study showed that the influence of all treatments was significant for improving concentrations and uptake of P and K by plant shoots. The highest increases in PK uptake were observed by plants treated with T2 (FYM) followed by T9 (combined application of FYM with BC at 0.4-0.8 mm) and T7 (combined application of FYM with BC at ≤ 2mm). In soil treated with T2, T7 and T9, the P uptake by shoots increased by 95.9%, 67.7% and 74.5% compared to control, respectively. The shoot uptake of K increased by 75.2%, 54.4% and 71.0% compared to control, respectively. Furthermore, the shoot uptake of N increased significantly in soil treated with T2, T5, T7, T8 and T9, with the highest increases of 47.9% (for T9) followed by 44.8 (for T2). Several reports found increase in plant content of nutrients due to biochar or farmyard manure application (Liu *et al*., 2022; Alazzaz *et al*., 2022). Contrary to our results, several reports found decreases in the plant content of nutrients in alkaline soils (Alazzaz *et al*., 2020). The discrepancy between our data and that of other studies could be explained because of varying soil characteristics and feedstock used to produce BCs. Our results suggested that the incorporation of low pyrolysis temperature BCs (with particle size of ≤2mm or 2-0.8 mm or 0.8-0.4) in combination with FYM into sandy calcareous soils may enhance the essential nutrient uptake by plants better than their sole application.

4-Correlation study

Correlation between different parameters of pH, EC, nutrient availability, and nutrient uptake by wheat plants was investigated (Table 5). A significant correlation was found between plant growth parameters and soil parameters including EC and nutrient availability as well as their uptake by plants. It was obviously due to the direct relationship between plant uptake of P and K to their bioavailability in soil. This suggests that more availability of nutrients in the soil due to applying soil amendments leads to more accessibility and accumulation in plant tissues. Alteration of nutrient availability in the soil treated with FYM and/or BC may explain observed changes in plant growth, confirming FYM and/or BC as useful amendments. Correlation results indicated that fresh and dry matter of shoots were positively correlated with nutrient (NPK) uptake ($r = 0.7073, 0.9631$) ($p <0.05$). However, these plant growth parameters were negatively correlated with EC values ($r=-0.2854, 0.5547$).

Conclusion

The results showed that the K_{sat} of soils amended with biochars decreased the K_{sat} but FYM increased K_{sat}. The addition of FYM and BC either alone or in combination increased soil EC values. However, the sole addition of BC treatments decreased soil pH values. The results showed that the soil available P and K concentrations exhibited higher increases in all investigated treatments compared to that of the control soil. The addition of T2, T5, T7, T8, and T9 significantly increased the aboveground biomass's dry matter. Among all treatments, the addition of T2 and T9 performed significantly better for enhancement in the aboveground biomass than other treatments. On the contrary, the dry matter of aboveground biomass was inhibited by T3 and T6 in a sandy soil. Therefore, it is important to consider these negative findings, depending on the fractions of applied BC. The results of the current study showed also that the influence of all treatments was significant for improving concentrations and uptake of NPK by plant shoots, especially for T2, T7, or T9. This study suggests that incorporation of mixed biochar and farmyard manure could improve nutrients content and plant growth better than biochar alone. However, to understand the mechanism controlling plants' uptake of these nutrients in relation to particle sizes of biochar, more research on the co-application of BC and FYM is necessary.

Reference

Alazzaz, A., Usman, A. R., Ahmad, M., Ibrahim, H. M., Elfaki, J., Sallam, A. S., Akanji, M. A., and Al-Wabel, M. I. (2020). Potential short-term negative versus positive effects of olive mill-derived biochar on nutrient availability in a calcareous loamy sand soil. PLOS ONE. 15(7): e0232811.

Alghamdi, A. G., Alkhasha, A., and Ibrahim, H. M. (2020). Effect of biochar particle size on water retention and availability in a sandy loam soil. Journal of Saudi Chemical Society. 24(12): 1042-1050.

Alotaibi, K. D., Arcand, M., and Ziadi, N. (2021). Effect of biochar addition on legacy phosphorus availability in long-term cultivated arid soil. Chemical and Biological Technologies in Agriculture. 8: 1-11.

Amzad, H. M., and Yukio, I. (2007). Effects of Farmyard Manure on Growth and Yield of Turmeric (Curcuma Longa L.) Cultivated in Dark-Red Soil, Red Soil and gray Soil in Okinawa, Japan. Plant Production Science. 10(1): 146-150.

Angelova, V. R., Akova, V. I., Artinova, N. S., and Ivanov, K. I. (2013). The effect of organic amendments on soil chemical characteristics. Bulgarian Journal of Agricultural Science. 19(5): 958-971.

Bashir, O., Ali, T., Baba, Z. A., Rather, G. H., Bangroo, S. A., Mukhtar, S. D., Naik, N., Mohiuddin, R., Bharati, V., and Bhat, R. A. (2021). Soil organic matter and its impact on soil properties and nutrient status. Microbiota and Biofertilizers, Vol 2: Ecofriendly Tools for Reclamation of Degraded Soil Environs. 129-159.

Bhat, S. A., Kuriqi, A., Dar, M. U. D., Bhat, O., Sammen, S. S., Towfiqul Islam, A. R. M., Elbeltagi, A., Shah, O., Al-Ansari, N., Ali, R., and Heddam, S. (2022). Application of biochar for improving physical, chemical, and hydrological soil properties: a systematic review. Sustainability. 14(17): 11104.

Blanco-Canqui, H. (2017). Biochar and soil physical properties. Soil Science Society of America Journal. 81(4): 687-711.

Bolan, N., Srivastava, P., Rao, C. S., Satyanaraya, P. V., Anderson, G. C., Bolan, S., Nortjé, G. P., Kronenberg, R., Bardhan, S., Abbott, L. K., Zhao, H., Mehra, P., Satyanarayana, S. V., Khan, N., Wang, H., Rinklebe, J., Siddique, K. H. M., and Kirkham, M. B. (2023). Distribution, characteristics and management of calcareous soils. Advances in Agronomy. 182: 81-130.

Bruun, S., Harmer, S. L., Bekiaris, G., Christel, W., Zuin, L., Hu, Y., Jensen, L. S., and Lombi, E. (2017). The effect of different pyrolysis temperatures on the speciation and availability in soil of P in biochar produced from the solid fraction of manure. Chemosphere. 169: 377–386. https://doi.org/10.1016/j.chemosphere.2016.11.058.

Carpenter, D., Westover, T. L., Czernik, S., and Jablonski, W. (2014). Biomass feedstocks for renewable fuel production: a review of the impacts of feedstock and pretreatment on the yield and product distribution of fast pyrolysis bio-oils and vapors. Green Chemistry. 16(2): 384-406.

Chen, C., Wang, R., Shang, J., Liu, K., Irshad, M. K., Hu, K., and Arthur, E. (2018). Effect of biochar application on hydraulic properties of sandy soil under dry and wet conditions. Vadose Zone Journal. 17(1): 1-8.

Chen, L., Li, X., Peng, Y., Xiang, P., Zhou, Y., Yao, B., Zhou, Y., and Sun, C. (2022). Co-application of biochar and organic fertilizer promotes the yield and quality of red pitaya (*Hylocereus polyrhizus*) by improving soil properties. Chemosphere. 294: 133619. https://doi.org/10.1016/j.chemosphere.2022.133619.

Cong, M., Hu, Y., Sun, X., Yan, H., Yu, G., Tang, G., Zhang, Y., and Jia, H. (2023). Long-term effects of biochar application on the growth and physiological characteristics of maize. Frontiers in Plant Science. 14: 1172425. https://doi.org/10.3389/fpls.2023.1172425.

Dawar, K., Khalil, Z., Mian, I. A., Khan, B., Ali, S., Rahi, A. A., Tahir, M. S., Ahmed, N., Fahad, S., Danish, S., Syed, A., Bahkali, A. H., and Datta, R. (2022). Effects of farmyard manure and different phosphorus inorganic fertilizer application rates on wheat cultivation in phosphorus-deficient soil. Sustainability. 14(15): 9030. https://doi.org/10.3390/su14159030.

Day, R.P. (1965) Pipette Method of Particle Size Analysis. In: Methods of Soil Analysis, Agronomy No. 9, ASA, Madison, 553-562.

Diacono, M., and Montemurro, F. (2011). Long-term effects of organic amendments on soil fertility. Sustainable Agriculture. 2: 761-786.

Dong, L., Zhang, W., Xiong, Y., Zou, J., Huang, Q., Xu, X., Ren, P., and Huang, G. (2022). Impact of short-term organic amendments incorporation on soil structure and hydrology in semiarid agricultural lands. International Soil and Water Conservation Research. 10(3): 457–469. https://doi.org/10.1016/j.iswcr.2021.10.003.

El-Bassi, L., Azzaz, A. A., Jellali, S., Akrout, H., Marks, E. A., Ghimbeu, C. M., and Jeguirim, M. (2021). Application of olive mill waste-based biochars in agriculture: Impact on soil properties, enzymatic activities and tomato growth. Science of the Total Environment. 755: 142531.

El-Syed, N. M. M., Helmy, A. M., Fouda, S. E. E., Nabil, M. M., Abdullah, T. A., Alhag, S. K., Al-Shuraym, L. A., Al Syaad, K. M., Ayyoub, A., Mahmood, M., and Elrys, A. S. (2023). Biochar with Organic and Inorganic Fertilizers Improves Defenses, Nitrogen Use Efficiency, and Yield of Maize Plants Subjected to Water Deficit in an Alkaline Soil. Sustainability. 15(16): 12223. https://doi.org/10.3390/su151612223.

Farrell, M., Macdonald, L. M., Butler, G., Chirino-Valle, I., and Condron, L. M. (2014). Biochar and fertiliser applications influence phosphorus fractionation and wheat yield. Biology and Fertility of Soils. 50: 169-178.

Gelardi, D. L., Ainuddin, I. H., Rippner, D. A., Patiño, J. E., Abou Najm, M., and Parikh, S. J. (2021). Biochar alters hydraulic conductivity and impacts nutrient leaching in two agricultural soils. Soil. 7(2): 811-825.

Glaser, B., and Lehr, V. I. (2019). Biochar effects on phosphorus availability in agricultural soils: A meta-analysis. Scientific Reports. 9(1): 9338.

Grau-Andrés, R., Pingree, M. R., Öquist, M. G., Wardle, D. A., Nilsson, M. C., and Gundale, M. J. (2021). Biochar increases tree biomass in a managed boreal forest, but does not alter N_2O, CH_4, and CO2 emissions. GCB Bioenergy. 13(8): 1329-1342.

Hu, W., Zhang, Y., Rong, X., Zhou, X., Fei, J., Peng, J., and Luo, G. (2024). Biochar and organic fertilizer applications enhance soil functional microbial abundance and agroecosystem multifunctionality. Biochar. 6(1): 3.

Hussain, A., Bashir, H., Zafar, S. A., Rehman, R. S., Khalid, M. N., Awais, M., Sadiq, M. T., and Amjad, I. (2023). The importance of soil organic matter (SOM) on soil productivity and plant growth. Biological and Agricultural Sciences Research Journal. 2023(1): 11. https://doi.org/10.54112/basrj.v2023i1.11.

Ibrahim, M., Khan, S., Hao, X., and Li, G. (2016). Biochar effects on metal bioaccumulation and arsenic speciation in alfalfa (*Medicago sativa* L.) grown in contaminated soil. International Journal of Environmental Science and Technology. 13: 2467-2474.

Igalavithana, A. D., Ok, Y. S., Niazi, N. K., Rizwan, M., Al-Wabel, M. I., Usman, A. R., Moon, D. H., and Lee, S. S. (2017). Effect of corn residue biochar on the hydraulic properties of sandy loam soil. Sustainability. 9(2): 266. https://doi.org/10.3390/su9020266.

Jackson, M. L. (1973). Soil chemical analysis, pentice hall of India Pvt. Ltd., New Delhi, India, 498: 151-154.

Jones, J. I. J. B., B. Wolf, and H. A. Milis. 1991. Plant analysis handbook, 213. Athens, Georgia 30607: Micro-Macro Publishing.

Khadem, A., Raiesi, F., Besharati, H., and Khalaj, M. A. (2021). The effects of biochar on soil nutrients status, microbial activity and carbon sequestration potential in two calcareous soils. Biochar. 3(1): 105-116.

Khan, N. I., Malik, A. U., Umer, F., and Bodla, M. I. (2010). Effect of tillage and farmyard manure on physical properties of soil. International Research Journal of Plant Science. 1(4): 75-82.

Klute, A., and Dirksen, C. (1986). Hydraulic conductivity and diffusivity: Laboratory methods. Methods of soil analysis: Part 1 physical and mineralogical methods. 5: 687-734.

Lehmann J. 2007. A handful of carbon. Commentary. Nature. 447: pp. 143-144.

Lehmann, J., and Joseph, S. (2015). Biochar for environmental management: An introduction. In Biochar for Environmental Management (pp. 1-13). Routledge.

Lentz, R. D., and Ippolito, J. A. (2012). Biochar and manure affect calcareous soil and corn silage nutrient concentrations and uptake. Journal of Environmental Quality. 41(4): 1033-1043.

Lipiec, J., Usowicz, B., Kłopotek, J., Turski, M., and Frąc, M. (2021). Effects of application of recycled chicken manure and spent mushroom substrate on organic matter, acidity, and hydraulic properties of sandy soils. Materials. 14(14): 4036.

Liu ,X.F., Han. W., Liu. Z., Wang .X., Zhao. X. (2016). Impacts of biochar amended soils on ryegrass (Lolium perenne) growth under different water stress conditions. Int. J. Agric. Biol. 18: 630-636.

Liu, M., Linna, C., Ma, S., Ma, Q., Song, W., Shen, M., Zhang, Y., and Wang, L. (2022). Biochar combined with organic and inorganic fertilizers promoted the rapeseed nutrient uptake and improved the purple soil quality. Frontiers in Nutrition. 9: 997151. https://doi.org/10.3389/fnut.2022.997151.

Liu, Y., Bai, M., Shen, F., Wu, Z., Yang, J., Li, N., Liu, H., Dai, J., and Han, X. (2024). Enhancing Soybean and Maize Yields through Improved Nitrogen and Soil Water Use Efficiencies: A 40-Year Study on the Impact of Farmyard Manure Amendment in Northeast China. Plants. 13(4): 500. https://doi.org/10.3390/plants13040500.

Liu, Z., Dugan, B., Masiello, C. A., and Gonnermann, H. M. (2017). Biochar particle size, shape, and porosity act together to influence soil water properties. Plos One. 12(6): e0179079.

Lusiba, S., Odhiambo, J., and Ogola, J. (2017). Effect of biochar and phosphorus fertilizer application on soil fertility: soil physical and chemical properties. Archives of Agronomy and Soil Science. 63(4): 477-490.

Meena, K. B., Alam, M. S., Singh, H., Bhat, M. A., Singh, A. K., Mishra, A. K., and Thomas, T. (2018). Influence of farmyard manure and fertilizers on soil properties and yield and nutrient uptake of wheat. International Journal of Chemical Studies. 6(3): 386-390.

Mensah, A. K., and Frimpong, K. A. (2018). Biochar and/or compost applications improve soil properties, growth, and yield of maize grown in acidic rainforest and coastal savannah soils in Ghana. International Journal of Agronomy. 2018(1): 6837404.

Nelson, D. W., and Sommers, L. E. (1996). Total carbon, organic carbon, and organic matter. Methods of soil analysis: Part 3 Chemical methods. 5: 961-1010.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Dep. Agric., Washington, D.C. Circ. 939.

Paslakis, G., Dimitropoulos, G., and Katzman, D. K. (2021). A call to action to address COVID-19–induced global food insecurity to prevent hunger, malnutrition, and eating pathology. Nutrition Reviews. 79(1): 114-116.

Rasuli, F., Owliaie, H., Najafi-Ghiri, M., and Adhami, E. (2022). Effect of biochar on potassium fractions and plant-available P, Fe, Zn, Mn and Cu concentrations of calcareous soils. Arid Land Research and Management. 36(1): 1-26.

Rizwan, M., Ali, S., Qayyum, M. F., Ibrahim, M., Zia-ur-Rehman, M., Abbas, T., and Ok, Y. S. (2016). Mechanisms of biochar-mediated alleviation of toxicity of trace elements in plants: A critical review. Environmental Science and Pollution Research. 23: 2230-2248.

Sg, L., Jjo, O., Adeleke, R., and St, M. (2021). The potential of biochar to enhance concentration and utilization of selected macro and micro nutrients for chickpea (Cicer arietinum) grown in three contrasting soils. Rhizosphere. 17: 100289.

Shi, Y., Yu, Y., Chang, E., Wang, R., Hong, Z., Cui, J., Zhang, F., Jiang, J., and Xu, R. (2023). Effect of biochar incorporation on phosphorus supplementation and availability in soil: a review. Journal of Soils and Sediments. 23(2): 672–686. https://doi.org/10.1007/s11368-022-03359-w.

Singare, P., Meshram, N., and Kausadikar, H. (2022). Calcareus soil and their management: A review. Just Agric. 3: 1-6.

Singh, H., Northup, B. K., Rice, C. W., and Prasad, P. V. (2022). Biochar applications influence soil physical and chemical properties, microbial diversity, and crop productivity: a meta-analysis. Biochar. 4(1): 8.

Singh, T. B., Ali, A., Prasad, M., Yadav, A., Shrivastav, P., Goyal, D., and Dantu, P. K. (2020). Role of organic fertilizers in improving soil fertility. In: Naeem, M., Ansari, A., Gill, S. (eds) Contaminants in Agriculture. Springer, Cham. pp: 61-77. https://doi.org/10.1007/978-3-030-41552-5_3

Sohi, S. P., Krull, E., Lopez-Capel, E., and Bol, R. (2010). A review of biochar and its use and function in soil. Advances in Agronomy. 105: 47-82.

Sparks, D. L. (1996). Methods of soil analysis part 3: Chemical methods. Madison: Soil Science Society of America, American Society of Agronomy.

Syuhada, A. B., Shamshuddin, J., Fauziah, C. I., Rosenani, A. B., and Arifin, A. (2016). Biochar as soil amendment: Impact on chemical properties and corn nutrient uptake in a Podzol. Canadian Journal of Soil Science. 96(4): 400-412.

Taalab, A. S., Ageeb, G. W., Siam, H. S., and Mahmoud, S. A. (2019). Some Characteristics of Calcareous Soils: A Review. Middle East Journal of Agriculture Research. 8(1): 96–105. https://www.curresweb.com/mejar/mejar/2019/96-105.pdf.

Tusar, H. M., Uddin, M. K., Mia, S., Suhi, A. A., Wahid, S. B. A., Kasim, S., Sairi, N. A., Alam, Z., and Anwar, F. (2023). Biochar-acid soil interactions—a review. Sustainability. 15(18): 13366. https://doi.org/10.3390/su151813366.

Usman, A. R. A., Abduljabbar, A., Vithanage, M., Ok, Y. S., Ahmad, M., Ahmad, M., Elfaki, J., Abdulazeem, S. S., and Al-Wabel, M. I. (2015). Biochar production from date palm waste: Charring temperature induced changes in composition and surface chemistry. Journal of Analytical and Applied Pyrolysis. 115: 392–400. https://doi.org/10.1016/j.jaap.2015.08.016.

Weber, K., and Quicker, P. (2018). Properties of biochar. Fuel, 217, 240-261.

Yazdanpanah, N., Mahmoodabadi, M., and Cerdà, A. (2016). The impact of organic amendments on soil hydrology, structure and microbial respiration in semiarid lands. Geoderma. 266: 58-65.

Zhang, Y., Wang, J., and Feng, Y. (2021). The effects of biochar addition on soil physicochemical properties: A review. Catena. 202: 105284.

التأثيرات المشتركة لسماد المزرعة والفحم الحيوي من مخلفات نخيل التمر على التوصيل الهيدروليكي المشبع وتيسر العنصر الغذائي لنباتات القمح في التربة الرملية الجيرية

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الملخص

يهدف هذا العمل الى اجراء تجارب أعمدة وصوبة لدراسة التأثيرات المحتملة لإضافة أحجام مختلفة من الفحم الحيوي الناتج من مخلفات نخيل التمر، مع سماد المزرعة (بنسبة إضافة 1.5٪)، على التوصيل الهيدروليكي وتيسر العناصر الغذائية في التربة الرملية الجيرية. تضمنت المعاملات ما يلي T1: تربة التحكم، T2: سماد عضوي، T3: فحم حيوي (≥2 مم)، T4: فحم حيوي (0.8-2 مم)، T5: فحم حيوي (0.4-0.8 مم)، T6: فحم حيوي (≥0.4 مم)، T7: فحم حيوي (≥2 مم) + سماد عضوي، T8: فحم حيوي (0.8-2 مم) + سماد عضوي، T9: فحم حيوي (0.4-0.8 مم) + سماد عضوي، T10: فحم حيوي (≥0.4 مم) + سماد عضوي. أظهرت النتائج أن إضافة الأحجام المختلفة من الفحم الحيوي أدت إلى خفض التوصيل الهيدروليكي المشبع. وأظهرت الدراسة الحالية أن جميع المعاملات كانت فعّالة في تحسين تركيزات وامتصاص الفوسفور والبوتاسيوم بواسطة نباتات القمح، حيث لوحظت أعلى زيادات في امتصاص الفوسفور والبوتاسيوم في النباتات المعاملة بسماد المزرعة، تليها المعاملات T7 وT9. زاد امتصاص النيتروجين بواسطة النباتات بشكل ملحوظ في المعاملات T2، T5، T7، T8، T9، حيث سجلت المعاملة T9 أعلى زيادة بنسبة 47٪، تليها المعاملة T2 بنسبة 44.8٪. يمكن استنتاج أن إضافة سماد المزرعة، سواءً بمفرده أو عند دمجه مع الفجم الحيوي، يمكن أن يحسّن امتصاص العناصر الغذائية ويعزز نمو النباتات، وذلك حسب احجام حبيبات الفحم.

الكلمات المفتاحية: *إعادة تدوير المخلفات، الفحم، التيسر الحيوي، محسنات التربة.*