IMPACT OF BIOCHAR ON THE WATER HOLDING CAPACITY AND MOISTURE OF BASALT AND GREY SOIL

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(Received: July 11, 2017; Revised: July 27, 2017; Accepted: August 08, 2017)

ABSTRACT

Climate change has been threatening the sustainable development of the agricultural sector around the globe. It is a main reason of prolonged drought which gives negative effects on productivity and quality of agricultural products. For solving these emerging challenges, there have been many solutions on improving soil health in order to increase the tolerance of soil and plant to adverse weather conditions. Recent researches on biochar show that this is a good soil amendment because of its water holding capacity, nutrient retention, increased porosity and enhanced soil microbial activity. This study investigated the effect of biochar from rice husk and coffee husk produced by gasifier on the ability to retain water and moisture in basalt and grey soil, which collected from farming areas in Vietnam. The result illustrates that water holding capacity and soil moisture depend significantly on each type of biochar and applied dosage as well as characteristic of soil. Accordingly, when adding 1% biochar by mass to the grey soil (initial moisture content of 13%) helped increase the efficiency of water holding capacity by 26-33% corresponding to coffee husk or rice husk biochar. It is different from basalt soil (initial moisture content of 27%) when adding 1% rice husk biochar will impact on water retention efficiency was 7%, equivalent to 3% biochar from coffee husk. Therefore, biochar can be introduced as a soil conditioner effectively in dry soil or enhance the water retention in fertile soil that eventually contributed to the sustainable agriculture.

Keywords: Biochar; rice husk; water holding capacity; basalt soil; grey soil.

1. Introduction

Agriculture is the vulnerable field due to its development based dramatically on the supply of fresh water. With the rise in global population and unexpected disasters caused by climate change, agriculture today is at a crossroads of self-revolution to overcome these challenges (IAASTD, 2009; Intergovernmental Technical Panel on Soils, 2015). One of the basic steps to protect soil health can begin at researching new methods to increase the water holding capacity and keep soil moisture as long as possible. Drip drop irrigation could be a perfect candidate for this situation (G. Megersaet et al, 2015). Nevertheless, if there were a sudden severe drought along with a shortage of water supply, it would lead to a sharp decline in productivity as well as damage soil biota seriously. To prepare for this issue, many generations of soil humidifiers or soil conditioners have been developed at the properties of absorbing water and retaining moisture for long time once applied in soil (H. Agaba et al, 2010). Amongst several brightest options available for enhancing soil health, biochar is becoming a more preferred option because of its novel characteristics which carefully examined in many studies (J. Lehman et al, 2009; F. Sun et al, 2014). In general, biochar is a carbon-rich product obtained by heating biomass, such as wood, manure or leaves in a sealed container with little or absence of oxygen rather than burning it (J. Lehmann et al, 2009; E. Wayne, 2012). Biochar is recommended as an effective soil amendment because it affects positively on three aspects of soil health from physical, chemical and biological health (B. P. Singh et al, 2011). For instance, adding 1%-5% biochar by mass in loamy soil can increase water holding capacity from 4-10% respectively (O.Y. Yu et al, 2013). However, water holding capacity of biochar has few researches because it depends on each type of feedstock and pyrolysis conditions which take responsible for the structure and surface area of biochar products (J. D. Streubel et al, 2011). In turn, these factors have directly effects to the water absorption of biochar and certainly help soil retain water better if biochar had been introduced into soil before (J.Ulyett et al, 2014; F. Sun et al, 2014). The interaction between soil and biochar becomes complicated in terms of considering to the soil texture that causes the water holding capacity and moisture may vary between each soil type with the same type of biochar applied (O. Y. Yu et al, 2013; K. Karhu et al, 2011). This study provides the data about water holding capacity of basalt and grey soil, that mixed with different rates of biochar, which are the two main soil types accounts for Vietnam food security (E. Petersen, 2017).

2. Materials and Methods

2.1. Sample preparation

Biochar from rice husk and coffee husk is produced by top-lit updraft gasifier at 550^{o}C thanks to Dr. Paul Olivier design (P. Olivier, 2010). Basalt soil has an initial moisture content of 26.93% and bulk density 0.83 g/cm^3 collected from a coffee garden in Dak Nong province. Grey soil has an initial moisture content of 13.18% and bulk density 1.53 g/cm^3 collected from an arid land in Ho Chi Minh city.

Figure 1. Biochar from rice husk (left) and coffee husk (right)

2.2. Methodology

Experiment has conducted with different mixing ratios between biochar and soil varied from 1%, 3%, and 9% by mass, which are equivalent to 21.6, 64.8, 194.4 metric ton/ha (O. Y. Yu et al, 2013), to investigate water holding capacity and soil moisture after 28 days at room temperature. B-0 and G-0 is the treatment without applying biochar. Each treatment replicates three times with details shown in Table 1. Treatment effects were analyzed by analysis of variance (ANOVA) with completely randomized design (CRD) using software package SAS 9.1. Mean separation was done using the t-test with least significant difference (LSD) arrangement. Treatments have conducted with the same preparation steps which described followed (H. Peron et al, 2007):

- Use 2 mm sieve to separate soil sample. Mix soil and biochar thoroughly then put the sample into a coffee filter and press on the surface at 1 kPa by a heavy thing.

- Add water slowly until observed the first drops falling to the bottom.

- Let soil sample saturated for 24 hours at room temperature.

- Collect a small sample from each treatment for investigating its water holding capacity and moisture content for each week.

The water holding capacity (WHC) by mass was calculated followed ASTM D2216-10 (ASTM, 2010):

WHC (%) = (($mass_{wet}$ – $mass_{dry}$) / $mass_{dry}$) x 100

The moisture content (MC) by mass was calculated followed ASTM D2974-87 (ASTM, 1993):

MC (%) = (($mass_{wet}$ – $mass_{dry}$) / $mass_{wet}$) x 100

$mass_{wet}$: sample weight before drying (g)

$mass_{dry}$: sample weight after drying (g)

Figure 2. Coffee filters were used for measuring the water holding content and soil moisture

Table 1

Experimental design

Types of soil	Types of biochar	Treatment	Mixing ratio (soil + biochar)	% biochar by mass
Basalt soil		B-0	1000g + 0g biochar	0
	Rice husk biochar (RHB)	BR-1	1000g + 10g biochar	1
		BR-3	1000g + 30g biochar	3
		BR-9	1000g + 90g biochar	9
	Coffee husk biochar (CHB)	BC-1	1000g + 10g biochar	1
		BC-3	1000g + 30g biochar	3
		BC-9	1000g + 90g biochar	9
Grey soil		G-0	1000g + 0g biochar	0
	Rice husk biochar (RHB)	GR-1	1000g + 10g biochar	1
		GR-3	1000g + 30g biochar	3
		GR-9	1000g + 90g biochar	9
	Coffee husk biochar (CHB)	GC-1	1000g + 10g biochar	1
		GC-3	1000g + 30g biochar	3
		GC-9	1000g + 90g biochar	9

3. Results and Discussion

3.1. Water holding capacity and moisture content of biochar from rice husk and coffee husk

From the data given, rice husk biochar and coffee husk biochar show triple times for holding water compare to its initial weight. Surprisingly, rice husk biochar does not keep moisture content better than coffee husk biochar after 28 days. It could be explained due to the bulk density of rice husk is 68 kg/m^3 in comparison to 92 kg/m^3 of coffee husk biochar. This leads water evaporation easier escape from the matrix of saturated rice husk biochar while coffee husk biochar maintains a stable moisture for nearly one month.

Table 2

Water holding capacity and moisture changes after 28 days in saturated RHB and CHB

Type	WHC (%)	Moisture content (%)					
		Day 1	Day 7	Day 14	Day 21	Day 28	Δ_{D1-D28}
RHB	302.89a ± 39.81	74.98a ± 2.48	73.56a ± 2.80	71.81b ± 2.36	70.86b ± 3.58	69.84b ± 3.99	5.14
CHB	322.87a ± 47.84	76.10a ± 2.83	76.41a ± 2.90	77.01a ± 2.46	77.18a ± 2.00	76.91a ± 2.69	-0.81
***p*-value**	0.4679	0.5030	0.1334	0.0060	0.0067	0.0084	
CV (%)	13.96	3.50	3.80	3.24	4.04	4.75	

*Different letters within each column indicate statistical significance at p-value < 0.05

3.2. Impact of biochar on the water holding capacity and moisture content of basalt soil

Basalt soil has a natural water holding capacity about 70% (Table 3) when saturated due to its soil texture higher in clay and silt and lower in sand (USDA and NRCS, 2014). Increasing mixture rates of biochar helps basalt soil absorb more water to maximum 79% for rice husk biochar and 100% for coffee husk biochar, respectively. This result extend the information on water holding capacity of biochar amendment in Ferric Acrisols soil at different rates from 5, 10 and 15 metric ton/ha, correspondingly 20%, 33% and 40% (E. Dugan et al, 2010). After 28 days left at room temperature, there is slight difference in moisture content between control and BR-3, BR-9, BC-3 and BC-9 treatments with data fluctuate around 2.03% to 2.63%.

Table 3

Water holding capacity and moisture changes after 28 days in basalt soil with different mixture rates of biochar varied from 0% to 9%.

Treatment	WHC (%)	Moisture content (%)					
		Day 1	Day 7	Day 14	Day 21	Day 28	Δ_{D1-D28}
B-0 (control)	70.60e ± 2.98	41.37e ± 1.01	40.19d ± 0.23	38.56d ± 0.71	39.26d ± 1.02	38.74e ± 0.94	2.63
BR-1	75.57cd ± 0.84	43.04cd ± 0.27	43.32b ± 0.41	41.71c ± 1.01	41.45cd ± 0.52	42.39c ± 1.10	0.65
BR-3	78.54c ± 3.15	43.98c ± 1.00	42.56bc ± 1.10	42.02c ± 0.92	42.47c ± 1.58	41.68cd ± 0.70	2.30

Treatment	WHC (%)	Moisture content (%)					
		Day 1	Day 7	Day 14	Day 21	Day 28	Δ_{D1-D28}
BR-9	79.83c ± 1.99	44.39c ± 0.62	43.63b ± 0.10	43.34b ± 0.43	44.12bc ± 0.60	42.11cd ± 0.85	2.28
BC-1	73.76de ± 2.90	42.44de ± 0.97	41.26cd ± 0.49	41.34c ± 0.45	41.36cd ± 1.09	40.76d ± 0.34	1.68
BC-3	86.14b ± 1.91	46.27b ± 0.55	43.79b ± 1.27	44.43b ± 0.87	46.12ab ± 3.84	44.24b ± 0.33	2.03
BC-9	100.57a ± 3.38	50.13a ± 0.83	49.43a ± 0.95	47.65a ± 0.43	47.98a ± 0.30	48.09a ± 0.84	2.04
***p*-value**	<0.0001	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	
CV (%)	3.20	1.78	1.78	1.70	3.92	1.82	

*Different letters within each column indicate statistical significance at p-value < 0.05

3.3. Impact of biochar on the water holding capacity and moisture of grey soil

Grey soil collected from arid area in this case has a natural water holding capacity approximately 20% when saturated (Table 3). Increasing mixture rates of biochar helps grey soil absorb doubling amount of water for 56% for rice husk biochar and 47% for coffee husk biochar respectively. This result share similar patterns to Streubel et al (2011) when adding biochar from 10 to 30 metric ton/ha to four loamy soils that could increases water holding capacity clearly (J.D Streubel et al, 2011). After 28 days left at room temperature, there is another pattern of moisture changes between treatments with rice husk biochar give 3.0-3.3% moisture loss higher than 1.6-2.0% from treatment with coffee husk. Since normal soil moisture should be kept around 25% will help microbial activities and plant growth healthily, grey soil requires at 9% biochar by mass or equivalent to 194.4 metric ton/ha to maintain its moisture for long periods (O.Y. Yu, 2013).

Table 4

Water holding capacity and moisture changes after 28 days in grey soil with different mixture rates of biochar varied from 0% to 9%.

Treatment	WHC (%)	Moisture content (%)					
		Day 1	Day 7	Day 14	Day 21	Day 28	Δ_{D1-D28}
G-0 (control)	19.52d ± 7.85	13.26e ± 2.41	14.75e ± 0.77	14.46d ± 0.31	13.66e ± 0.59	11.96d ± 0.44	1.30
GR-1	26.05cd ± 0.43	20.66cd ± 0.27	20.01d ± 0.33	19.15c ± 0.56	18.69c ± 0.36	17.67cb ± 0.82	2.99
GR-3	29.14c ± 2.12	22.55cd ± 1.27	21.94c ± 0.42	21.32b ± 0.57	20.89b ± 0.40	19.48b ± 1.54	3.07
GR-9	56.47a ± 8.07	35.98a ± 3.22	31.16b ± 0.46	32.77a ± 2.23	32.57a ± 1.48	32.61a ± 3.22	3.37

Treatment	WHC (%)	Moisture content (%)					
		Day 1	Day 7	Day 14	Day 21	Day 28	Δ_{D1-D28}
GC-1	24.67cd ± 0.22	19.79d ± 0.14	19.38d ± 0.40	18.41c ± 0.90	16.84d ± 0.17	15.21cd ± 0.35	1.68
GC-3	30.87c ± 1.94	23.58c ± 1.12	22.38c ± 0.95	21.69b ± 1.04	21.65b ± 1.44	21.14b ± 0.87	2.03
GC-9	46.90b ± 2.70	31.91b ± 1.24	33.19a ± 0.74	32.18a ± 1.38	30.91a ± 1.53	29.43a ± 3.68	2.04
***p*-value**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	
CV (%)	13.52	7.18	2.66	5.08	4.60	9.48	

*Different letters within each column indicate statistical significance at p-value < 0.05

3.4. Comparison the impact of biochar on water holding capacity of basalt and grey soil

Basalt soil and grey soil are completely different from their characteristics as well as percentages of sand, clay and silt in soil texture analysis. Represent for the fertile soil in this study, basalt soil has natural moisture content about 27% shows a little increase in performance for each percent adding biochar. In contrast to, grey soil is considered as an arid soil sample in this case, has its natural moisture around 13% shows a dramatic impact for each percent adding biochar which interestingly higher two to three fold of water holding capacity efficiency in compared with basalt soil. Furthermore, rice husk biochar and coffee husk biochar have similar trends on each soil types. However, rice husk biochar shows better performance on grey soil whereas coffee husk biochar gives higher results on basalt soil.

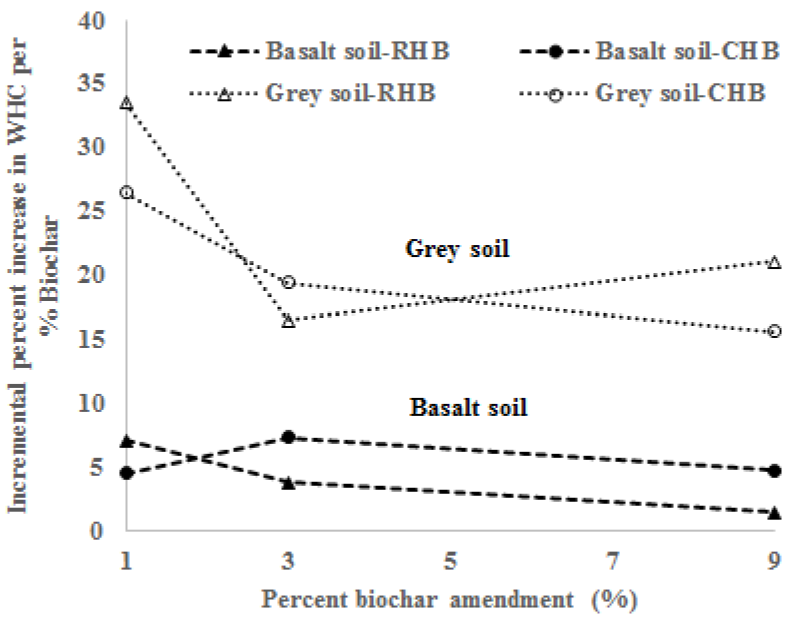

Figure 3. Incremental increase in percent water holding capacity normalized to percent biochar amendment corresponding to basalt and grey soil.

4. Conclusion

Both of two types of biochar also have positive impacts on the water holding capacity and moisture content regardless to basalt or grey soil with different levels. This result indicates that farmers can use biochar as a soil conditioner not only to improve soil health followed traditional practices but also to increase water absorption and water retaining in soil at minimum significant level 1% by mass. There are further experiments need to be conducted to describe the effect of feedstock source of biochar to the water holding capacity of other main soil types such as arid soil, sandy soil or fertile soil in Vietnam. With each piece of data collected, we could build a clear picture about biochar potential and confidently introduce it widespread that brings benefits to farmers and of course protects soil health for food security assurance■

Acknowledgement

This study is a part of the research coded VS01/16-17, which was financially supported by Biotechnology center of Ho Chi Minh City. We would like to show our gratefulness to all the colleagues as well as internship students from Division of Microbial Biotechnology who provided insight and expertise that greatly assisted the research.

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