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Carbon sequestration in a sandy soil amended with either organic wastes or their biochar in relation with lettuce productivity

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1.Abstract:

One potential method of capturing atmospheric carbon and assisting in both climate change adaptation and mitigation is the pyrolysis of biomass into biochar, which is then added to soil. Intensive research on soil CO_2 emission is necessary due to the lack of carbon capture in soil. As a result, a pot experiment including sandy soil and five treatments was carried out: (T_0) Control (T_1) compost derived from town refuse (CTR), (T_2) fresh sewage sludge (FSS), (T_3) biochar derived from compost town refuse (BCTR) and (T_4) biochar derived from sewage sludge (BSS) to quantify CO_2 emission and its effect on lettuce growth. The CO_2 emissions decreased in the biochar amended treatments, The biochar augmented treatment represented a reduction in soil CO_2 emissions, with the lowest value (803 ppm) being recorded under BSS (T_4) at the end of the experiment. The highest vegetative parameters values of lettuce plants and organic carbon fractions dissolved organic carbon (DOC), microbial organic carbon (MOC) and oxidized organic carbon (OOC) of soils were achieved in BSS treatment (T4), while the lowest values were shown in control treatment (T_0). In addition to the pathogenic bacteria completely disappeared from the residues after burning it at 500°C and turning into biochar. Therefore, using biochar is an important technique for enhancing carbon sequestration, and improving soil quality in arid regions.

2.INTRODUCTION

The objective of "cutting global carbon dioxide emissions by almost half by 2030" was proposed at the 26th United Nations Climate Change Conference in 2021, which indicates that the greenhouse gases (GHGs) emitted by human activities (CO_2eq) should be offset by energy-saving or carbon-sequestration technology. The globally carbon storage in soils is the second largest in the biosphere, making the dynamics of soil organic carbon an important issue that must be understood if we are to fully comprehend global climate change **Lal R. (2004)**. Agricultural lands occupy large portions of the global land area, therefore, there is a great potential to regain some of the lost carbon by adopting effective carbon sequestration practices on arable lands. A novel method for storing carbon in soil has been developed that may provide a low-risk and effective solution to reduce climate change while restoring soil fertility (**Meyer *et al*., 2011 ; Many'a, 2012)**. A portion of the carbon is switched from soil respiration to mineralized carbon, which is much slower, more stable, and resistant. Biomass that has been pyrolyzed into biochar and then put back into soil, it leads to the withdrawal of carbon dioxide from the atmosphere in the long term **(Zhao *et al*., 2013; Voca and Ribic, 2020).** The biochar application might cut average GHG emissions by 0.27 to 0.48 Mg $Ceq.ha^{-1}.yr^{-1}$ and reach 20% net carbon "negativity" **(Lehmann, 2007).** Based on biomass residues now available worldwide, the study of maximum annual net global greenhouse gas emissions found that biochar is capable of removing 1.80 pg of carbon (CO_2e) each year, equivalent to 12% of total annual greenhouse gas emissions, caused by human activity. **(Woolf et al., 2010).** Over the course of the twenty-first century, biochar has the potential to store almost 400 billion Mg of carbon, reducing atmospheric CO_2 concentrations by 37 ppm, a major greenhouse gas that accounts for 60% of the entire greenhouse impact is carbon dioxide (CO_2) **(Rastogi *et al.*, 2002).** There has been an increase in the emission of naturally occurring greenhouse gases like methane (CH_4), CO_2, and nitrous oxide (N_2O) in the last few decades, the industrial revolution caused the atmospheric CO_2 concentration to rise from 280 ppmv to its current level of 391 ppmv **(WMO 2012).** This increase is related to human-caused activities such as changes in land use and agriculture, the burning of fossil fuels, deforestation, automotive emissions, forest fires, etc. Regarding the availability of plant nutrients and the enhancement of soil's physical, chemical, and biological qualities, soil organic carbon (SOC) is of utmost significance **(Kundu *et al.*, 2006).** Declining soil C reduces crop productivity, and maintaining SOC is crucial for sustainable agricultural production **(Lal 2006).**

The type and quantity of organic materials added to soil, as well as the intricate interactions between soil's physical, chemical, and biological processes and external factors like temperature, all have a significant impact on the rate of soil carbon emission **(Agehara and Warncke 2005)**.

In order to reduce global climate change, biochar has been a key technology put to agricultural soils, produced as a result of the thermochemical reaction between organic wastes and a low-oxygen environment **(Scott and Jan 1984).** Due to its recalcitrant carbon content, biochar is extremely resistant to deterioration and has the potential to enhance soil quality **(Ahmad *et al.*, 2014)**. The porosity, moisture content, and pH of the soil have all been shown to change with the addition of biochar, which would have a significant effect on soil CO_2 emissions. However, prior research has demonstrated that adding biochar to various raw materials and soil textures can have a variety effects on the CO_2 emission in pot experiments, including an increase, a decrease, or no effect **(Stavi and Lal 2013)**. According to certain research, adding biochar could encourage the mineralization of soil organic carbon (SOC), which would increase CO_2 emissions. However, it was also noted that SOC mineralization has been suppressed, resulting in a reduction in CO_2 emissions. The various processes of SOC mineralization are influenced by the interactions between biochar and soil characteristics **(Cely *et al.*, 2014).** Carbon mineralization caused by bacteria is quickly occurred when biochar was applied to the soil **(Cheng *et al.*, 2006)**.

Therefore, the primary objectives of this study were to determine the impacts of amending a sandy soil with fresh sewage sludge, compost town refuse or their biochar derived from on carbon sequestration, Soil enzymes activity, organic carbon fractions, and lettuce growth thereon.

3.Materials and Methods:

The experiments were conducted at the lab of soils and water department , faculty of agriculture, Damietta University, Egypt and cultivation experiment was carried in a private farm under greenhouse conditions.

3.1. Biochar production and close chamber design:-

The experiment's biochar was produced by slowly pyrolyzing sewage sludge, which was collected from the sewage station, Mansoura city, El-Dakahlia Governorate and compost town refuse collected from the waste recycling factory in the Abo greda area, Damietta Governorate under oxygen-limited conditions in the oven at 500◦C. The biochar was grind and passing it through a 2 mm sieve (**Yang *et al.*, 2017**).

A close-chamber **(Fig.1)** was used to determine CO_2 emission in three replicates of each treatment. The close chamber was 50 cm height, 30 cm width. A sliding door and electrical fan were installed for the close chamber, a bend was made at the top of the greenhouse using metal wires. Close-chamber was covered with a sheet of polyethylene (thickness 120 micron) and an airtight hole was made at the back of the greenhouse to facilitate the entry and exit of the CO_2 meter **(Fig.1)**.

Fig. 1: **Close-chamber and CO_2 meter**

3. 2. Chemical and physical characteristics of residues and biochar

3. 2. 1. Chemical properties of residues and biochar

Data in **Table 1** showing chemical and physical characterization of the used organic residues and their biochar. Electrical conductivity and pH were analyzed according to **Rayment and Higginson (1992)**. Determination of organic matter using the modified dichromatometric oxidation method **Yeomans and Bremner (1988).** Carbonates, bicarbonates and chlorides were determined by titration method as described by **Elnaggar and El-Alfy (2016)**. Sulphate was determined using difference method between cations and anions. Magnesium (Mg^{+2}) and calcium (Ca^{+2}) were determined titrametrically according to **Gharaibeh *et al.* (2021).** Total nitrogen (%) in digested samples (samples were digested by a mixture of Sulfuric acid and perchloric acid) was determined by Kjeldhal method as aforementioned by **Ghosh *et al*., (2020).** Total phosphorus in digested extract was determined calorimetrically (Olsen′s method) as described by **Singh *et al.*, (2015**). Total Potassium was determined in digested extract by Flame photometer method. Soluble sodium was determined according to **Islam and Shamsad (2009).**

Table 1. Physiochemical characteristics of fresh organic residues and its biochar.

Property	Fresh organic residues		Biochar derived from	
	SS	CTR	BSS	BCTR
*pH	6.1	7.96	8.73	9.81
EC(dSm^{-1})	13.45	26 .65	4.7	18.65
CEC($cmol_c\ kg^{-1}$)	56.5	20.1	64.2	23.9
OM ($g\ kg^{-1}$)	397.8	220.8	201.5	181.1
TN($mg\ kg^{-1}$)	820	616	560	476
TP ($mg\ kg^{-1}$)	0.56	0.027	3.47	0.70
ESP (%)	32.21	68.66	25.71	53.56
Cations ($mmol_cL^{-1}$)				
Ca^{+2} ($mmol_cL^{-1}$)	21	11	28	10
Mg^{+2} ($mmol_cL^{-1}$)	31	15	14	4
Na^+($mmol_c/100g$)	18.2	13.8	16.5	12.8
K^+ ($mg\ kg^{-1}$)	1513.78	5227.29	4724.58	8647.57
Anions ($mmol_cL^{-1}$)				
CO_3^{--}	0	0	0	0
CL^-	15	6	6.4	6.2

HCO_3^-	20	12	11	3
SO_4^{--}	35.2	21.8	41.1	17.6
physical Properties				
BD (gcm^{-3})	0.5	0.8	0.6	0.9
moisture content (%)	0.89	0.06	0.78	0.04
Ash (%)	N.D	N.D	8.9	3.9

SS: sewage sludge, CTR:compost derived from town refuse, BSS: Biochar derived from sewage sludge, BCTR= Biochar derived from compost of town refuse
TN= total nitrogen, TK= total potassium, TP=total phosphorus, OM= organic matter percentage
ESP= exchangeable sodium percentage, * was determined in suspension (1:5)

3.2.2. Physical analysis of residues and biochar : -

Moisture content and Bulk density were determined according to **Parsons *et al*. (2001)**. Ash percentage was determined in biochar samples according to **Aller *et al*.,(2016).**

3.3. Counting of pathogenic bacteria in residues and biochar samples.

Salmonella, *Shigella* and *Staphylococcus* count were done using plate count methods according to **Ronald (2010)**. Coliform and Clostridium were counted using the method of Most Probable Number (**LQAD, 2008**).

3.4. Experimental procedure .

Surface soil samples were collected at a depth of 0-30 cm from cultivated sandy soil with *Triflium alexandrium* (Egyptian clover) in New-Damietta city located at 31.42938 north latitude and 31.64188 east longitude, Damietta governorate, Egypt. During the winter season of 2019-2020, portion of the collected soil samples were taken and a pot experiment was done for 40 days at the private farm in Kafr-sad city, Damietta governorate. Three replicates of the experimental treatments were conducted using a completely randomized block design, hence, carried out with one type of soil (sandy soil), and two types of organic residues (fresh sewage sludge and compost of town refuse) and their biochar as follows: Sewage sludge (SS), compost town refuse (CTR), biochar of sewage sludge (BSS) and biochar compost town refuse (BCTR), the residues and its biochar were added at the rate of 3% (w/w) according to **Alotaibi *et al*., (2021)**. The following treatments were applied**:** T_1 control treatment (sandy soil) without residues, T_2 sandy soil + compost town refuse, T_3 sandy soil + biochar compost town refuse, T_4 sandy soil + fresh sewage sludge, T_5 sandy soil + biochar of sewage sludge. Soil, residues and biochar were mixed before filling pots (20 cm diameter, capacity 500g). Lettuce seedlings were cultivated in pots and incubated from day five in close-chamber, which provided with a small electric fan for ventilation. CO_2 emission was determined every two days by CO_2 meter while water was added to treatments after determination of carbon dioxide emission. Plants were thinned to two seedlings per pot after emergence and left to grow for 40 days under the green house conditions. Plants were fertilized with N, P and K at the rate of 22.4, 48, 186 kg ha^{-1} respectively.

After the lettuce harvesting, plant length was measured, the stem diameter was evaluated with venire caliper, fresh root weight, dry root weight, root diameter, root length, plant fresh weight and leaf area were measured according to **Hasan *et al*., (2017).** Thereafter, plants were oven, dried at 70ºC for 24h for determination of their dry weights.

Table 2 . Physiochemical characteristics of the studied soil before cultivation

Property	value
*pH	7.75
**EC(dSm^{-1})	3.89
CEC ($cmol_ckg^{-1}$)	34.8
% ESP	15.7
TN ($mgkg^{-1}$)	308
TP ($mgkg^{-1}$)	0.011
TK ($mgkg^{-1}$)	347

OM (%)	1.859
physical Properties	
Particle size distribution %	
Sand	58
Silt	18
Clay	24
Texture	Sandy
BD (Mg m^{-3})	1.57
FC%	19
SP%	34.6
MC%	5

TN= total nitrogen, TP= total phosphorus, TK = total potassium, OM= organic matter,

BD= bulk density, FC= field capacity, SP= saturation percentage, MC= moisture content,
**** was determined in soil suspension 1:5, ** was determined in soil paste extract***

3.5. Measurement of biochemical parameters of lettuce plant samples.

Ascorbic acid concentration was determined on leaves by Tillman's titration method, which was modified by **Pijanovski *et al*., (1973).** Total carbohydrates was determined according to **Brooks *et al*., (1986)**. Measurement of photosynthetic pigments (chlorophyll a, b and carotenoids) using N-N dimethylformamide according to **Kowitcharoen *et al*., (2021)** by the following equations :

Chlorophyll a = $(12.64A_{665}) - (2.99A_{647})$
Chlorophyll b = $(23.26A_{647}) - (5.6A_{665})$
Total chlorophyll = $(20.27A_{647}) + (7.04A_{665})$
Carotene = $(1000A_{470} - 1.02cha - 34.07chb)/ 245$

3.6. Determination of enzymes

3.6.1. Nitrogenase activity

The activity of nitrogenase enzyme was determined by estimating the fixed nitrogen in a nitrogen-free medium and containing enzyme cofactors according to **(Bhaduri *et al*., 2016).**

3.6.2. Phosphatase activity

The activity of phosphatase enzyme was determined by estimating the available phosphorus in medium containing tricalcium phosphate $[Ca_3(PO_4)_2]$ as a source of insoluble phosphate according to **(Manzoor *et al*., 2017).**

3.6.3. Dehydrogenase enzyme

The activity of dehydrogenase enzyme was determined according to **Casida *et al*., (1964).**

3.6.4. Amylase enzyme

Using the method of reducing sugars, amylase activity was measured. **(Mishra *et al*., 1979)**.

3.7. Statistical analysis

Data obtained throughout this study were analyzed by one-way ANOVA computer-assisted, using the software package statgraphics version 5.0 (costat). Least significant differences (LSDs) were calculated at 99% level of significance $P < 0.05$ **(Murica *et al*., 1997)**.

4.Result and Discussion

4.1.Counting of pathogenic bacteria in residues and biochar samples.

Data in Table 3 and Fig.2 show counting of pathogenic bacteria in fresh organic residues and its biochar. *Staphylococus* sp. count was (35.5 C.F.U $\times10^4$/g) in FSS and (45 C.F.U $\times10^4$/g) in CTR, *Salmonella* sp. and *Shigella* sp.count was (5.5 C.F.U $\times10^4$/g) in FSS and (11 C.F.U$\times10^4$/g) in CTR, *Clostridium* sp.count was (210 C.F.U $\times10^4$/g) in FSS and (15 C.F.U $\times10^4$/g) in CTR and E. *Coli* Count was (240 C.F.U $\times10^4$/g) in FSS and (7.4 C.F.U $\times10^4$/g) in CTR. The pathogenic bacteria completely disappeared from the residues after burning it at 500°C and turning into biochar.

Table 3. Counting of pathogenic (CFU$\times10^4$/g) in examined SS and CTR sample

and its biochar.

Treatment	*Staphylococus* sp.	*Salmonella* sp. and *Shigella* sp.	*Clostridium* sp.	E. *Coli*
FSS	35.5	5.5	210	240
CTR	45	11	15	7.4
BSS	0	0	0	0
BCTR	0	0	0	0

Staphylococus sp. E.*Coli* *Salmonella* sp. and *Shigella* sp. *Clostridium* sp.

Fig.2. Pathogenic bacteria in examined SS and CTR sample and its biochar.

4.2.Carbon dioxide emission

Time of incubation, organic residues and its biochar had a significant effect on the levels of CO_2 emission from the sandy soil compared to control (**Fig.3**). With increasing incubation periods, the CO_2 emission increase slightly till day 16 after that CO_2 emission increased significantly until reaching day 18. CO_2 emission remained almost constant until day 24 then decreased significantly until reaching day 26, after that CO_2 emission remained almost constant until day 40 at the end of the experiment. In the last day levels of CO_2 emission ranged from 803 ppm to 884 ppm, the BSS treatment recorded the lowest amount of CO_2 output, while the control treatment (T0) produced the highest CO_2 emission values, according to the data.

These findings are consistent with **(Yang *et al*., 2019; Amin 2020a),** they found that adding biochar made at pyrolysis temperatures (400 °C and 700 °C) resulted in a greater cumulative loss of CO_2-C compared to the unamended soil. In the current investigation, the CO_2 emissions from sandy soil incubated with fresh sewage sludge and compost town refuse were higher than its biochar's (Fig. 3). This is possible because fresh wastes contain a higher concentration of dissolved organic carbon than biochar, **(El-Naggar *et al*., 2015; Amin, 2020b).** Biochar was primarily composed of aromatic and heterocyclic carbon, which are resistant to biological degradation, and it was mostly present in a stable form, Crop residues contained biodegradable labile organic carbon components such as cellulose, hemicelluloses, and lignin. Additionally, crop leftovers have greater H/C and O/C atomic ratios than biochar made from them (**Wei *et al*., 2019)**. With incubation times lengthened, the cumulative CO_2-C emissions increased from their initial levels (Fig. 3). These findings obtained are consistent with this investigation **(Grutzmacher *et al*., 2018).** Due to the concentration of dissolved organic matter released from biochars at low pyrolysis temperatures between 300 and 500 °C, and their high unstable organic carbon content was greater than those at high pyrolysis temperatures between 600 and 700 °C. Where they had a high content of aromatic and heterocyclic carbon and low H/C and O/C ratios **(Wei *et al*., 2019; Wu *et al*., 2019).** The rate of carbon emission in this investigation increased slightly till day 16 then increased significantly till day 18, from day 18 till 24 almost constant after that decreased till the end of the experiment with time **(Fig. 3)**. Many studies found the carbon emission rate at the beginning of the incubation period was maximum and decreased with increasing incubation time **(Amin, 2020b; Senbayram et al., 2019)**. This is attributed to the high microbial activity at the beginning because of the existence of a large content of degradable labile carbon by microorganisms in the soil **(El-Naggar et al., 2015; El-Naggar et al., 2018)**.

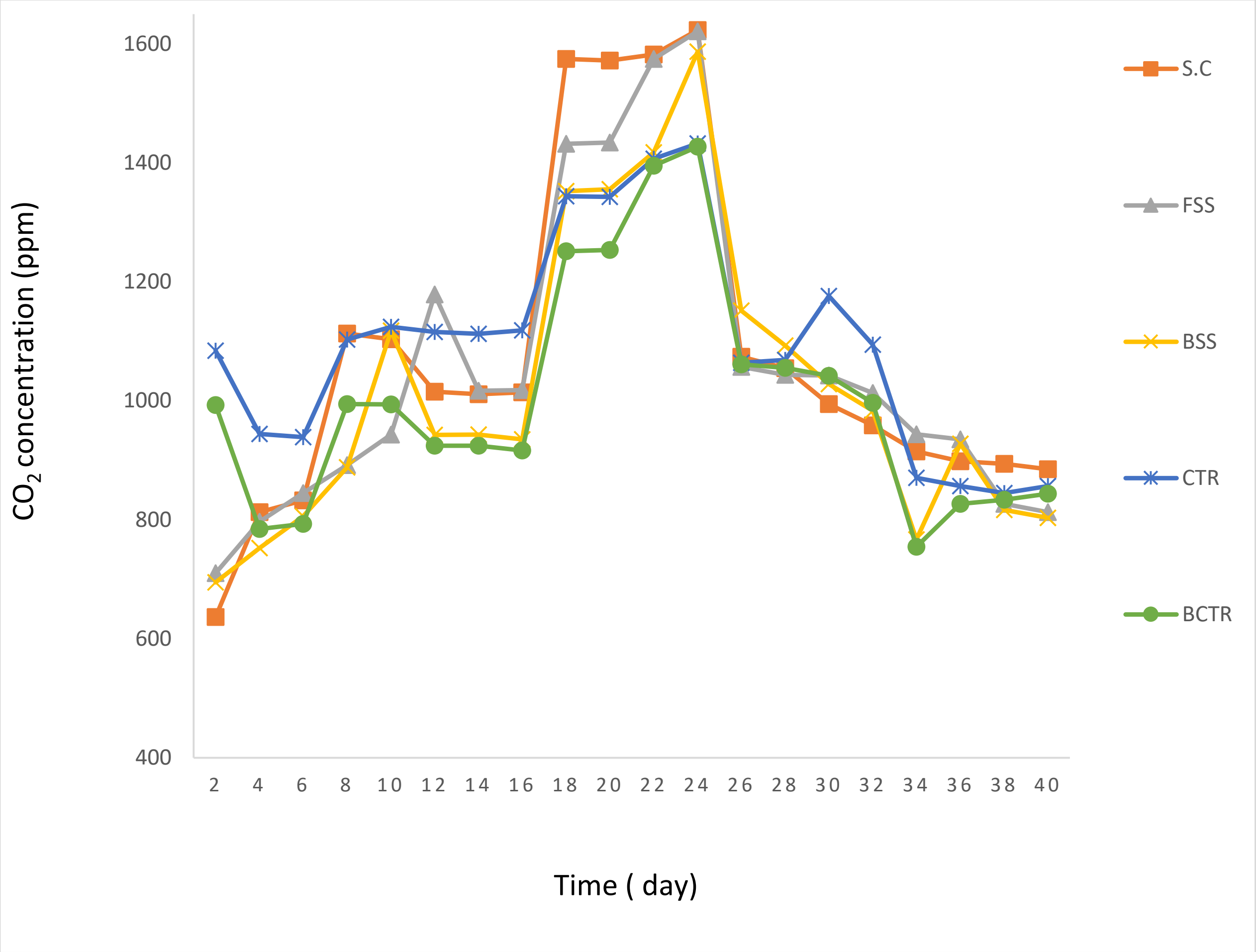

Fig.3.The concentration of CO_2 emission during the experiment of cultivation in sandy soil treated with organic residues and their biochar.

C= control, FSS= fresh sewage sludge, CTR= compost town refuse, BSS= biochar sewage sludge, BCTR= biochar compost town refuse.

4.3. Soil enzyme activity levels

Table. 4 shows the responses of dehydrogenase, amylase, nitrogenase and phosphatase activity to organic residues (FSS and CTR), and their biochar (BSS and BCTR). The studied soil enzymes activity were significantly promoted. Compared with control, dehydrogenase and amylase activity were increased by 280.1 and 41.4% under B.CTR treatment respectively**.** According to our study from table 4. The highest values of dehydrogenase activity 39.533 (µg formazan /g soil /h) and amylase activity 86.500 (µg glucose /g soil /h) were obtained with BCTR treatment meanwhile the highest values for nitrogenase activity 24.427 (µg NH_3 /g soil /h) and phosphatase 15.196 (µg Ca $(H_2PO_4)_2$ /g soil /h) were obtained with BSS and FSS treatments, respectively, these results agree with those obtained by (**Awasthi *et al*., 2020 and Ky Nguyen *et al*., 2022),** they reported that the dehydrogenase and xylanase activities were enhanced with a higher added biochar dosage (10%) during the composting of poultry manure. These results were attributed to the growth of microbes enzyme-producing thanks to biochar enhanced porosity, surface area, nutrients, and temperature. In addition, the phosphatase and beta-glucosidase activity at the mesophilic and thermophilic phases can be decreased by combining biochar, poultry manure, and straw **(Sun *et al*., 2016).**

The sludge sources carry various microorganism communities, which could also promote the microorganisms' activity in the soil by adding exogenous microbes into the soil (**Zoghlami *et al*., 2016**). In addition, FSS application could be related to the high deterioration capability of organic materials in SS, which made useable substrates for microbes (**Mackie *et al*., 2015**). On the other hand, in some studies application of BSS restricted enzyme activities in all cases during the period of stabilization from day 1 to day 60. In some cases, such as dehydrogenase activity on day 60, the enzyme activity was reduced more than 3 times compared to control. These results agree with the findings reported by (**Zhang *et al*., 2018; Hazrati *et al*., 2020; Tang *et al*., 2020**). After applying SDB (Biochar derived from Sewage Sludge), enzyme activity was thought to have decreased because biochar harms microorganisms, limiting their ability to produce enzymes in the soil (**Huang *et al*., 2017**). Organic and inorganic compounds can block SDB reaction sites and limit enzyme production by microorganisms (**Elzobair *et al*., 2016**).

Table 4. Determination of soil enzyme after cultivation experiment.

Treatment	Dehydrogenase Activity(μg formazan /g soil/h)	Amylase Activity(μg glucose/g soil/h)	Nitrogenase Activity (μg NH_3/g soil/h)	Phosphatase activity(μg $Ca(H_2PO_4)_2$ /g soil/h)
Control	10.400^{d}	61.167^{e}	9.509^{c}	13.413^{d}
FSS	13.633^{c}	69.533^{d}	18.091^{b}	15.496^{a}
BSS	22.500^{b}	73.400^{c}	24.427^{a}	14.032^{b}
CTR	23.000^{b}	78.167^{b}	18.313^{b}	13.935^{b}
BCTR	39.533^{a}	86.500^{a}	18.651^{b}	5.645^{c}
LSD 0.05	0.512	0.598	0.772	0.622

a, b, c,…: LSD ($p < 0.05$) groups, means followed by a common letter in the same column do not differ significantly.

4.4. Determination of organic carbon fractions in soil

Fig. 4 illustrates the effect of fresh residues and its biochar on organic carbon fractions in soil after cultivation. The levels of (DOC) dissolved organic carbon, (MOC) microbial organic carbon, and (OOC) oxidized organic carbon can be arranged in the descending order BSS >BCTR >FSS >CTR > Control, these results are in line with those obtained by (**Cheng *et al*. 2017; Chen *et al*. 2021**), they found that dissolved organic carbon (DOC) and microbial biomass carbon (MBC) are important components of labile OC, and biochar addition increases them in the short term. Meanwhile, adding biochar encourages the mineralization of DOC (including condensed aromatics and tannin) by altering the composition of microbial populations, particularly bacterial colonies (**Ling *et al*. 2022**).

In contrary, some studies found that field-aged biochar reduced DOC content, which is consistent with the results of **Zheng *et al*.** (**2016**). More function groups containing oxygen, such as phenolic and carbonyl C, are generated on the surface of biochar as it ages, increasing the DOC and other organic compounds' ability to bind to it (**Luo *et al*., 2017; Yu *et al*., 2020**). Biochar pores can be blocked by the organo-mineral layers that formed on the surface during biochar ageing (**Mia *et al*., 2017; Joseph *et al*., 2018**), so that microorganisms and their extracellular enzymes cannot access organic C (**Rasul *et al*., 2022**). In turn, the degradation of soil organic C is reduced, thus enhancing long-term soil C sequestration (**Zimmerman *et al*., 2011; Herath *et al*., 2015; Liu *et al*., 2018**)

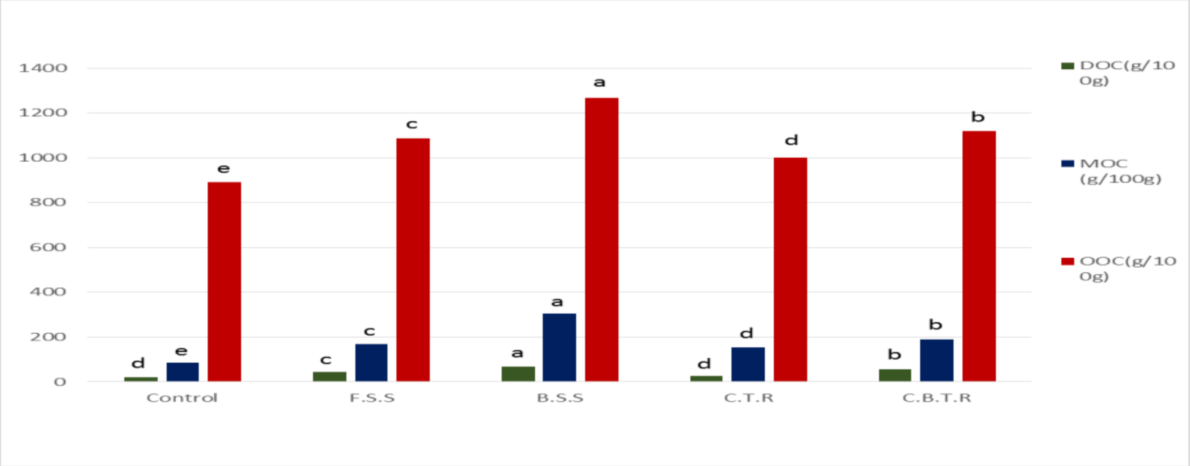

Fig. 4. Organic carbon fractions (MOC, DOC, OOC) as affected by organic residues and their biochar treatments.

DOC= dissolved organic carbon, MOC= microbial organic carbon, OOC= oxidized organic carbon.

4.5. Vegetative characteristics.

In this study, all treatments have a significant effect on all vegetative characteristics of lettuce in comparison to the control treatment. Biochar compost town refuse (BCTR) significantly increased plant fresh weight, fresh root weight, stem diameter with the corresponding values of 50.63%, 34.48% and 30.63%, compared by control treatment respectively. Also BSS significantly increased dry root weight, root diameter, stem diameter, root length and plant length with the corresponding values of 39.44%,74.78%,31.1%,10.5% and 9.62% compared by control treatment ,respectively, **(Table 5)**. Such phenomenon was agreed with the previous studies, for instance **Khan *et al.*** (**2020**), who showed that applying biochars made from poplar wood and sugar cane bagasse at rates of 3% and 7% enhanced the fresh and dry weight of lettuce, and **Zheng *et al.*** (**2017**) reported a 15% increase in lettuce yield using rice straw biochar. The improvement of soil physiochemical conditions, NPK nutrient availability, and soil enzyme activity may be responsible for these positive outcomes.

Table 5.Vegetative characteristics of lettuce plant.

Treatment	plant fresh weight (g)	leaf area (cm^2)	Dry root weight (g)	Fresh root weight(g)	Root diameter (mm)	stem diameter (mm)	root length (cm)	plant length (cm)
Control	43.260^{e}	35.284c	0.507^{b}	4.757^{c}	9.080^{d}	19.177^{b}	4.977^{c}	25.633^{b}
FSS	51.437^{d}	39.531b	0.327^{e}	2.613^{e}	9.257^{cd}	17.000^{b}	3.577^{d}	28.000^{a}
BSS	58.620^{c}	42.656a	0.707^{a}	5.140^{b}	15.870^{a}	25.14^{a}	5.500^{a}	28.100^{a}
CTR	60.463^{b}	36.386c	0.388^{d}	3.253^{d}	10.050^{c}	15.677^{b}	5.133^{bc}	27.177^{ab}
BCTR	65.163^{a}	39.330b	0.457^{c}	6.397^{a}	13.020^{b}	25.000^{a}	5.277^{b}	26.777^{ab}
LSD 0.05	0.028	2.030	0.014	0.064	0.909	4.939	0.188	1.529

a, b, c,…: LSD ($p < 0.05$) groups, means followed by a common letter in the same column do not differ significantly.

These results are in line with **(Jabborova *et al.*, 2021)** they also found that The application of biochar is frequently used to increase soil fertility and enhance plant development. Both biochar 3% and biochar 2% treatment significantly improved lettuce growth such as leaf number, leaf length, and leaf width compared to the control, in the treatment of biochar 1%, no significant differences were observed. However, root morphological characteristics were enhanced with the treatment of biochar 3% such as the root surface area, the projected area, total root length, and the root volume compared with control.

4.6. Photosynthetic pigments, carbohydrates and Vitamin C.

Table 6 show that all treatments have a significant effect in photosynthetic pigments, carbohydrates and Vitamin C of lettuce. Biochar had a significant effect on chlorophyll A, chlorophyll B, carotenoids, and vitamin C except carbohydrates were recorded with compost town refuse. The highest values of chlorophyll A (29.247 mg g^{-1}) and Chlorophyll B (50.537 mg g^{-1}) were obtained with BCTR treatment, meanwhile, the highest values of carotenoids (9.703 mg/g^{-1}) and vitamin C (7.267 mg/100gm) were observed with BSS treatment except carbohydrates highest value (0.232 mg/100g) were recorded with CTR treatment. These results are accompanied by several studies that show using biochar only or in combination with other modifications dramatically boosted the concentration of chlorophyll in plant leaves. As the report of **Zeeshan *et al*. (2020**), which suggested that tomato leaves in Cd-contaminated soils had higher levels of chlorophyll a, b, total chlorophyll, and carotene when treated with biochar of wood (Acacia arabica). Besides, **Rahi *et al*. (2022)** observed that maize grown in soil treated with biochar compost had significantly higher concentrations of nutrients and chlorophyll. Chlorophyll concentrations may have increased mostly due to increased nutritional availability or a decrease in pollutants such as heavy metals.

Table 6. Photosynthetic pigments (chlorophyll A, B, Carotenoids), Carbohydrates, and Vitamin C as affected by organic residues and its biochar.

Treatment	Chlorophyll A (mg/g)	Chlorophyll B (mg/g)	Carotenoids (mg/ g)	Carbohydrates (mg/100g)	vitamin C (mg/100g)
Control	28.063^{ab}	42.553^{b}	5.731^{b}	0.071^{d}	4.033^{e}
FSS	27.655^{b}	15.257^{e}	5.183^{b}	0.189^{c}	6.533^{c}
BSS	25.043^{c}	36.940^{c}	9.703^{a}	0.219^{b}	7.267^{a}
CTR	28.183^{ab}	31.990^{d}	9.085^{a}	0.232^{a}	5.001^{d}
BCTR	29.247^{a}	50.537^{a}	5.771^{b}	0.187^{c}	6.767^{b}
LSD 0.05	1.128	1.887	1.204	0.008	0.081

a, b, c,…: LSD ($p < 0.05$) groups, means followed by a common letter in the same column do not differ significantly.

CONCLUSION

From previous results, it can be concluded that biochar of sewage sludge (BSS) could enhance the properties of sandy soil and decreasing CO_2 emission, so reducing the effect of global warming.

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The authors declare no conflicts of interest relevant to this article.

AUTHORS CONTRIBUTION

El-Metwally Selim; Mokhtar Beheary; Ramy Khalifa and Dina Zidan developed the concept of the manuscript. All authors checked and confirmed the final revised manuscript.

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الملخص العربى

إحتجاز الكربون في تربة رملية محسنة إما بالمخلفات العضوية أو الفحم الحيوي وعلاقته بإنتاجية الخس.

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إحدى الطرق المحتملة لمسك الكربون الموجود في الغلاف الجوي والمساعدة في التكيف مع تغير المناخ والتخفيف من آثاره هي التحليل الحراري للكتلة الحيوية وتحويلها إلى الفحم الحيوي، والذي يتم إضافته بعد ذلك إلى التربة حيث انه من الضروري إجراء أبحاث مكثفة حول انبعاث ثاني أكسيد الكربون من التربة بسبب نقص احتجاز الكربون في التربة. ونتيجة لذلك، تم إجراء تجربة أصص باستخدام التربة الرملية وتم تنفيذ خمس معاملات (T_0): الكنترول ، (T_1) الكمبوست المنتج من مخلفات المدن ، (T_2) حمأة الصرف الصحي ، (T3) الفحم الحيوي المشتق من كمبوست مخلفات المدن، (T_4): الفحم الحيوي المنتج من حمأة الصرف الصحي وذلك لقياس انبعاث ثاني أكسيد الكربون وتأثيره على نمو الخس حيث انخفضت انبعاثات ثاني أكسيد الكربون المتراكمة من التربة في المعاملة المضاف لها الفحم الحيوي، مع تسجيل أدنى قيمة (803 جزء في المليون) تحت المعاملة المضاف لها الفحم الحيوي المنتج من حمأة الصرف الصحي في نهاية التجربة وتم تحقيق أعلى قيم للصفات الخضرية لنباتات الخس، الكربون العضوي المذاب، الكربون العضوي الميكروبي والكربون العضوي المؤكسد للتربة في المعاملة المضاف لها الفحم الحيوي المنتج من حمأة الصرف الصحي ، بينما ظهرت أقل القيم في معاملة الكنترول. بالإضافة إلى أن البكتيريا المسببة للأمراض اختفت تماما من المخلفات بعد حرقها على درجة حرارة 500 درجة مئوية وتحولها إلى فحم حيوي. ومن ثم، يعد استخدام الفحم الحيوي تقنية مهمة لتعزيز تخزين الكربون، وتحسين جودة التربة في المناطق الجافة.