Application of biochar from coconut shells to different soils in Thua Thien Hue province, Vietnam

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ABSTRACT

We used biochar produced from coconut shells at 500°C. The objective of the study was to determine the influence of the biochar application to different soils on crop growth and nutrient balances under greenhouse conditions in Thua Thien Hue Province, Vietnam. Pot experiments with Komatsuna (*Brassica rapa* var. *perviridis*) were conducted in three different soils: sandy soil with high organic matter content, clay soil, and sandy soil with low organic matter content, collected in Quang Dien district. Chemical fertilizer was applied to the soil at rates of 12 g N/m^2, 10 g P_2O_5/m^2, and 12 g K_2O/m^2. Half of the pots were treated with the biochar at 1,500 g/m^2. Experimental results showed that biochar application changed soil quality, resulted in improving the growth of Komatsuna. We will report differences of nitrogen and phosphorus balances (crop uptake, leaching, retention, etc.) in experimental pots. Our results indicated that the use of biochar from agricultural wastes would be beneficial for farmers, the environment under soil and climatic conditions in Thua Thien Hue province.

KEYWORDS

Biochar, coconut shells, nutrient, nitrogen, phosphorus

INTRODUCTION

We evaluate soil application effects of biochar produced from coconut shells at 500°C. Biochar is preferably produced from local agricultural wastes from viewpoints of treatment and material costs. Coconut shells can be raw materials in rural areas in developing countries because of sufficient and constant supply.

Biochar is defined as a solid material obtained from carbonization of biomass. Benefits of biochar application to soil are: increased soil carbon content, improved physical properties (increased water retention and drainage), decreased nutrient leaching, improved fertility (nutrients release) and reduced emissions of green house gases (Clough and Condron, 2010; Nelson et al. 2011).

The purpose of our study is to determine the influence of the biochar application to different soils on crop growth and nutrient balances under greenhouse conditions in Thua Thien Hue Province, Vietnam. Pot experiments with Komatsuna (*Brassica rapa* var. *perviridis*) were conducted in three different soils: sandy soil with high organic matter content, clay soil, and sandy soil with low organic matter content, collected in Quang Dien district. Our results indicated that the use of biochar from coconut shells would be beneficial for farmer, the environment under soil and climate conditions in Thua Thien Hue province.

MATERIALS AND METHODS

1. Biochar materials used

Coconut shells were collected from dumping garbage near Dong Ba market in Hue city, Vietnam in September 2011. Feedstock was dried at the temperature 110^{o}C for 3 hours. Pyrolysis of coconut shells was performed using a muffle furnace for 60 minutes at the temperature 500^{o}C with a rise rate of 10^{o}C/min in a nitrogen flow of 1L/min for 2 hours to remove any oxygen remaining in the furnace. This biochar was produced in Okayama University, Japan (Maeda et al., 2012; Uddin et al., 2012).

2. Pot experiments

We used three different soils (sandy soil (S) and clay soil (C) with low organic matter content, sandy soil with high organic matter content (O)) which were collected in Quang Dien district, Thua Thien Hue province, Vietnam in May 2012.

Komatsuna was grown in Wagner's pots with 200 cm^2 area and 20 cm deep, in which 2.7 kg soil (14 cm high) on 1 kg of gravel (4 cm high) was packed, in a greenhouse at Center for Application and Technology Transfer, Institute of Resources, Environment and Biotechnology- Hue University (Phu Vang district, Thua Thien Hue province, Vietnam) from 12 June to 18 July 2012. Total N and P contents in initial soils were both detectable. As shown in Table 1, experimental treatments include no addition of biochar and additions of coconut shell biochar (1,500 g/m^2 each) in triplicate. The biochar materilas were mixed in the top layer (0- 9 cm). Chemical compounds were applied to the top layer just before sowing of Komatsuna seeds (3- 4 seeds in each pot) at rates of 12 g N/m^2, 10 g P_2O_5/m^2 and 12 g K_2O/m^2. Irrigation was applied according to schedule following: 12 and 13 June: 1,000 mL/ 2 days, from 15 June to 03 July: 400 mL/ 3 days, from 06 July to 15 July: 600 mL/ 3 days, 17 and 18 July: 1,000 mL/ day.

Table 1 Experimental design of the study in Thua Thien Hue province, Vietnam

Sample	**Treatment (In triplicates)**	**Biochar from coconut shells** 1,500g/m^2	**N fertilizer** 12 g N/m^2	**P fertilizer** 10 g P_2O_5/m^2	**K fertilizer** 12 g* K_2O/m^2	**Soil**
		(g/pot)	g/pot $(NH_4)_2SO_4$	g/pot KH_2PO_4	g/pot KCl	
SN1	No Char- Poor	**0**	1.131	0.384	0.169	Sandy soil
SB2	Biochar- Poor	**30**	1.131	0.384	0.169	Sandy soil
CN3	No Char- Fertilizer	**0**	1.131	0.384	0.169	Clay soil
CB4	Biochar- Fertilizer	**30**	1.131	0.384	0.169	Clay soil
ON5	No Char- More Fertilizer	**0**	1.131	0.384	0.169	Organic soil
OB6	Biochar- More Fertilizer	**30**	1.131	0.384	0.169	Organic soil

* 6.63 g K_2O/m^2 is applied as KH_2PO_4; the rest (5.37) is applied as KCl.
Effects of soil types: 6 treatments x 3 replicates= 18 pots.

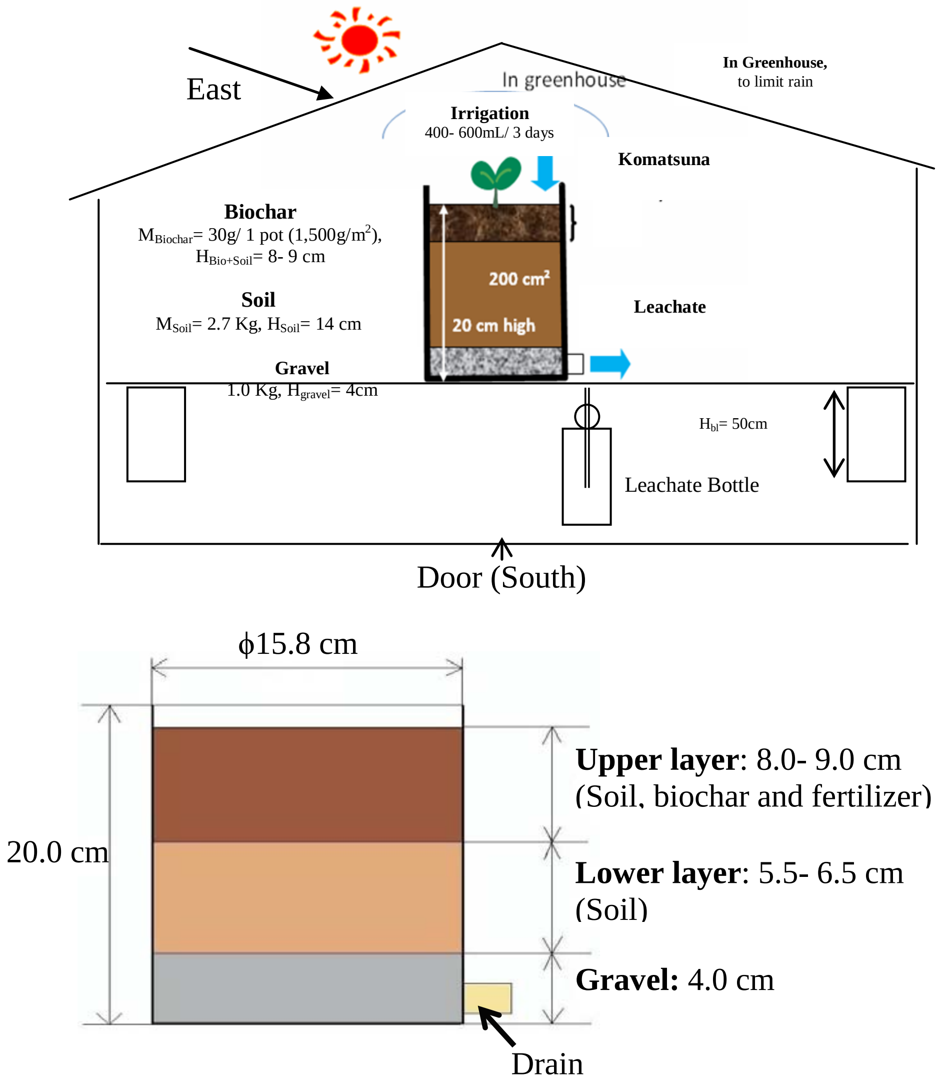


Fig. 1 Pot experiments in Thua Thien Hue province, Vietnam

3. Chemical analysis

The drainage of pots was collected in a 500 mL polyethylene bottle for few hours after every irrigation event. The weight of the leachate was measured. The samples were kept at 0- 2^oC until the analysis of total N, nitrate (NO_3-N) and total P by using UV- VIS spectrophotometer (V530, JASCO, Japan).

Harvested Komatsuna vegetable was separated into above and root parts, immediately weighed and dried at 70^oC for 1 week. Total N and P contents were determined after the Kjeldahl digestion. After the harvest of Komatsuna vegetable, soil samples were destructively collected from two layers: the upper (0- 9 cm) and lower layers (9- 14 cm). Total N and P contents in soils were determined after the digestion (3 mL H_2SO_4 and 3.5 mL H_2O_2 at 300^oC). Those concentrations in extracts were analyzed with Kjeldahl system and UV-VIS spectrophotometer.

4. Statistical analysis

Microsoft Excel was used to calculate and process sample results.

RESULTS AND DISCUSSION

1. Nutrient uptake by Komatsuna

Both biochar applications increased the uptake of P (Fig. 2 and 3) and N (Fig. 4 and Fig. 5) in roots and leaves by Komatsuna. This is probably because soil water retention was improved with the incorporation of biochar materials. The uptake of P and N by Komatsuna in clay and organic soils was better than the uptake of nutrients in sandy soil. Besides, dry matter yields in soils with biochar were higher than it is in soils without biochar (Fig. 6 and Fig. 7).

2. Nutrient leaching and retention

Most of total P leached was in the form of PO_4-P. Biochar application reduced significantly total P. The amount of leaching losses of total P during the experiment in organic soil was particularly better than it is in clay and sandy soils. After the harvest of Komatsuna, total P content in the upper layer was the highest in organic soil. Soils with biochar retained more P, resulting in reduced P leaching (Fig. 8, Fig. 10 and Fig. 11).

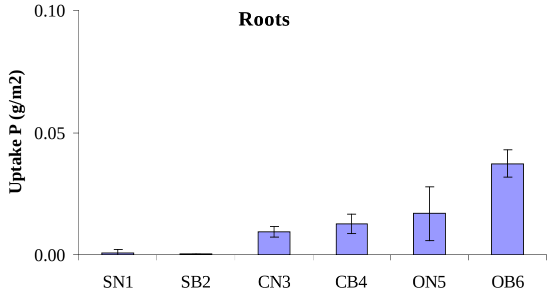


Fig. 2 Phosphorous in roots absorbed by Komatsuna

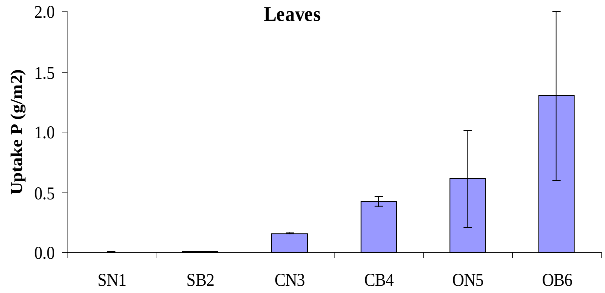


Fig. 3 Phosphorous in leaves absorbed by Komatsuna

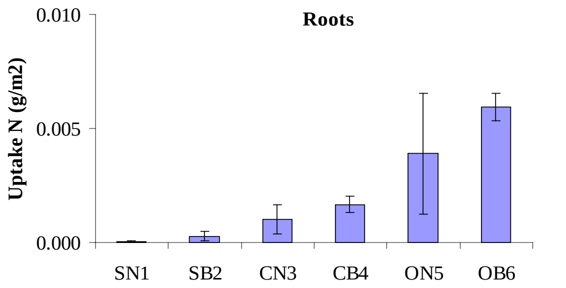


Fig. 4 Nitrogen in roots absorbed by Komatsuna

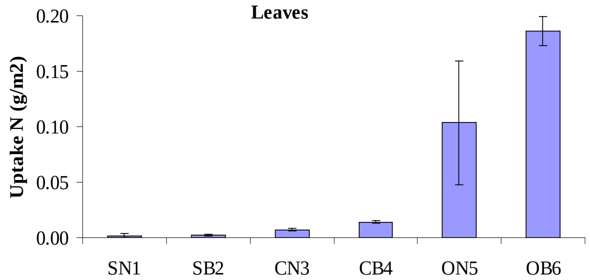


Fig. 5 Nitrogen in leaves absorbed by Komatsuna

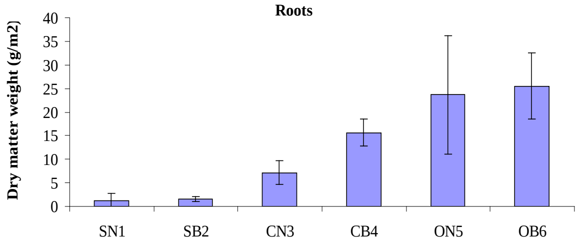


Fig. 6 Dry matter weight in roots

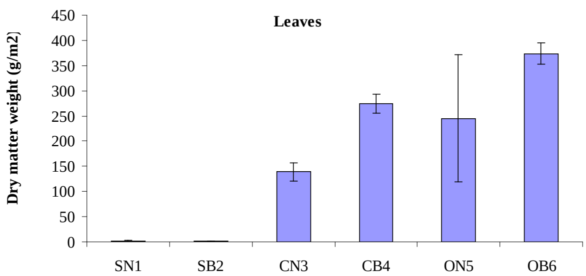
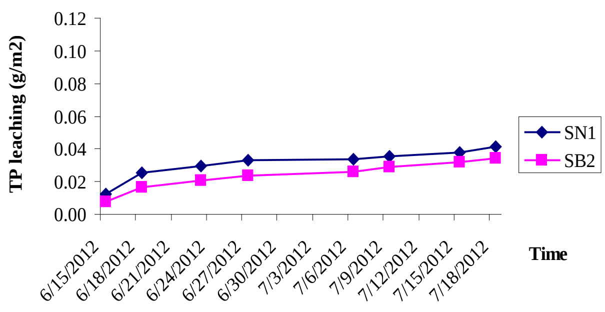
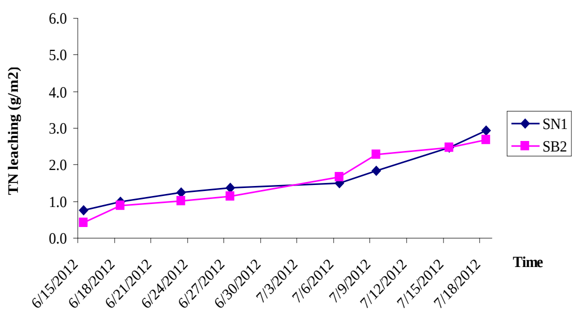
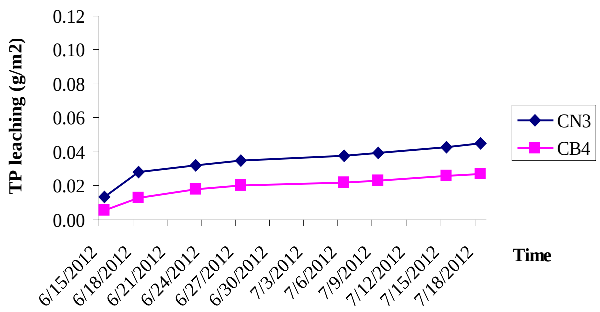
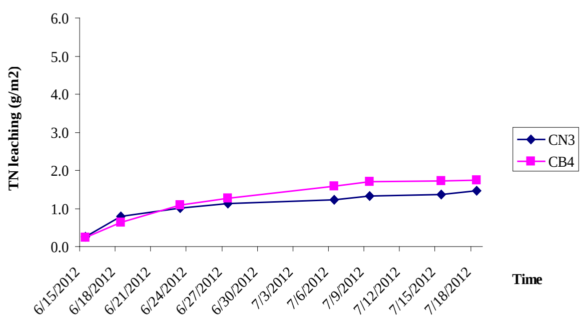


Fig. 7 Dry matter weight in leaves









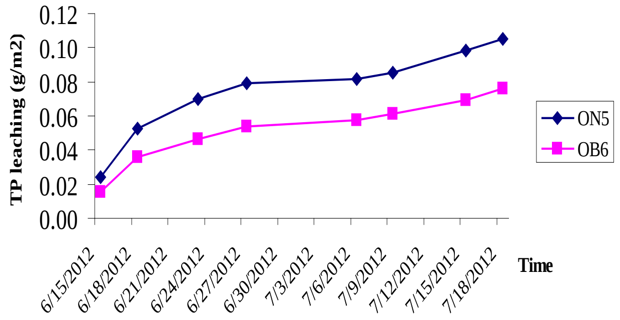


Fig. 8 Leaching loss of total phosphorous during the experiment

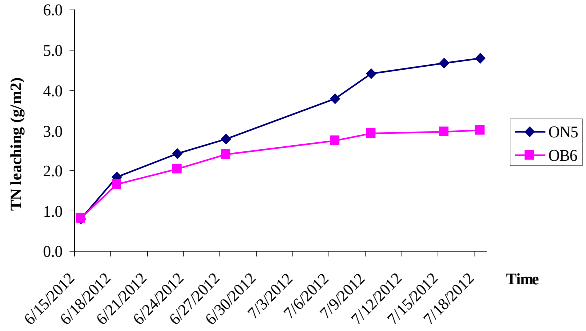


Fig. 9 Leaching loss of total nitrogen during the experiment

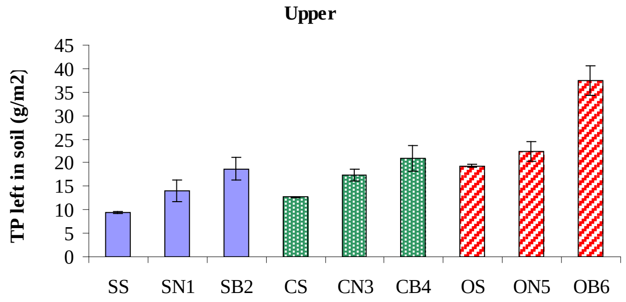


Fig. 10 Total P left in upper layer

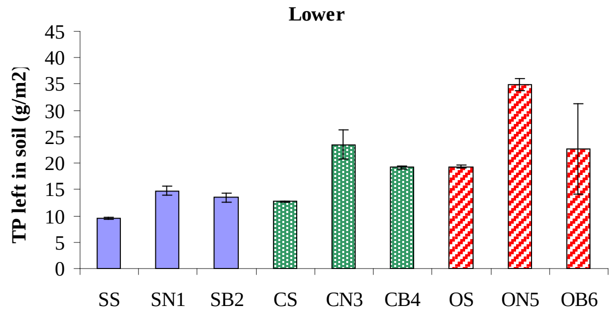


Fig. 11 Total P left in lower layer

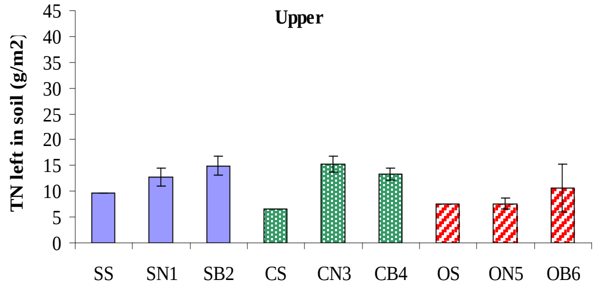


Fig. 12 Total N left in upper layer

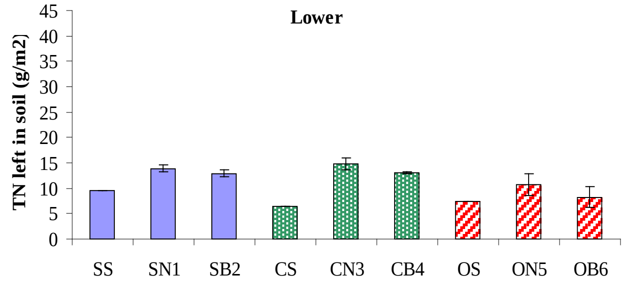


Fig. 13 Total N left in lower layer

Most of total N leached was in the form of nitrate (NO_3-N). The amount of total N losses during the experiment was the greatest in organic soil. After the harvest of Komatsuna, total N content in the upper layer changed unclearly in every soil. Total N content increased in the upper layer with sandy and organic soils; however it decreased in the upper layer with clay soil. Soils with biochar retained more N in sandy and organic soils, resulting in reduced N leaching in those soils (Fig. 9, Fig. 12 and Fig. 13).

3. Inputs and outputs of nutrients

Inputs and outputs during the experiment is shown in Table 2. Recovery rates of P were 71-96% of each input (Table 2). Total P in the initial soil was comparable to the standard application rate of P fertilizer. More than 90% of input P remained in soil after the harvest of Komatsuna. The amount of P leached smaller than the total P inputs in soil.

Recovery rates of N were 19- 93% of each input (Table 2). In clay soil, the amounts of unknown N were smaller than in other soils. The unknown fraction of N was large in sandy and organic soils and may have released nitrous oxide during the processes of nitrification and denitrification (Clough and Condron, 2010). Therefore, we should further study the N dynamics in soil treated with biochar materials.

Table 2 Inputs and outputs of nutrients during the experiment

	Treatment (g/m^2)					
P inputs	**SN1**	**SB2**	**CN3**	**CB4**	**ON5**	**OB6**
Fertilizer	4.3	4.3	4.3	4.3	4.3	4.3
Soil	9.5	9.5	12.7	12.7	19.4	19.4
Biochar	0.0	0.0	0.0	0.0	0.0	0.0
Total	*13.8*	*13.8*	*17.1*	*17.1*	*23.7*	*23.7*
P outputs						
Soil	9.8	13.2	15.3	14.6	18.6	21.4
Leaching	0.0	0.0	0.0	0.0	0.0	0.0
Plant uptake	0.0	0.0	0.2	0.4	0.6	1.3
Total	*9.8*	*13.2*	*15.5*	*15.0*	*19.2*	*22.8*
Unknown P	*4.0*	*0.6*	*1.6*	*2.1*	*4.5*	*0.9*
N inputs	**SN1**	**SB2**	**CN3**	**CB4**	**ON5**	**OB6**
Fertilizer	12.0	12.0	12.0	12.0	12.0	12.0
Soil	9.6	9.6	6.5	6.5	7.5	7.5
Biochar	0.0	0.0	0.0	0.0	0.0	0.0
Total	*21.6*	*21.6*	*18.5*	*18.5*	*19.5*	*19.5*
N outputs						
Soil	7.49	8.72	17.08	13.48	3.39	3.91
Leaching	0.5	0.2	0.1	0.0	0.1	0.0
Plant uptake	0.0	0.0	0.0	0.0	0.1	0.2
Total	*8.0*	*8.9*	*17.2*	*13.5*	*3.6*	*4.1*
Unknown N	*13.6*	*12.6*	*1.3*	*5.0*	*15.9*	*15.3*

CONCLUSIONS AND PERPECTIVES

We examined the effect of biochar application to different soils on crop growth, phosphorus and nitrogen balances under greenhouse conditions in Thua Thien Hue Province, Vietnam. Results showed that: (1) Komatsuna growth in sandy soil less than clay and organic soils. Biochar improved crop yield in clay and organic soils, but it did not improve in sandy soil. (2) Biochar increased P and N uptake in leaves and roots in clay and organic soils. (3) Biochar reduced P leaching; furthermore biochar reduced TN leaching in organic soil. Besides, biochar reduced NO_3-N leaching in clay and organic soils. We further study the N dynamics in soil treated with biochar materials.

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FY 2012 Debrief Meeting of Practical Research and Education of Solid Waste Management Based on the Partnership among Universities and Governments in Asia and Pacific Countries

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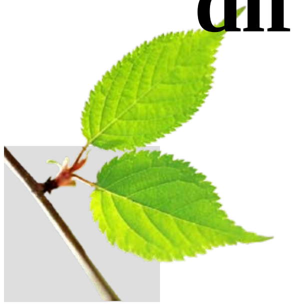

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CONTENTS

- Purpose
- Biochar from coconut shells (production in Japan)
- Research in Hue city 2012
- Conclusions

PURPOSE

- Using Biochar produced from coconut shells at 500^{o}C.

- Research determines the influence of the biochar application to different soils on crop growth and nutrient balances under greenhouse conditions in Thua Thien Hue Province, Vietnam. Pot experiments with Komatsuna (*Brassica rapa* var. *perviridis*) were conducted in three different soils: sandy soil with high organic matter content, clay soil, and sandy soil with low organic matter content, collected in Quang Dien district.

- Our results indicated that the use of biochar from coconut shells would be beneficial for farmer, the environment under soil and climate conditions in Thua Thien Hue province.

POT EXPERIMENTS IN HUE CITY

Materials and methods:

+ **Biochar:** Coconut shell (at 500^{o}C, 60 minutes)

+ **Soil:** Sandy soil (S) and Clay soil (C) with low organic matter content, Sandy soil with high organic matter content (O) collected in Quang Dien district, Thua Thien Hue province, Vietnam.

Soil (M_{Soil}= 2.7 Kg) + Gravel (M_{gravel}= 1.0 Kg)

+ **Wagner pot** (Size: 200 cm^2, 20 cm deep)
+ **Plant:** Komatsuna (*Brassica rapa* var. *perviridis; shin- Komatsuna*)
+ **Growth period:** 12 June – 18 July, 2012 (1 month)
+ **Fertilizer:** N: $(NH_4)_2SO_4$; P: KH_2PO_4; K: KH_2PO_4, KCl
+ **Irrigation:**

12 and 13 June:	1,000 mL/ 2days
15 June- 03 July:	400 mL/ 3 days
06- 15 July:	600 mL/ 3 days
17 and 18 July:	1,000 mL/ day

+ **Analysis:** Leachate (Total P, Total N and NO_3-N), Plant and Soil (Total P and Total N).

BIOCHAR FROM COCONUT SHELLS (PRODUCTION IN JAPAN)

Raw materials:

Coconut shells

→

Drying:

110^{o}C, 3h

↓

Loading into the Pyrolysis reactor (N_2 purging for 2 hours)

Pyrolysis:

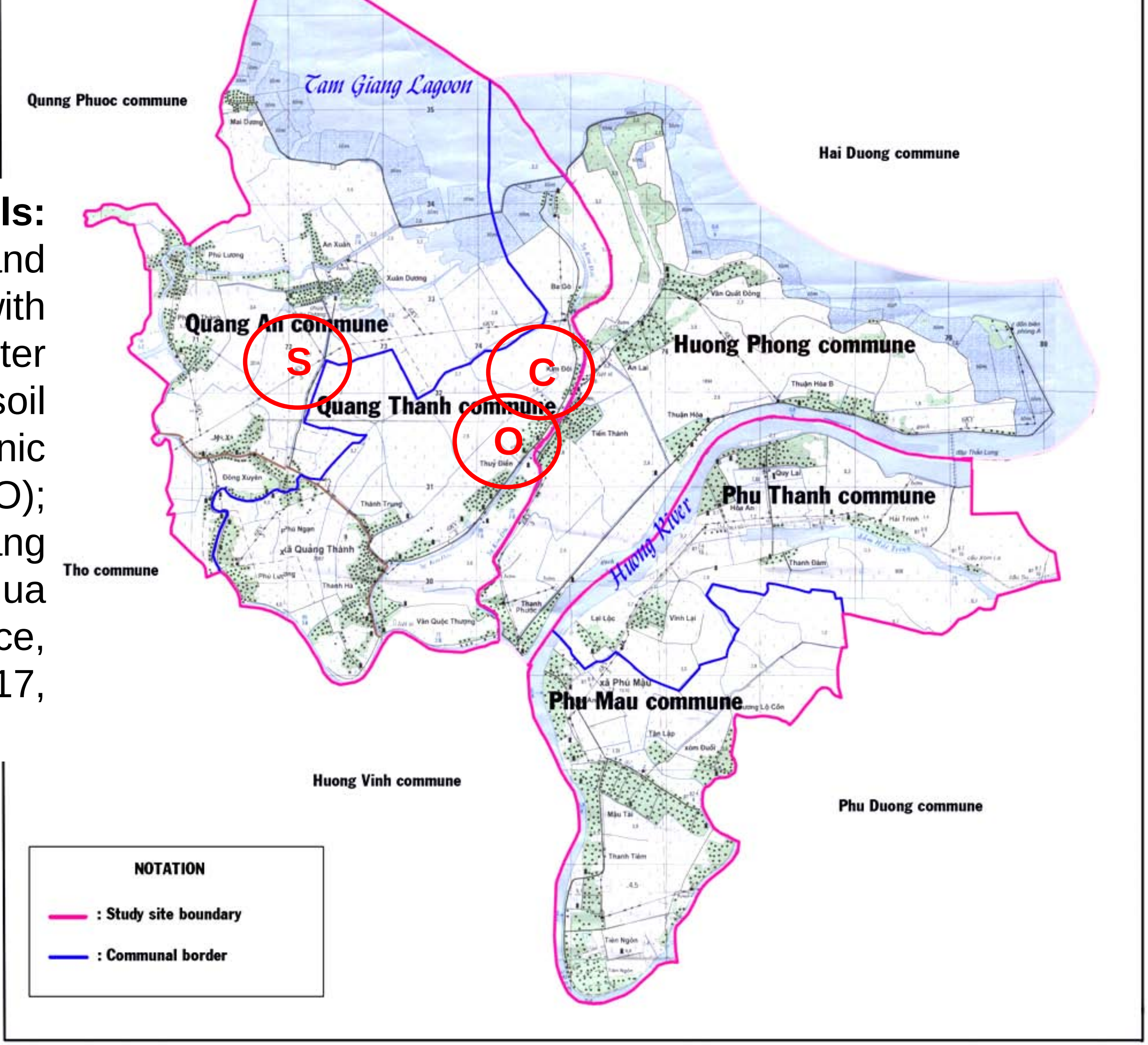
- N_2 flow, 1.0 L/min.
- Target temperature: 500^{o}C
- Heating Rate: 10^{o}C/min.
- Pyrolysis time: 60 min.

←

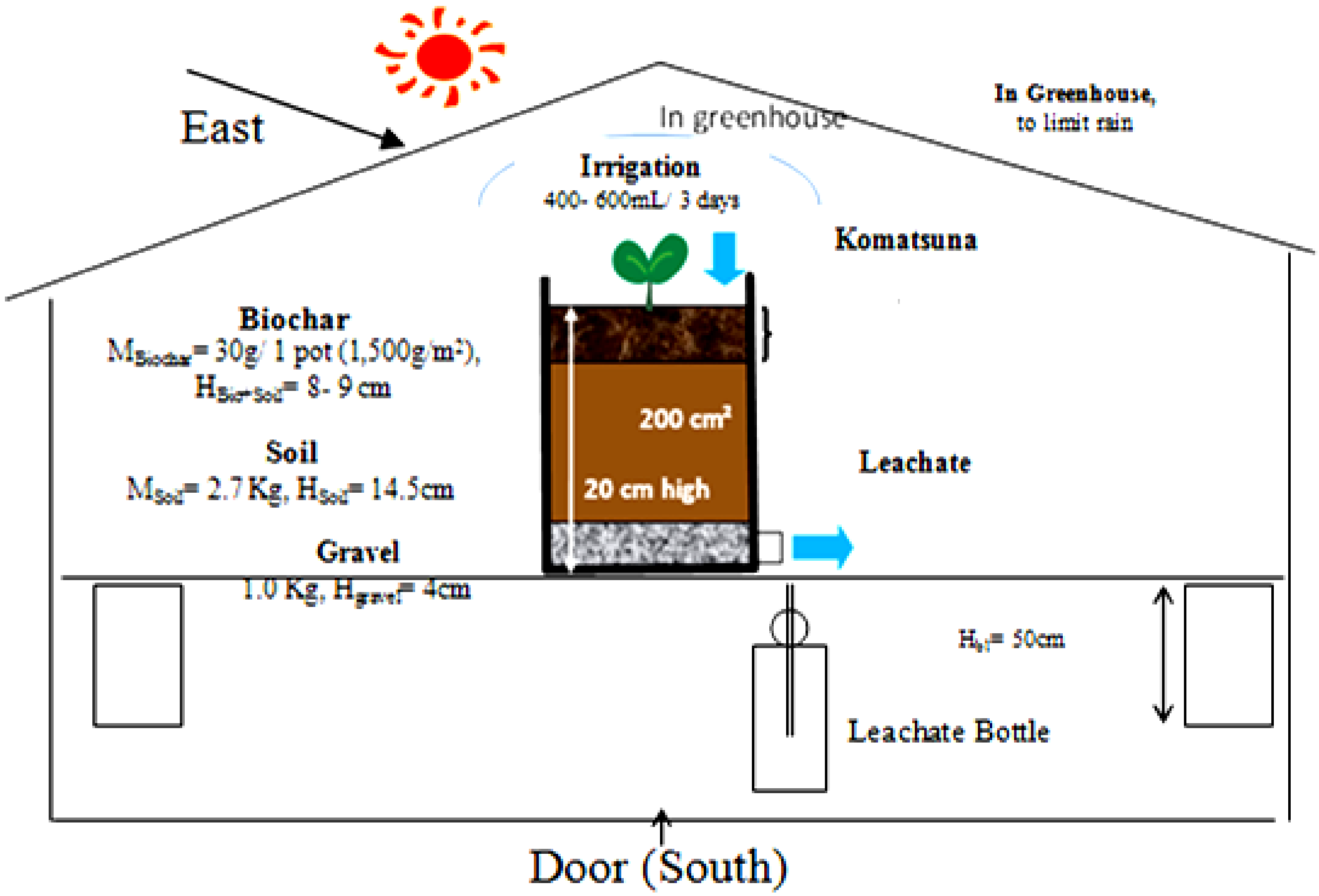
Biochar

LOCATION OF SOIL SAMPLING

Three different soils: Sandy Soil (S) and Clay Soil (C) and with low organic matter content, Sandy soil with high organic matter content (O); collected in Quang Dien district, Thua Thien Hue province, Vietnam on May 17, 2012.



POT EXPERIMENTS IN GREENHOUSE



- **Location:** Center for Application and Technology Transfer- IREB (Phu Vang district, Thua Thien Hue province, Vietnam)

POT EXPERIMENTS IN GREENHOUSE

HOUSE 2

HOUSE 1

LIMIT DIRECTLY SUNSHINE INTO HOUSE

1

2

3

cover with black mesh layer and
cover surrounding by mesh
to limit insects and directly sunshine

EXPERIMENTAL DESIGN

Chemical fertilizer was applied to the soil at rates of 12g N/m^2, 10g P_2O_5/m^2, and 12g K_2O/m^2. Half of the pots were treated with the biochar at 1500 g/m^2.

Table 1. Experimental design in Hue city

Sample	Treatment (In triplicates)	Biochar from coconut shells (g/pot)	N fertilizer 12 g N/m^2	P fertilizer 10 g P_2O_5/m^2	K fertilizer 12 g* K_2O/m^2	Soil
			g/pot $(NH_4)_2SO_4$	g/pot KH_2PO_4	g/pot KCl	
SN1	No Char- Poor	**0**	1.131	0.384	0.169	Sandy soil
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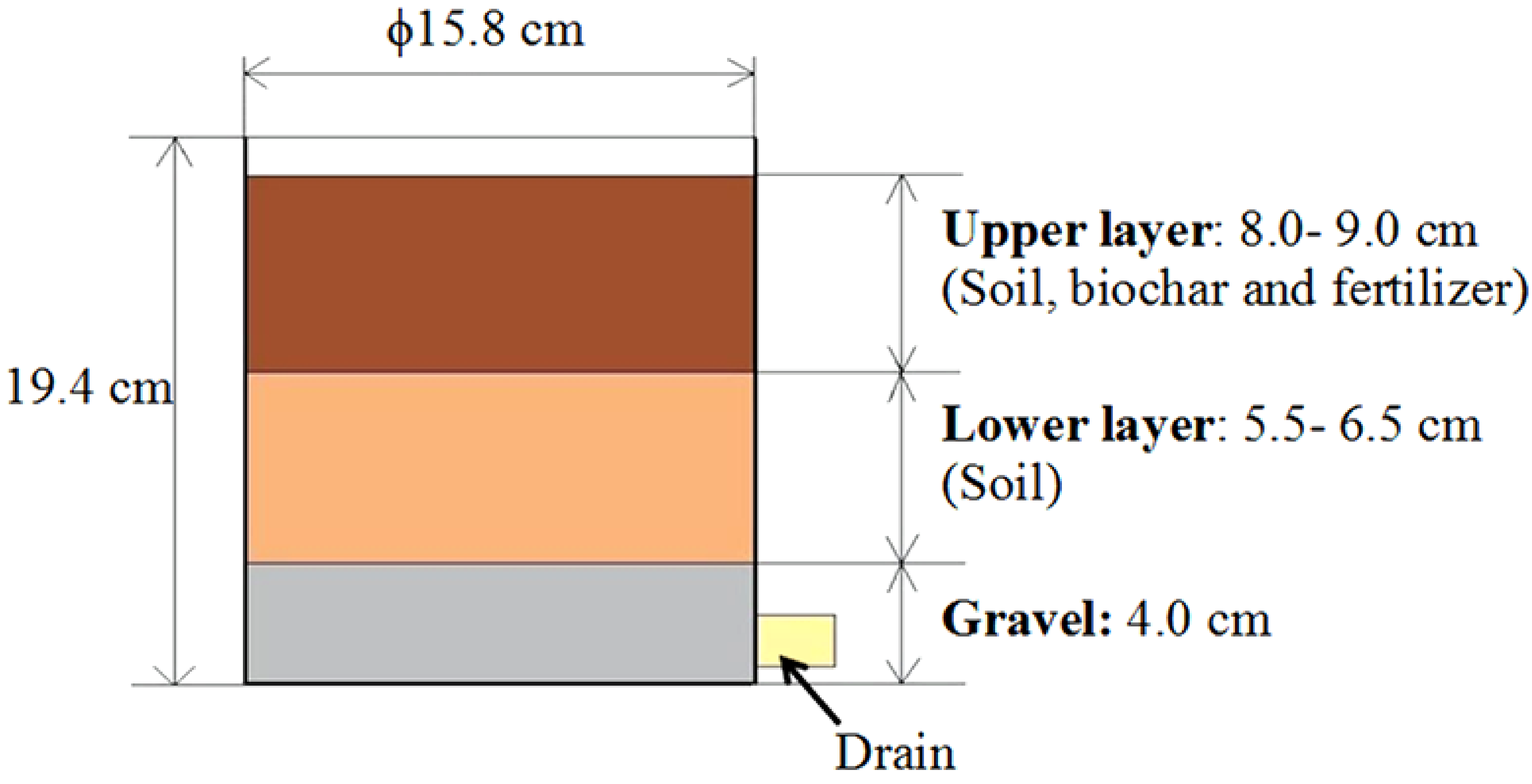
Effects of soil types: 6 treatments x 3 replicates= 18 pots

Experimental pots



RESULT AND DISCUSS

1. Komatsuna growth (dry matter weight)
2. P uptake by Komatsuna
3. N uptake by Komatsuna
4. Leaching (TP, TN, NO_3-N leaching)
5. TP and TN in soil after the experiment
6. P input and output
7. N input and output
8. Water balance

Komatsuna growth at the end of the experiment

No Biochar- Sandy soil (SN1)

Biochar- Sandy soil (SB2)

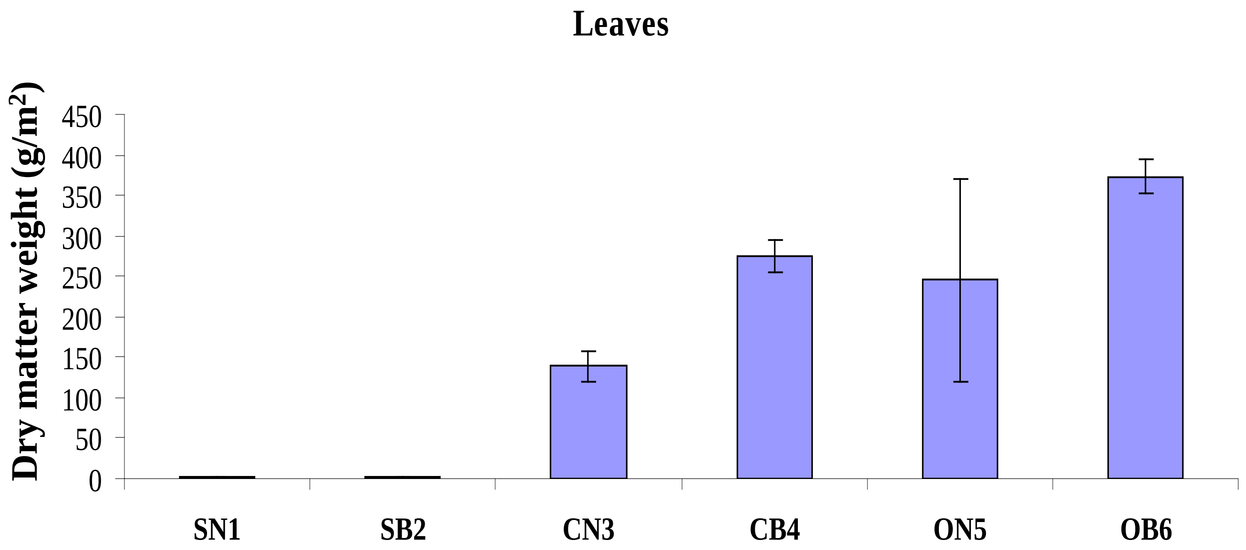
No Biochar- Clay soil (CN3)

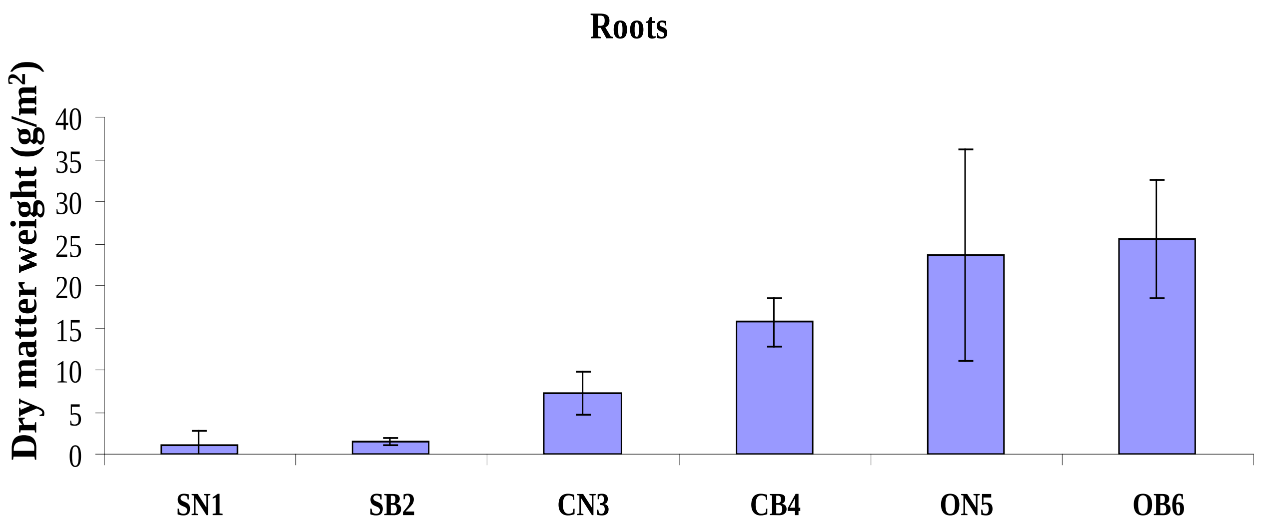
Biochar- Clay soil (CB4)

No Biochar- Organic soil (ON5)

Biochar- Organic soil (OB6)

1. Komatsuna growth (dry matter weight)

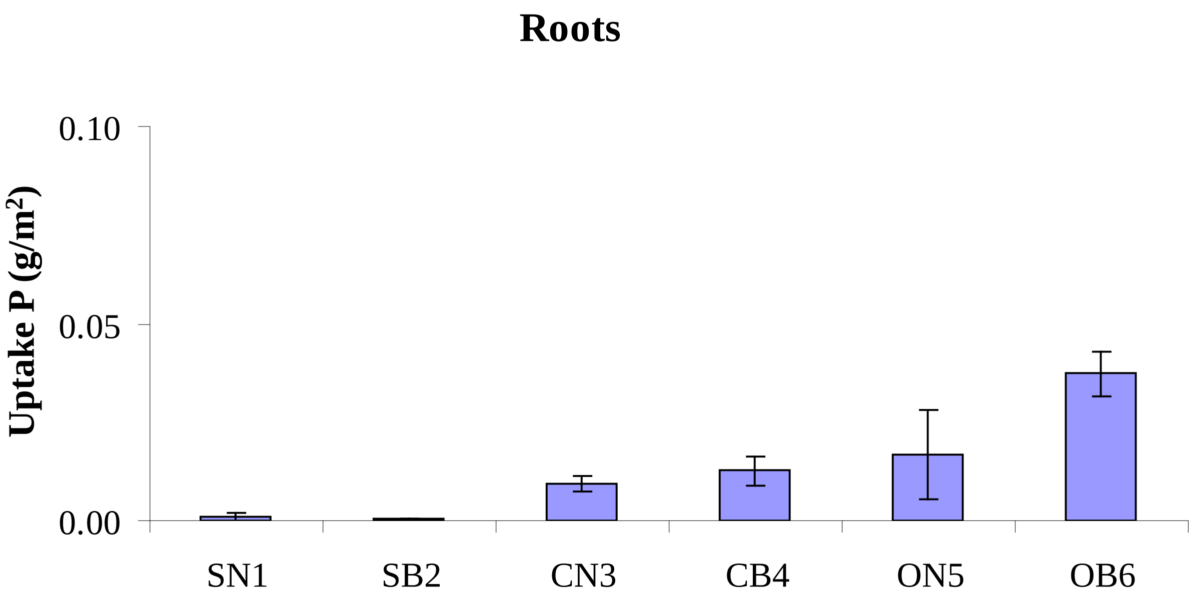


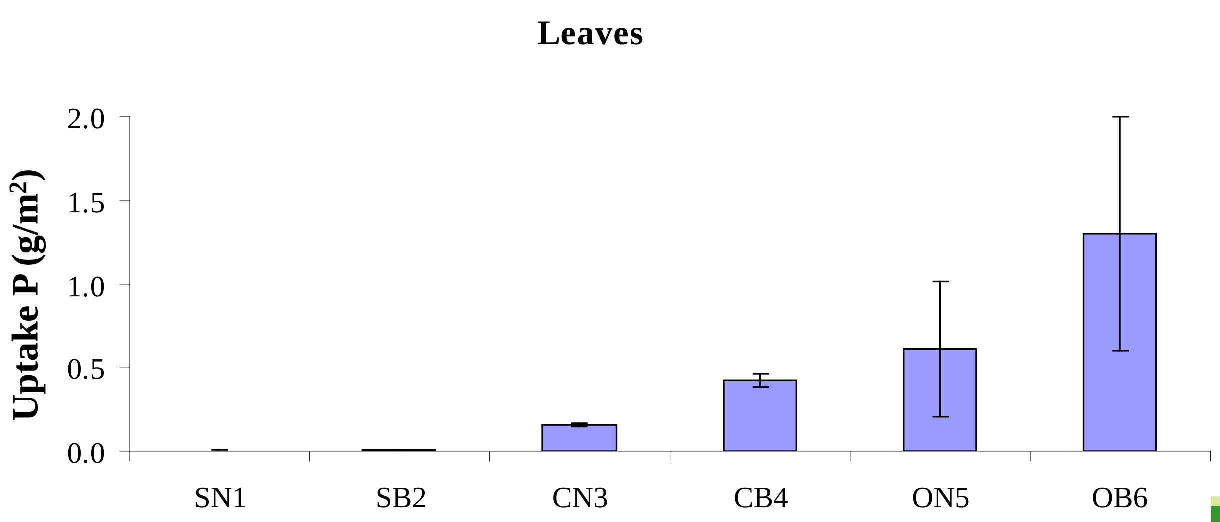


- Sandy soil (S) < Clay soil (C) < Organic soil (O)

- Biochar improved crop yield in Clay soil and Organic soil, but did not improve it in Sandy soil.

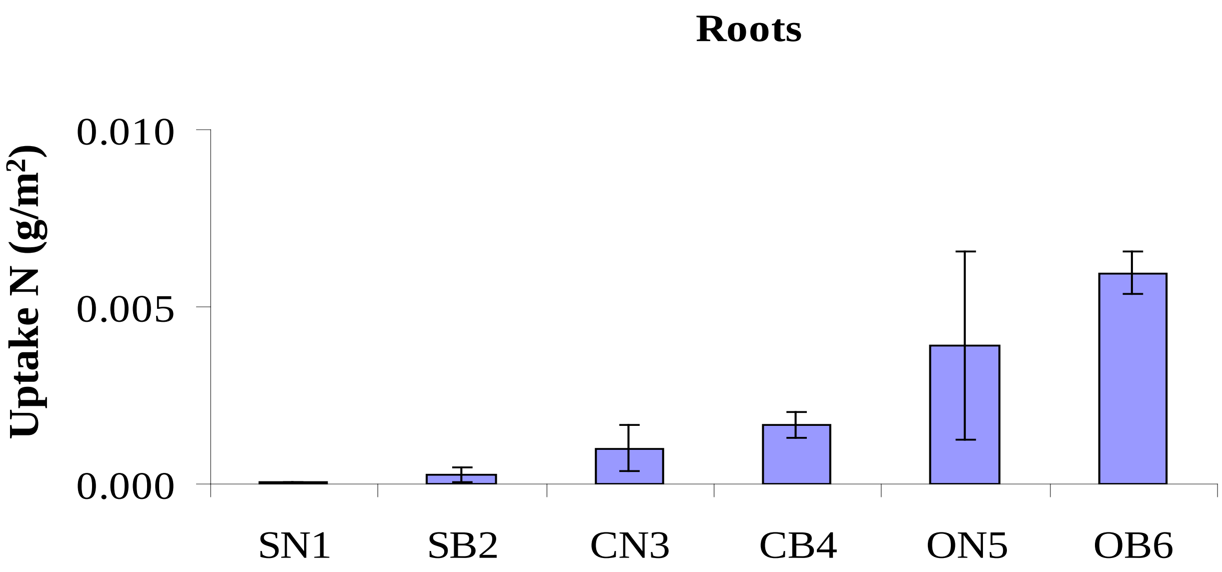
2. P uptake by Komatsuna

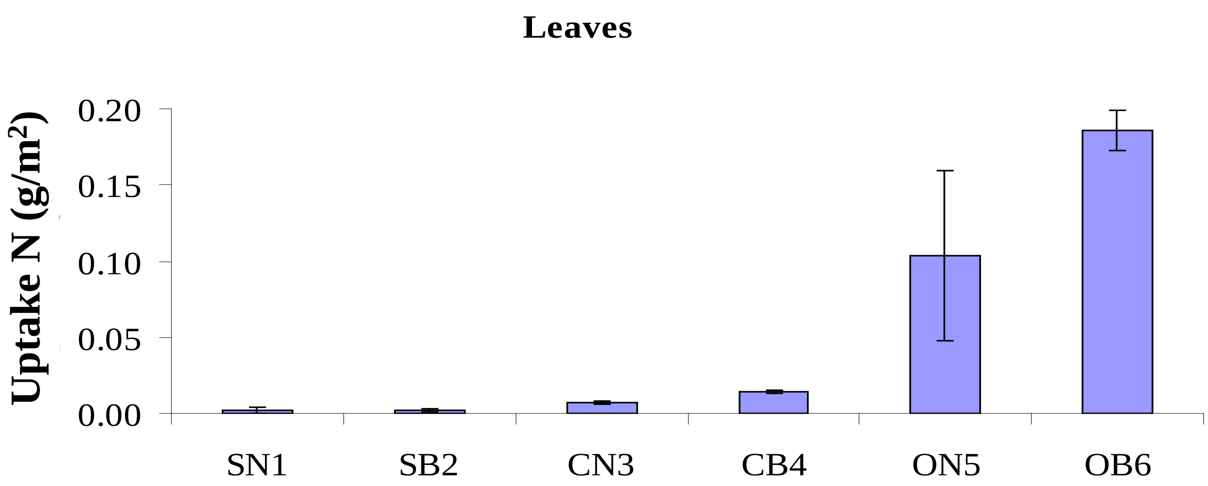




Biochar increased P uptake in leaves and roots in Clay soil and Organic soil.

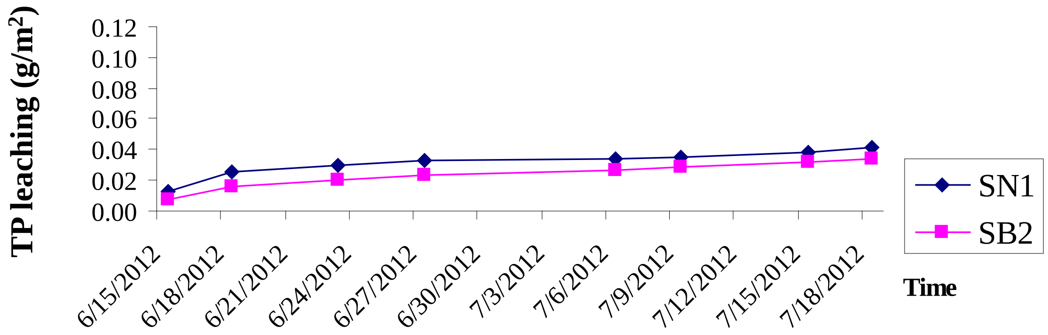
3. N uptake by Komatsuna

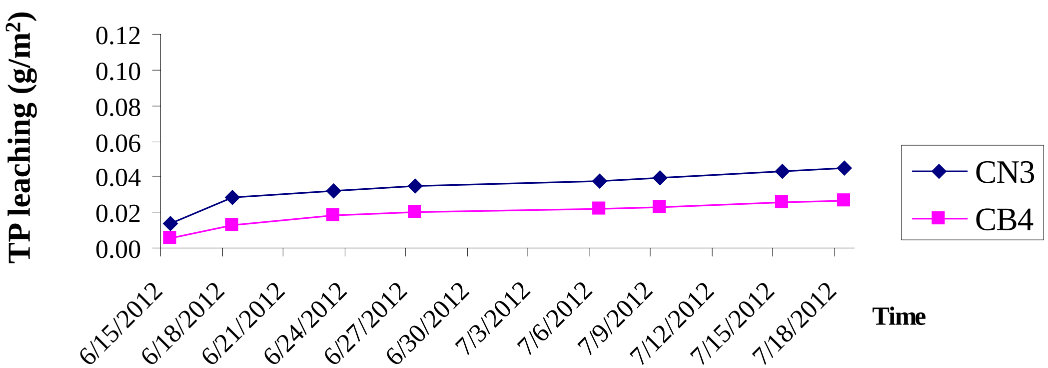


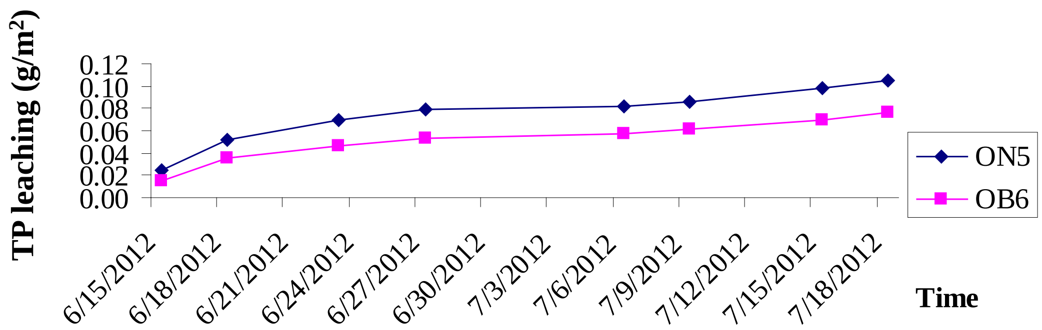


Biochar increased N uptake in leaves and roots in Clay soil and Organic soil.

4. Total P leaching

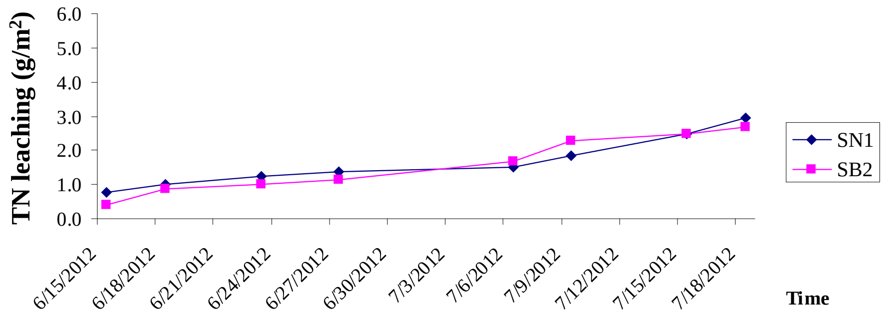


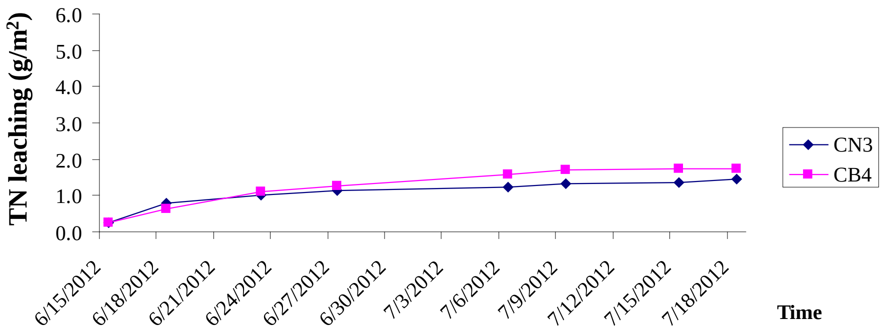


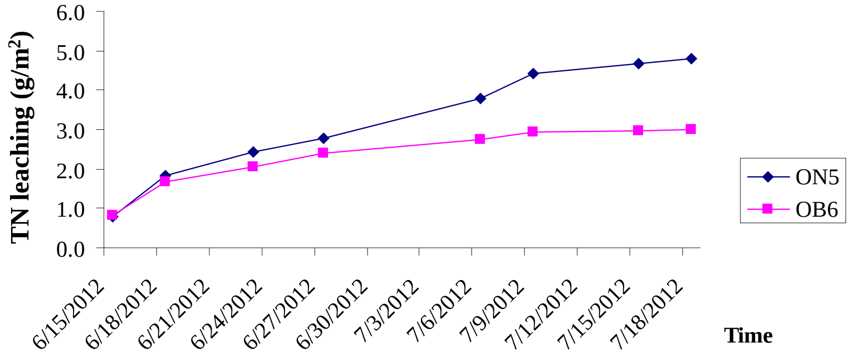


Biochar reduced TP leaching

4. Total N leaching

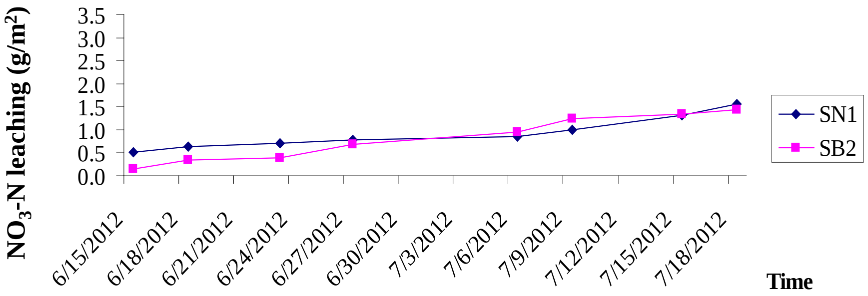


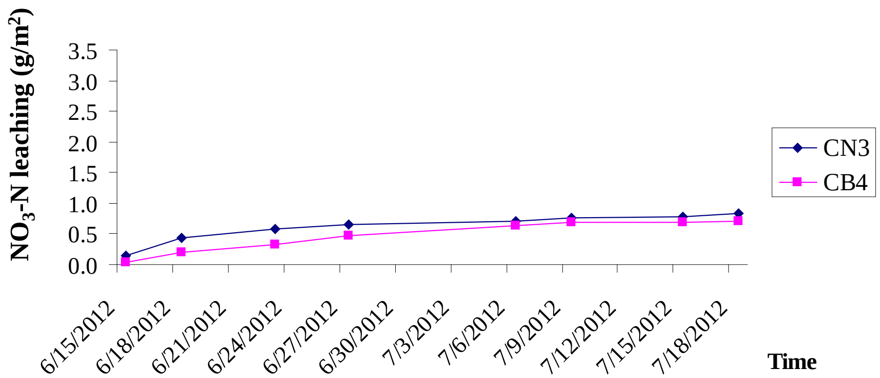


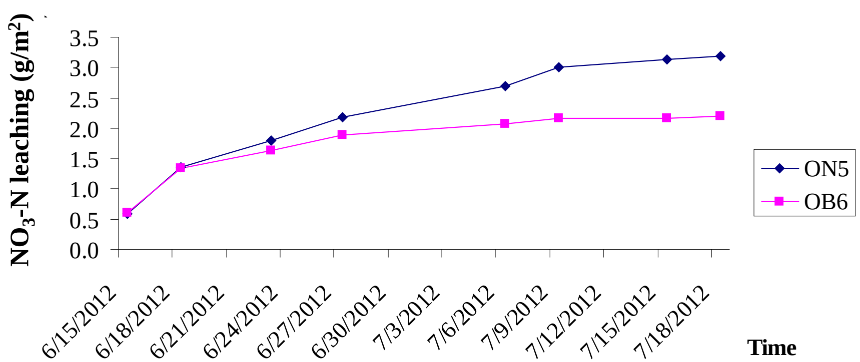


Biochar reduced TN leaching in Organic soil.

4. NO_3-N leaching

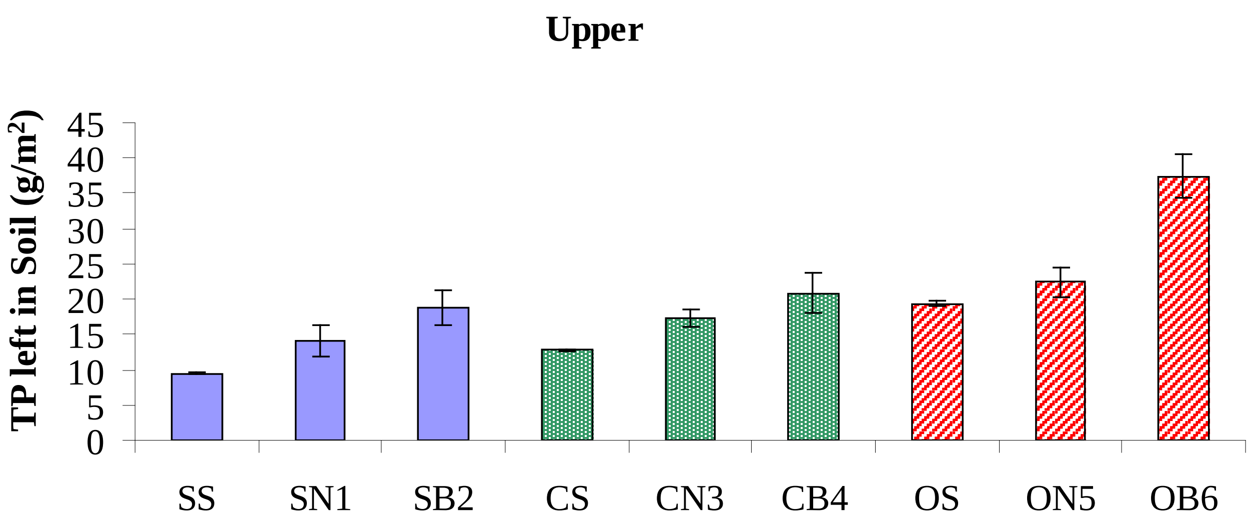


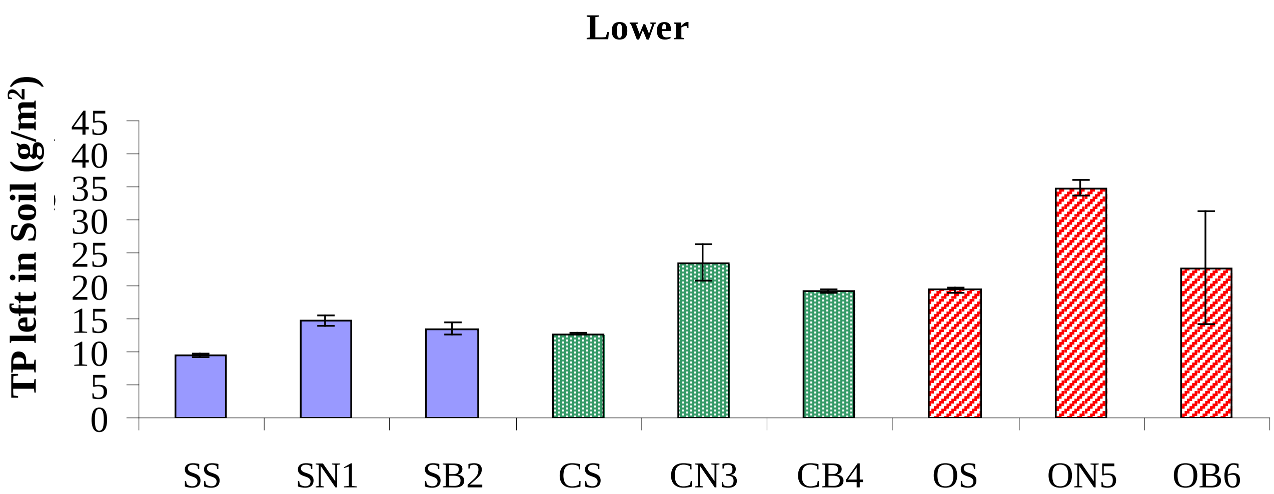




Biochar reduced NO_3-N leaching in Clay soil and Organic soil.

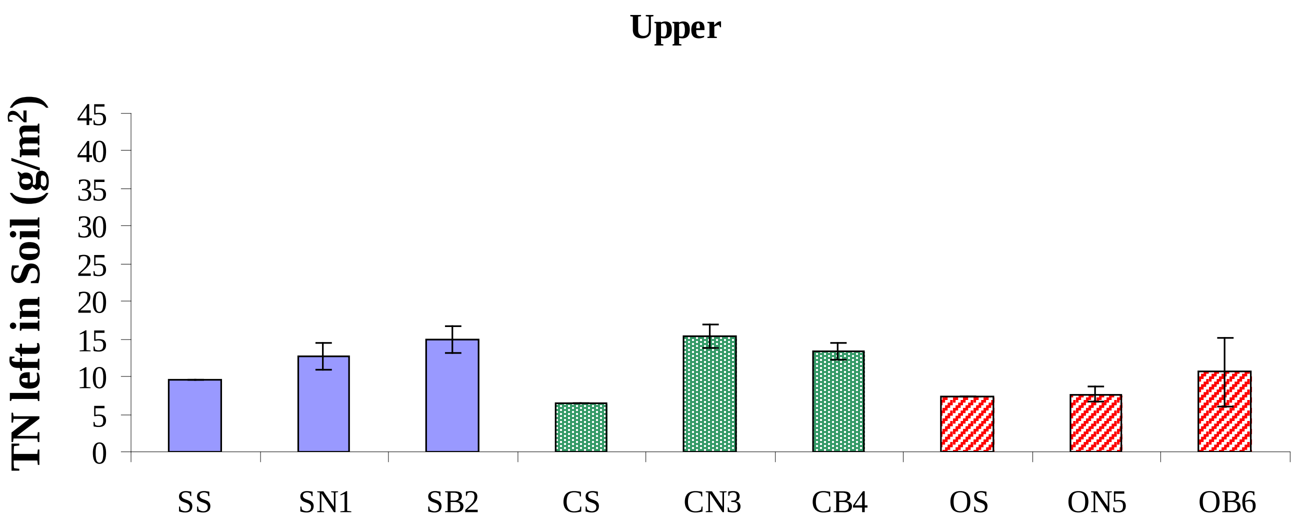
5. Total P left in soil after the experiment

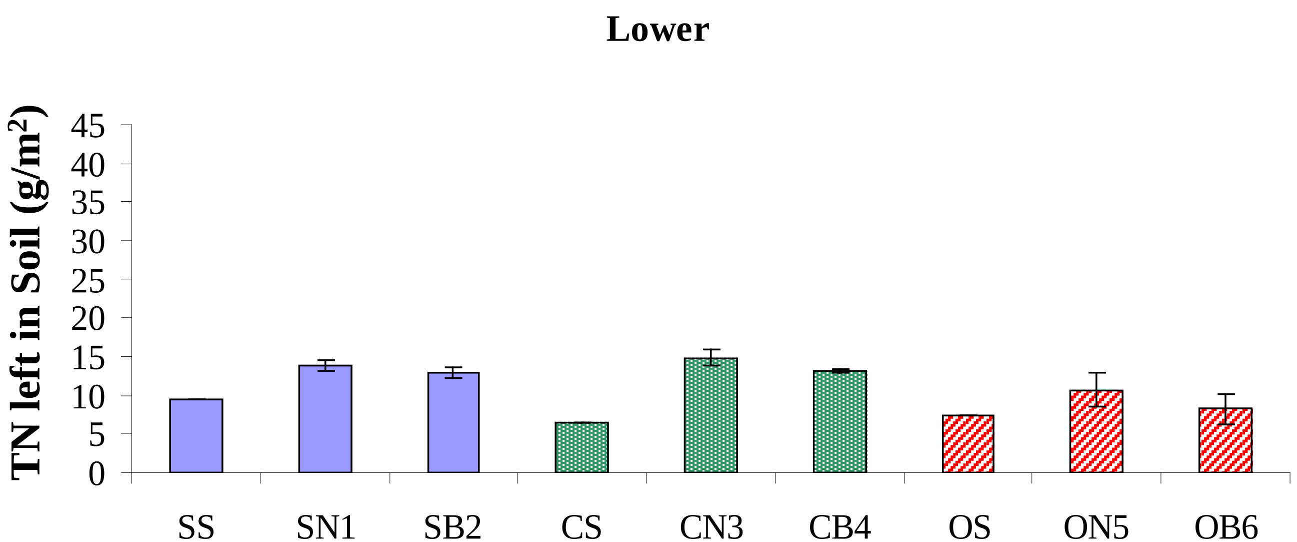




Biochar retained more P in the upper layer.

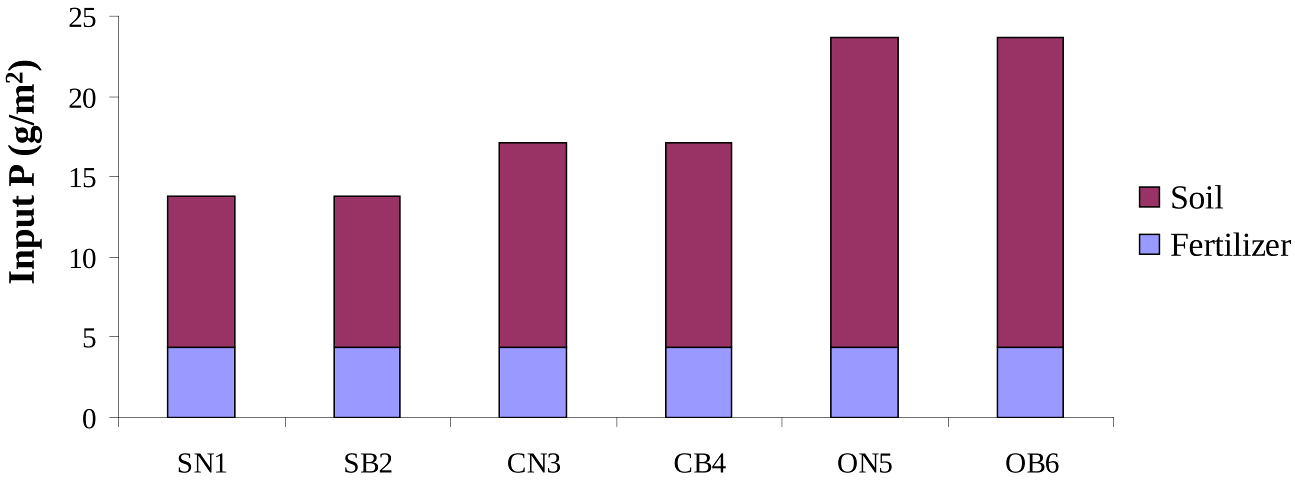
5. Total N left in soil after the experiment

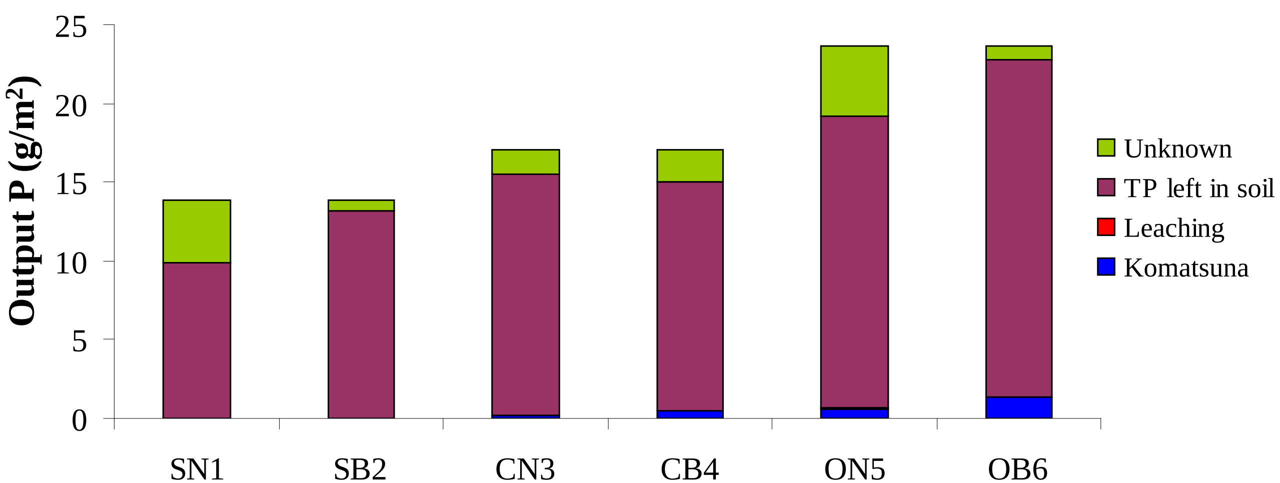




Biochar retained more N in the upper layer (Sandy and Organic soils).

6. P input and output

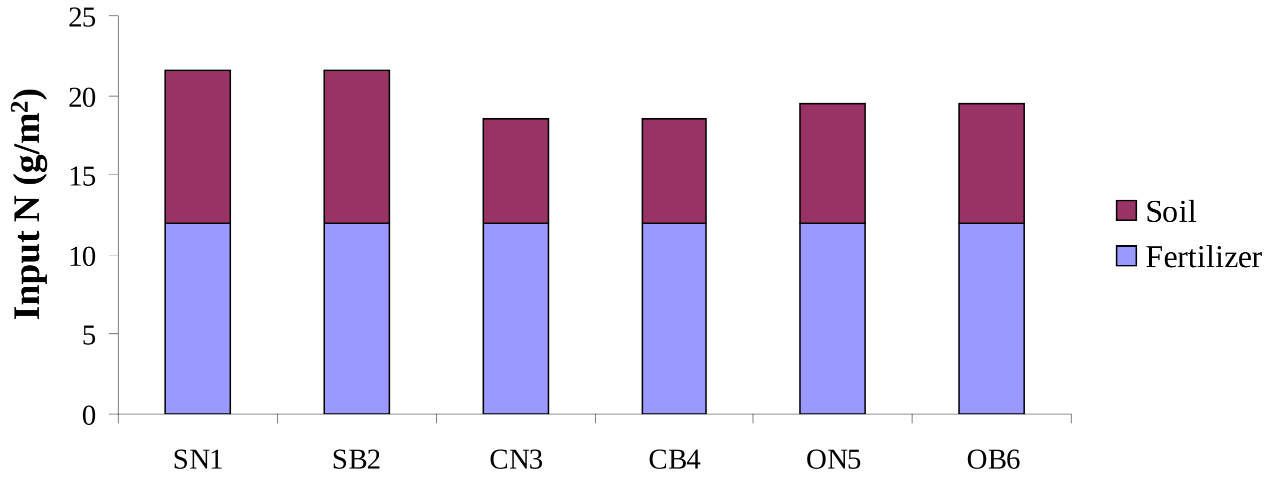


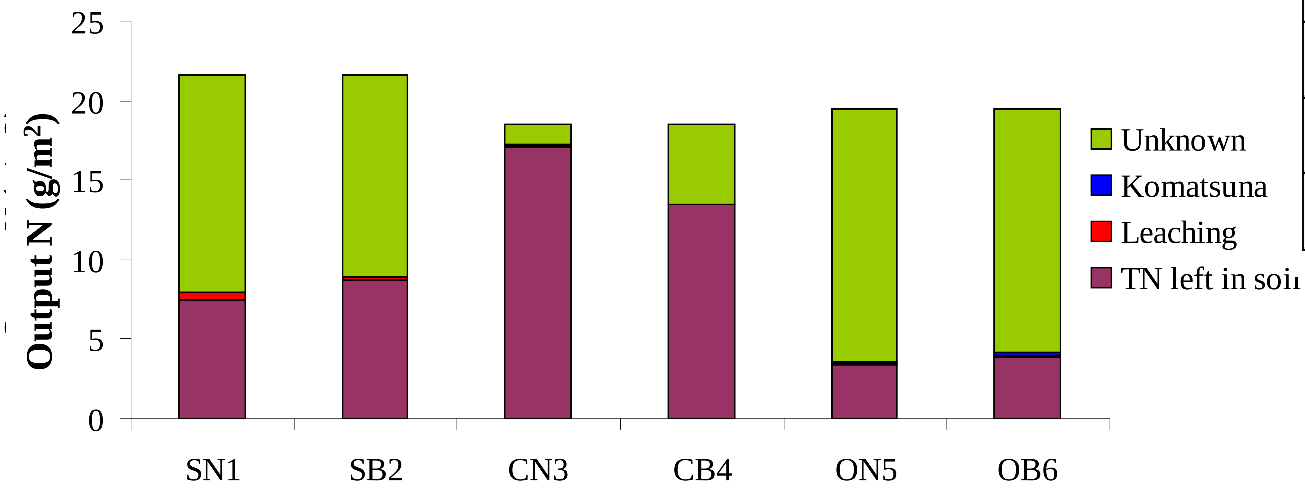


Sample	Recovery rate (%)
SN1	71
SB2	95
CN3	91
CB4	88
ON5	81
OB6	96

Input: Fertilizer and soil mineral P, Biochar (NA)
Output: P uptake by Komatsuna, TP leaching, TP left in soil and Unknown

7. N input and output

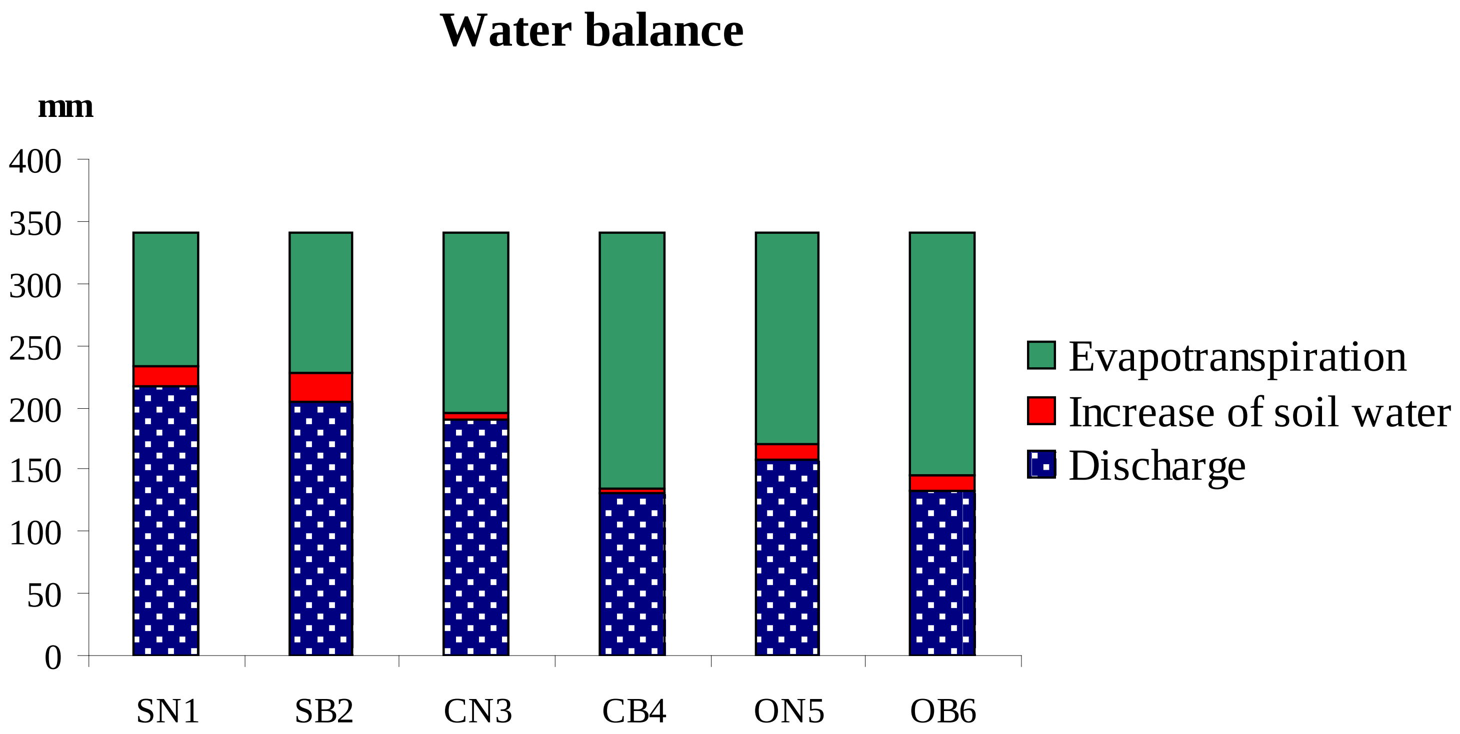




Sample	Recovery rate (%)
SN1	37
SB2	41
CN3	93
CB4	73
ON5	19
OB6	21

Input: Fertilizer and soil mineral N, Biochar (NA)
Output: N uptake by Komatsuna, TN leaching, TN left in soil and Unknown

8. Water balance during the entire experiment



- Discharge: S > O > C
- Increase of soil water: S > O > C
- Evapotranspiration: C > O> S

--> Biochar kept soil moisture content higher in Sandy soil and Organic soil.

CONCLUSIONS

We examined the effect of biochar application to different soils on crop growth, P and N balances under greenhouse conditions in Thua Thien Hue Province, Vietnam.

Results showed:

1. Komatsuna growth in Sandy soil (S) < Clay soil (C) < Organic soil (O). Biochar improved crop yield in C and O soils, but did not improve in S soil.

2. Biochar increased P and N uptake in leaves and roots in C and O soils.

3. Biochar reduced P leaching.

4. Biochar reduced TN leaching in O soil. Biochar reduced NO_3-N leaching in C and O soils.

THANK YOU FOR YOUR ATTENTION !