Straw Biochar: The Eco-Environment Protector

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ABSTRACT: In this study, a series of experiments was used to improve methods of removing river pollutants using biochar. The experimental results show the amount of CO_2 released from the soil after straw biochar is applied to soil is lower than that of the control and straw directly being applied. This indicates that straw biochar is not easily decomposed into CO_2 by soil microorganisms and thus has the potential for reducing farmland CO_2 emissions. Returning straw biochar to the soil also significantly increases soil water content of about 25-48% compared to the control so it can save agricultural irrigation water. The biochar bricks made of straw biochar and silt have significantly higher hygroscopicity and permeability than silt-only bricks so it can be used for the construction of sponge cities to alleviate urban flooding during rainstorms. Finally, biochar and silt are used to prepare a rigid biochar strip which can be suspended at any position in the water. The biochar strip is effective at removing pollutants. In short, straw biochar has many eco-environmental functions that can aid in environmental conservation of farmland.

KEYWORDS: Biochar brick, biochar strip, soil respiration; soil water content, hygroscopicity and permeability.

INTRODUCTION

China produces 1.4 billion tons of agricultural and forestry straw every year.[1] A large amount of straw is not used effectively and is burned. Straw incineration not only causes haze, but also produces greenhouse gases like CO_2 which seriously damage the environment and endanger people's health.[2] Additionally, untreated straw pollutes the water environment and releases CO_2 as it decomposes.

Previous studies show that straw biochar amendments to soil can significantly improve soil texture and promote crop growth. The Chinese government advocates for straw application to agricultural land.[3] However, farmers are not active in returning straw directly to farmlands because straw is incompatible with the soil. Too many straw surface applications increase the difficulty of crop planting for the next season.[4] The more effective, deeper applications are difficult because they require more manpower and money.

In the past 20 years, the popularity of biochar has increased. Straw biochar is a fine-grained, carbon-containing, porous material obtained by pyrolysis of straw in the absence of oxygen at high temperatures.[5] Its make-up is similar to soil and has very stable properties. Biochar is also rich in ash elements, like potassium, calcium and magnesium, that are nutrients for plants. It has been reported that the application of biochar can increase soil fertility and crop yields by 30-50%.[5] Additionally, due to its porous nature, biochar has a strong adsorption capacity for pollutants and can be usd for water pollution control. Therefore, producing biochar is an effective way to utilize straw.

Straw biochar is a highly stable organic matter. It is porous and very light. When used as a water pollutant treatment, it adsorbs pollutants. However, the biochar floats on the surface and/or is washed away making it difficult to effectively recover the pollutant-containing biochar.

This project aims to answer the following questions through experiments:

(1) Can straw biochar be retained in soil long-term?
(2) Does soil release less CO2 after biochar is applied to the field?
(3) Does straw biochar application increase soil moisture, thus decreasing agricultural irrigation water use?
(4) Do the bricks made from straw biochar and silt have better hygroscopicity and permeability than silt bricks?
(5) How can one enhance the ability of straw biochar to remove pollutants in flowing water?

RESULTS AND DISCUSSION

Effects of Straw Biochar Returning to Field on Soil CO2 Release: Figure 1 shows that the amount of biochar applied to the soil is directly proportional to the content of organic carbon in the soil. Biochar is rich in organic carbon so the soil's

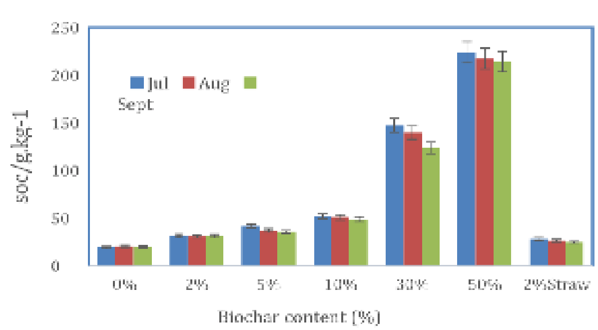

Figure 1. Soil organic carbon content with different proportions of biochar.

carbon content in is rapidly supplemented.Soil absorbs oxygen and release CO_2 through soil respiration.[6] Microorganisms in the soil absorb oxygen and decompose the soil's organic compounds into CO_2. Therefore, the higher the soil respiration, the more released CO_2. If organic compounds returned to the soil cannot be rapidly decomposed by the microorganisms, the compounds can remain in the soil for an extended period. Using biochar maintains soil nutrients and decreases CO_2 content, helping combat global warming.

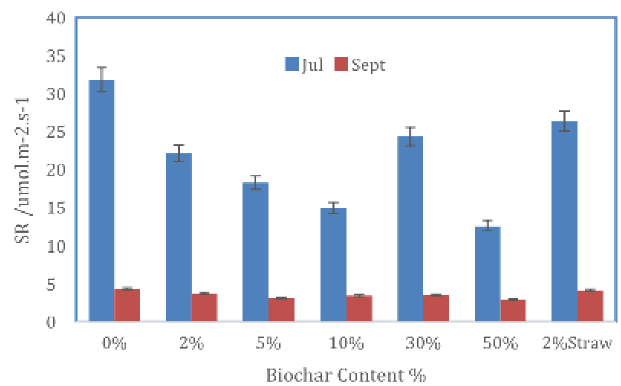

Figure 2. Respiration intensity of the soil with different proportions of biochar.

Figure 2 shows that the soil respiration intensity (the amount of CO_2 released per unit area of soil in a unit time) decreases with the increase of straw biochar application (except 30% biochar). Both straw direct application and the control group had higher respiration intensities than biochar. These results indicate that, compared to the organic carbon in soil and straw, the organic carbon in biochar is harder for soil microorganism to decompose. Therefore, biochar can be retained in soil for a longer time which reduces CO_2 released by farmland (soil).

The above results show that biochar straw release less CO_2 into the atmosphere which can alleviate global warming caused by excessive greenhouse gas emissions. Moreover, the biochar is compatible with soil so application to fields can significantly promote plant growth. Plants fix CO_2 from the atmosphere which further reduces the atmospheric CO_2 concentration

Soil Moisture after Straw Biochar Application to Soil: Soil water content was measured in June, July, August and September 2016. The results show the soil water content with biochar-containing soils was higher than that of the blank control each month as shown in Figure 3. Soil with 30% and 50% biochar was significantly higher than the blank control and the straw application control. The water content of 50% biochar soil was consistently the highest and reached 35.49% in July, a 48% increase compared to the blank control (24.0%). The results show that water absorption and retention were greatly improved after straw biochar application. There was a direct relationship between amount of biochar applied and the water absorption and retention. Therefore, applying straw biochar to soil can decrease agricultural irrigation.

Hygroscopicity and Permeability of Straw Biochar Bricks: The hygroscopicity and permeability of straw biochar brick were preliminarily analyzed. The overall water absorption capacity of bricks containing 5% biochar was nearly 60% higher than that of bricks made of pure silt. Furthermore, the biochar bricks' water absorption in the first minute was twice as high as that of silt bricks, shown in Figure 4 and Table 1.

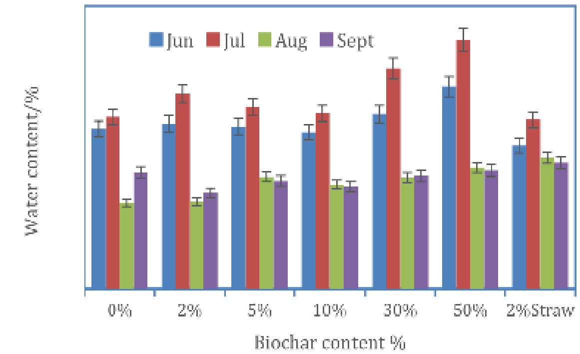

Figure 3. Water content of the soils with different proportions of biochar.

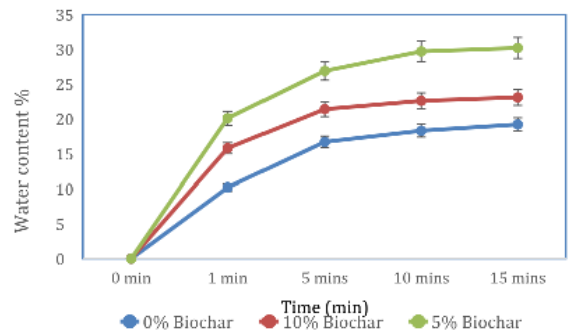

Figure 4. Water absorption capacity of bricks with different proportions of

Table 1. Water absorption and permeability of bricks with different proportions of biochar.

Biochar proportions	0%	5%	10%
Water absorption capacity in 1 min (g/g)	0.101	0.201	0.169
Final water absorption capacity (g/g)	0.189	0.301	0.224

The results show the hygroscopicity and permeability of biochar bricks is better than silt bricks so it can be used in road and sidewalk pavement to alleviate urban flooding caused by rainstorms.

Strangely, the 5% straw biochar bricks have a better hygroscopicity and permeability than the 10% straw biochar bricks. It may be because too much biochar (the mass ratio of 10% is almost equal to the volume ratio of 50%) cannot form a stable, porous structure with clay during hydrothermal reactions. Further research must be done to test this hypothesis.

The results indicate the biochar strips suspended in water can effectively remove eutrophic substances in flowing water. Moreover, unlike straw biochar powder, once the efficiency of the biochar strip fails, the strips can be easily recovered and can be regenerated for reuse.

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Purification Effect of Biochar Strips on Pollutants in Flowing Water: As shown in Figure 5a, biochar and silt were combined into biochar balls containing 5-10% mass ratio of biochar. These balls were made with a specified strength through a hydrothermal reaction.

To ensure the biochar ball can be suspended in water without floating away, a nylon strip mesh bag was constructed as shown in Figure 5b. The biochar balls are placed inside to make biochar strips that can be suspended in different positions in the water to improve contact efficiency between biochar balls and the waters pollutants.

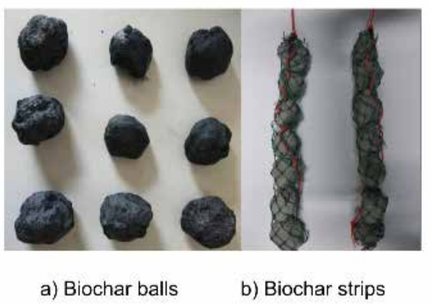

Figure 5. The Pictures of the biochar balls and biochar strips.

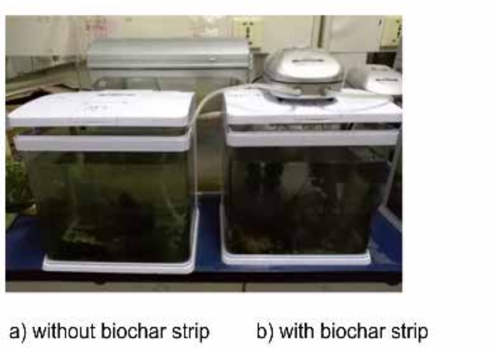

Figure 6. Experimental device for verifying purification efficiency of biochar strips.

The biochar strips were placed in simulated flowing eutrophic water system as seen in Figure 6. During the experiment, ammoniacal nitrogen (NH_4^+-N), total nitrogen (TN), and total organic carbon (TOC) concentrations in the water were measured and compared with those in the control water without biochar strips. The results in Figure 7 show that after one day with the biochar strip the NH_4^+-N, TN, and TOC concentrations were reduced by about 60%, 40%, and 15% respectively.

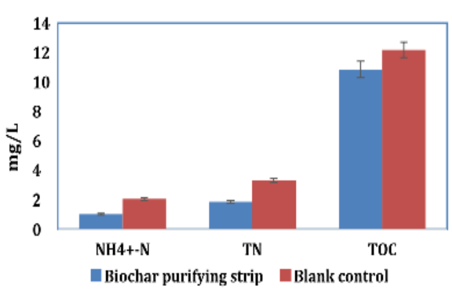

Figure 7. Removal efficiency of biochar strips of NH_4^+-N, TN and TOC in flowing water of fish jar.

CONCLUSION

Through this project, several conclusions were made. Applying straw biochar to soil can reduce CO_2 emissions from farmland and increase soil water content. This helps alleviate global warming and lessens the water required for agricultural irrigation. The water absorption and permeability of straw biochar bricks is better than those of silt bricks while maintaining the same strength so they can be used for construction of sponge cities. Straw biochar balls within nylon strip mesh bags can be suspended in flowing water, enhancing pollutant removal and ease of recovery. The biochar strip can also be regenerated after use.

METHODS

Preparation of Biochar: Wheat straw was collected in early summer to be sun dried and smashed. The project commissioned the Shanghai Jinghua Company to make the straw biochar using a small pyrolysis device at 500°C, shown in Figure 8.

Figure 8. A small pyrolysis device.

Effects of Biochar Application on Soil Respiration and Soil Water Content: In this experiment, five treatments were set up with differing amounts of carbonized straw accounting for 2%, 5%, 10%, 30%, and 50% of the soil weight respectively. The biochar was completely mixed with soil and placed in an uncovered 50cm x 40cm x 40cm plastic box. A group of blank soil controls was set up, recorded as 0%. A control group was set up with 2% straw applied. Triplicates were set for each treatment. The soil was collected from Chongming Island, Shanghai. The appearance of the mixed soil samples is shown in Figure 9.

Figure 9. The Picture of Biochar Returning Experiment.

In June 2016, eight soybean seedlings were planted in each box. During plant growth, the plants were watered equally. I observed the plants, recorded their growth and tested the soil's organic carbon content, soil respiration, and soil water content each month.

Organic carbon was measured by a TOC analyzer and soil respiration was measured by a LICOR-8100A portable soil respirator. Soil water content was determined by wet weight of soil minus weight after drying at 100°C for one hour. Figure 10 shows the soil respiration test instrument and breathing ring

Figure 10. Soil respiration test instrument and test process: a) left is the soil respiration test instrument, b) right is breathing ring

Verification of Hygroscopicity and Permeability of Biochar Bricks: Bricks containing silt plus 5% and 10% straw biochar respectively were made via a hydrothermal reaction at 180 °C, shown in Figure 10. The hygroscopicity of the biochar brick was measured by weighing at different times after soaking bricks in water. Water absorption is directly related to hygroscopicity. The water absorption in one minute represents the brick's water permeability.

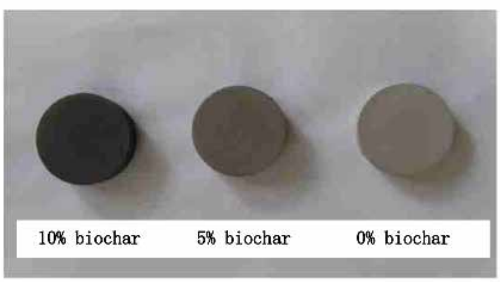

Figure 11. Picture of Biochar Bricks.

Preparation of Suspendible Biochar Strip and Its Purification Effect on Pollutants in Flowing Water: When the formed biochar ball is put into the water it sinks to the bottom and the contact efficiency with pollutants is poor. So, a strip mesh bag was made to hold the biochar ball suspended in the water. The eutrophic water from a fishpond is placed in the fish jar and circulated by a pump to make the water flow. After running for two days, the TN and TOC in the water were measured and compared with the water without biochar strips. The content of ammoniacal nitrogen in water was determined by Nessler reagent spectrophotometry, [7] the total nitrogen content was determined by potassium persulfate digestion, [8] and the total organic carbon content was determined by TOC analyzer.

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