International Journal of Agricultural and Soil Science Vol. 2(1) pp. 5-13, January, 2014
Available online http://internationalinventjournals.org/journals/IJASS


*Full Length Research Paper*

# Biochar Treatment and its Effects on Rice and Vegetable Yields in Mountainous Areas of Northern Vietnam

**Vinh NC. [1*], Hien NV.[1], Anh MTL.[2], Johan Lehmann[3], Stephen Joseph[4]**

[1]Soil and Fertilizer Research Institute (SFRI), Hanoi, Vietnam.
[2]Faculty of earth science and environment. Thai Nguyen science University.
[3]Cornell University. USA.
[4]University of New South Wale. Australia

Abstract

**In Vietnam, uplands cover '3/4 total area, where most of ethnic minority groups reside on. They have a low living standard that is poor and nearly poor standard. Rice and vegetable production play an important role in food security. However, agricultural production faces soil degradation problems. Due to soil erosion and over exploited cultivation, soil is becoming degraded in both quality and quantity, causing low crop yield and quantity. In addition, environment degradation is also a significant barrier for the course of hunger elimination and poverty reduction as well as sustainable development for communities in mountainous regions. This study is to contribute to agricultural sustainable production by providing new biochar technology; test and evaluate the efficiency of biochar application for rice and vegetables in mountainous areas of Vietnam. Biochar functioning is soil fertility enrichment as well as increase of efficiency compost for better crops and environment. To obtain this target, experiments with different biochar rates (0.5 and 2.5 t/ha) with and without NPK and compost incubated with 5% biochar (10 t/ha) were implemented to compare with NPK application for rice and vegetable in Thai Nguyen and Thanh Hoa provinces. Result of experiment show that application of biochar for rice in the first year has increased the plant nutrient uptake (NPK) for rice. If lonely application of 2.5t biochar/ha for rice, grain yields were reduced by 24.7% in spring and 17.9% in summer rice. In comparison with NPK treatment, rice yields were increased by 5.9-22.3% in treatments with biochar and by 26.3- 34.2% in treatments of compost mixed with 5% biochar. Application of biochar for vegetables increased the yields by 4.7-25.5%, compared with farmer practices in both sites.**

**Keywords:** Biochar, compost, rice, vegetables, nutrient uptake, yield.

## INTRODUCTION

Throughout the world, there is obvious evidence supporting the link between poverty and soil conditions. For example the wealth of people living in low-fertile sandy soils is much lower than that of those living in rich volcanic soils, (Hartemink, 2005). Due to unreasonable land use, soil erosion and current climate change in Vietnam, agro-forestry lands are currently being degraded and desertified, leaving behind wastelands. Improvement of degraded soil to develop sustainable agriculture is one of essential and long term strategies of national policy, particularity on the mountainous regions.

Biochar (BC) is a product of incomplete combustion of biomass and fossil fuel. It mineralizes more slowly than unpyrolyzed organic matter, and was reported to accumulate in soils (Skjemstad et al., 1998; Swift, 2001). With such an important property, BC amendment to soil is currently taken into consideration as a potential way to combat global warming, which is caused by anthropogenic emissions of mainly carbon dioxide from

*Corresponding Author Email: vinhsfri@gmail.com

landuse changes and fossil fuel usages (IPCC, 2007). In addition, BC addition to soil also increased crop production through nutrient and water retention (Lehmann et al., 2002; Lehmann and Rondon, 2006). The loss of soil fertility in many mountainous provinces in Vietnam, as above explanation, has consequences for the agricultural productivity, especially for poor farmers who do not have knowledge and technology for better farming; they also cannot afford enough fertilizer. In mountainous areas this often results in using more sloping land, which again causes more erosion and reduced levels of soil fertility and low land productivity. Land allocation and clearance for farming, with essentially uncontrolled forest exploitation, has therefore resulted in shortage of local water resources.

The objectives of this study are to evaluate the agronomic value of biochar and biochar-compost mixtures for lowland rice and rainfed vegetable production.

## MATERIAL AND METHOD

### Materials

### Study sites

Study sites were selected from poor households living on mountainous areas in the Northern Vietnam. The selection of poor households was based on classification criteria in the Decision No. 9/2011/QD-TTG by the Prime Minister on issuance of applicable classification criteria of poor households, near poor household for period 2011-2015. During this period, households in rural areas with average income of VND 400,000/capita/month (from VND 4,800,000/capital/year) and less are considered to be poor class; near poor households with average income of VND 401,000 and 520,000/capital/month (The Prime Minister, 2011, MOLISA, 2012) .

Based on these criteria, 2 typically poor districts of Dinh Hoa and Ba Thuoc in 2 poor provinces of Thai Nguyen and Thanh Hoa were selected for the project. Thai Nguyen is one of the poorest provinces in Vietnam North upland areas with total households of 285790, of which, total poor households in the province are 58,791, comprising of 20.57%, total near poor households are 30,391, comprising of 10.63 %. Dinh Hoa district is the second poorest district in the province with total households of 24.147, of which 8,205 are poor households, comprising of 33.98% and 5,753 are near poor households, comprising of 23.82% (Thai Nguyen PPC, 2011). Meanwhile, the province with the largest number of poor households is Thanh Hoa with 182,439 poor households, comprising of 20.37% over total 895,816 survey households in the entire province (MOLISA, 2011) and Ba Thuoc district is the poorest district of the province.

The study has selected communes with quite high rate of poverty and main subjects are ethnic minority farmers. Binh Thanh and Boc Nhieu communes of Dinh Hoa district, Thai Nguyen province, Dien Quang commune of Ba Thuoc district, Thanh Hoa province are selected for the project. In Thai Nguyen province: Binh Thanh commune covers a natural area of 2464.6 ha with a population of 5760 people, including San Chi, Kinh (Viet) and Tay groups which are member of 1217 households, comprising of 42% poor households. Average income is 4.8 million VND/year. Boc Nhieu community covers a natural area of 2615.4 ha with a population of 4263 people, including San Chi, Kinh (Viet) and Tay groups. There are 1217 households, comprising of 37% poor households. Average income is 10 million VND/year, (President of Thai Nguyen province, 2011; MOLISA, 2011). In Thanh Hoa province: Dien Quang commune covers a natural area of 2562.8 ha with a population of 6963 people, including Muong and Kinh (Viet) groups. There are 1719 households, comprising of 55% poor households. Average income is 5.3 million VND/year, (MOLISA, 2011*).*

Climate condition in both sites is humid tropic. Period of 2007-2012, temperature ranges from 17.4$^{o}$C to 30.5$^{o}$C maximum value and 9.0$^{o}$C to 24$^{o}$C in minimum value at Thai Nguyen site, and 17.2- 32.3$^{o}$C in maximum value and 9.6-25.5$^{o}$C in minimum value, representatively at Thanh Hoa site. Annual average precipitation was 1738.5mm in Thai Nguyen and 2054.5mm in Thanh Hoa. Air humidity was 74.9-83.6% in Thai Nguyen and 76.2-95.6% in Thanh Hoa.

Soil types at study sites are classified as Plintic Acrisol for rice experiments and Haplic Acrisol for vegetable experiments, by USDA-FAO classification, in both sites. (Vietnamese society of soil science, 2000). Figure 1

### Materials

### Biochar properties

Biochar used in this study was produced by Top- Lid-Updraft (TLUD) technology improved by PED and SFRI. Raw materials for biochar productions were rice straw, bamboo and tree branches. The main characteristics of biochar were shown in table 1 below.

### Compost

Traditionally, compost was always used alone as organic manure for crop and soil improvement. When composted with biochar, organic materials such as animal dung and

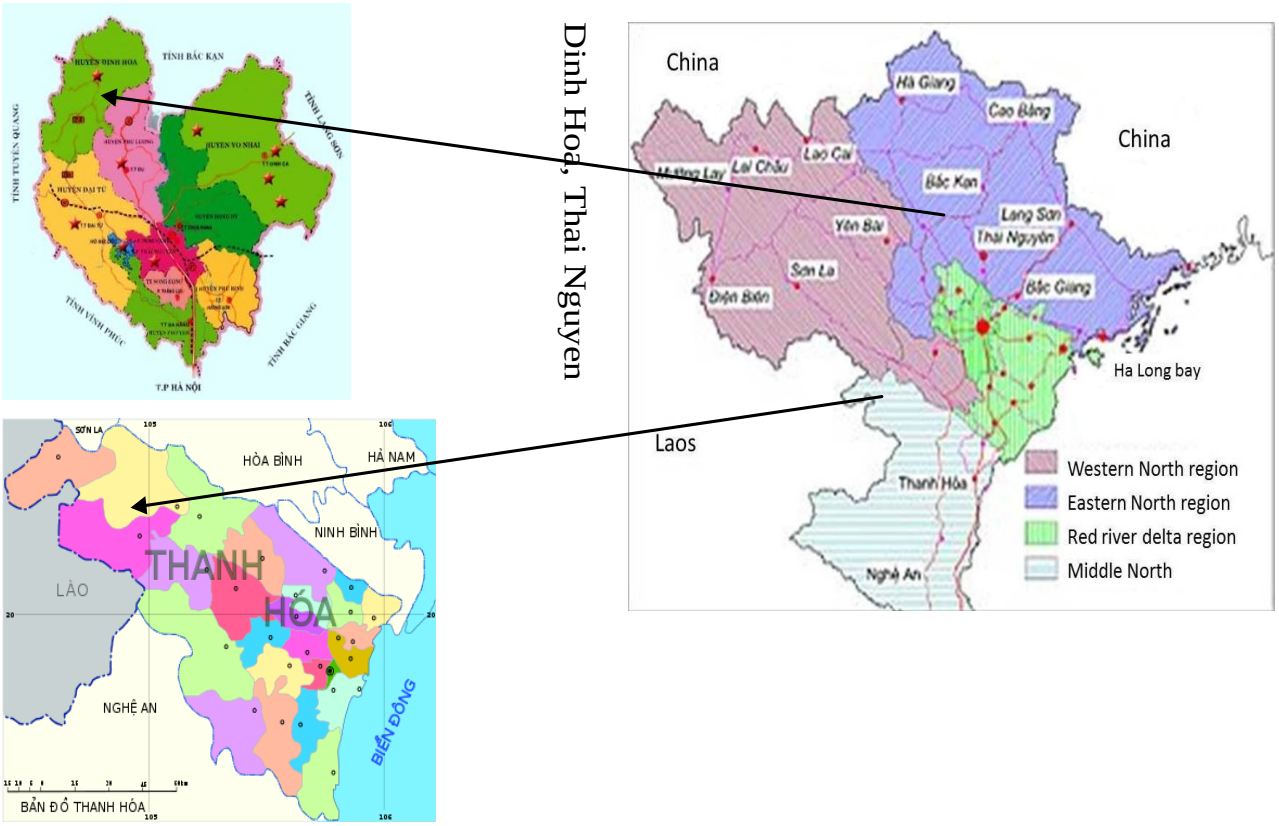


**Figure 1.** Experiment sites in the project areas

**Table 1.** Biochar characteristic in study sites

| Study site | pH | CEC, (cmol/kg) | $P_2O_5$ | $K_2O$ | Ca | Mg |
|---|---|---|---|---|---|---|
| | | | ----------(% dry weight)---------- | | | |
| Thai Nguyen | 9.3-9.6 | 7.27-10.43 | 0.09-0.36 | 0.68-2.71 | 0.56-1.24 | 0.12-0.30 |
| Thanh Hoa | 9.3-9.6 | 5.45-10.10 | 0.28-0.65 | 0.46-2.82 | 0.58-1.49 | 0.16-0.34 |

crop residues may decompose differently. In this study, compost for the 2 project sites was made of crop residues and buffalo dung, incubated to decompose in spring and summer seasons. Chemical analysis was shown in below table. For mixed biochar compost, Biochar was well mixed with animal dung and soft plant residues at the rate of 5 or 25% biochar by weight then composting. Table 2

## Plant variety

Plants used for this study included rice (*Oryza sativa*) and vegetables. Rice variety was Khang Dan in Thai Nguyen and Nhi Uu 838 in Thanh Hoa. Vegetables used for this study included Malabar nightshade (*Basella alba L*) in Thai Nguyen and Water morning glory (*Ipomoea aquatic Forssk.)* i) in Thanh Hoa.

## Methods

### Field trial for rice

Field trial for rice was conducted with 6 treatments and 3 replications on farmer field. Plot size was 30 $m^2$ (5m x 6m). Experiment was complete block design.
Treatments of the field trial:
T1. NPK
T2. Biochar (2.5 t/ha)
T3. NPK + Biochar (0.5 t/ha)
T4. NPK + Biochar (2.5 t/ha)
T5. NPK + Compost mixed with 5% biochar (10 t/ha)

### Demonstration of rice

The demonstration of rice was implemented in 6 different

**Table 2.** Compost characteristic in study sites

| Study site | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| | ----------(% dry weight)---------- | | |
| Thai Nguyen | 1.48- 1.68 | 1.04- 1.23 | 1.66- 1.77 |
| Thanh Hoa | 1.28- 1.45 | 0.78- 0.81 | 1.23- 1.51 |

farmer fields at 3 communes. The demonstration was designed with large plot including 2 treatments on each plot. One was for farmer's practices and another was for improved fertilization with biochar.

Treatments of demonstration:

T1. Farmers' practice

T2. Improved fertilization (NPK+10 tons of compost/ha with 5% biochar). Table 3

+ Compost used for experiment in 2 project sites is buffalo-dung mixed with soft plant residues (compost) and biochar. The compost was made by mixing compost, soft plant residues with biochar at the ratio of biochar of 5% by weight.

+ Raw materials for biochar production: In Thai Nguyen site, they were straw, bamboo and wood and they were rice husk, bamboo and wood in Thanh Hoa site.

+ Quantity of compost used for experiment: is 9.7 tons in Thai Nguyen site and 10.6 tons of compost/ha in Thanh Hoa site.

**Field trial for vegetable**

Field trial is conducted in home garden with 4 treatments and 4 replications. The trials were undertaken using a randomized complete block design.

+ Treatments for vegetable experiment:

T1. Farmers' traditional cultivation

T2. NPK+ 20 tons of compost/ha without biochar

T3. NPK+ 20 tons of compost/ha with 5% biochar

T4. NPK+ 20 tons of compost/ha with 25% biochar

Biochar was well mixed with FYM and soft plant residues before composting by the ratio of the former being 5 and 25% (w/w). The compost was applied for the crops after 45 days

*Demonstration of vegetables:

T1. Farmers' traditional cultivation

T2. NPK+ 20 tons of compost.Table 4

Demonstration was replicated in 3 times from 3 different home gardens as a block design.

+ Compost used for experiment in 2 project sites is buffalo-dung.

+ Raw materials for biochar production: In Thai Nguyen province, raw materials for biochar production is straw, bamboo and wood. They are rice husk, bamboo and wood in Thanh Hoa.

**Sample analysis**

**Biochar samples**

Biochar pH values were measured twice using a ratio of 1:20 w/w for biochar to water. The resultant mixture was shaken for 1.5 hours. Biochar C and N analyses as well as N isotope determination were performed after sample combustion to $CO_2$ and $N_2$ at 1,000°C (PDZ Europa ANCA-GSL, Crewe, UK).

Total P, Ca, Mg and K were obtained after dry ashing of 200mg biochar by heating to 500°C over 2 h and holding at 500°C for 8h. Added 5 ml $HNO_3$ to digest at 120°C until dryness. Cooling sample and adding 1.0 mL $HNO_3$ and 4.0 mL $H_2O_2$. Then heating at 120°C to dryness. dissolved sample with 1.43 mL $HNO_3$, made up with 18.57 mL deionized water to achieve 5% acid concentration, sonicated for 10 min, and filtered.

**Soil samples**

Before setting up the field experiments, soil samples were taken at the depth of 0-20cm from the fields where experiments for rice and vegetables were located in.

Soil samples were analyzed by Vietnamese standard methods. The codes of method are $pH_{KCl}$(1/5): TCVN 4401-1987, OC- Walkley Black: TCVN 378:1999; total and Kjeldahl (TCVN 4698:1999), total P: TCVN4052: 1985 and K: TCVN 4053: 1985, Available P- Bray No2: 10 TCVN 4052:1999 and K: TCVN 5254: 1985, Exchangeable $Ca^{2+}$, $Mg^{2+}$ and CEC: 10TCVN: 368: 1999.

**Compost samples**

Total N- Kjeldahl TCVN 8557:2010, P: TCVN 8563:2010, K: TCVN 8562:2010, Ca and Mg -AOAC .

**Plant samples**

Rice leaves were taken at flowering stage. Each sample was collected from 15 hills by 2 cross lines per plot. Leave sample was taken form 2 plants in each hill and 4

**Table 3.** Chemical fertilizers used for experiment and demonstration, (kg/ha)

| Treatment | In Thai Nguyen | | | | In Thanh Hoa | | | |
|---|---|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | Compost | N | $P_2O_5$ | $K_2O$ | Compost |
| - Spring rice | 90 | 60 | 60 | 10,000 | 120 | 60 | 60 | 10,000 |
| - Summer rice | 90 | 60 | 60 | 10,000 | 90 | 60 | 60 | 10,000 |

**Table 4.** Fertilizers in Demonstration (Kg/Ha)

| Treatment | In Thai Nguyen | | | In Thanh Hoa | | |
|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| 1. Improved treatment | 90 | 60 | 60 | 90 | 60 | 60 |
| 2. Farmer practice | 112 | 42 | 39 | 116 | 52 | 15 |

*Remark*: *Farmers' level is based on investigation data of farmers in project sites.*

leaves from the tip leave down the 4th leave were taken in each plant. Then, all leaves from 15 hills were well mixed for each sample per plot.

Plant samples were analyzed by Vietnamese standard methods. Total N- Kjeldahl 10 TCN 451: 2001; total P: 10 TCN 453: 2001; total K: 10 TCN 454: 2001; total Ca and Mg: 10 TCN 455: 2001.

## RESULT AND DISCUSSION

### Biochar treatment

In tradition, compost was always used alone as organic manure for crop and soil improvement. Composting with biochar, organic materials as animal dung and crop residues are quick discomposed and compost is softer and of good quality. In this study, compost was made of crop residues and buffalo dung, treated with different rates of biochar.

Compost with different biochar rates indicates that nitrogen content in compost in Thanh Hoa and Thai Nguyen sites seems to be similar. N content in compost is not different from compost without biochar and with low rate of biochar (5%). Increasing the rate of biochar to 25%, N content in compost is clearly reduced. Compost without and with 5% biochar has higher N content than that in compost with 25% biochar treated. Meanwhile, phosphorus content ($P_2O_5$) in the treatment with 25% biochar tends to be higher than that in other treatments. It is 0.88% in Thanh Hoa and 1.25% in Thai Nguyen. Compost with 5% biochar treatment consists of 0.81%$P_2O_5$ in Thanh Hoa and 1.06%$P_2O_5$ in Thai Nguyen. In comparison, total content of potassium ($K_2O$) in compost treated with 5% of biochar is higher than that in compost treated with 25% of biochar. There is insignificant difference in $K_2O$ content in the composts with different rate of biochar treated. It changes from 1.44 to 1.60%$K_2O$ in Thanh Hoa, and 1.44-1.60%$K_2O$ in Thai Nguyen, (Table 5).

Nevertheless, this is just primary results; there should be more researches on role of biochar with compost for evaluation and transfer of results to farmers. Humidity (Hu.) in the samples change in the range of 62-68.1% in Thai Nguyen and 61.3-69.8% in Thanh Hoa. The physical properties of the compost made with biochar were different to those of the compost made without biochar. There was no smell, the material had less water and was easier to transport and apply to the soil.

### Soil properties

Soil was sampled at the depth of 0-15 cm from the experimental field and analysed. The soil properties for rice experiment at study sites are presented in Table 6.

Study soils are very acidic with a pH of 4.4 in Thai Nguyen and with a pH of 5.1 at Thanh Hoa site. Cation Exchange Capacity (CEC) of soil in the 2 sites ranges from 11.70-17.60 cmol/kg soil. Extractable Al ($Al^{3+}$) in the soil at 2 project sites varies between 0.18- 0.35cmol/kg soils. Exchangeable content of $Mg^{2+}$ grade in soil at 2 project sites is quite similar, varying from 0.76 to 0.94 cmol/kg soil, meanwhile $Ca^{2+}$ in Thanh Hoa area (6.21 cmol/kg soil) is almost 3 times higher than that in Thai Nguyen soil (2.31 cmol/kg soil). Results of analysis of mechanical composition indicate that soil in these 2 areas is heavy soil with extractable iron changing from 17.2-25.7%, lime is about 31.1-38.3%, sand fraction accounts for 43.2-44.5%. Soil texture is characterized by sandy loam, with sandy fraction more than 40% and silt fraction is 31- 38%.

**Table 5.** Nutrient content in compost alone and compost with biochar (after incubation for 45 days).

| Treatment | Thai Nguyen, (% of dry substance) | | | | Thanh Hoa, (% of dry substance) | | | |
|---|---|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | Hu.% | N | $P_2O_5$ | $K_2O$ | Hu.% |
| 1. Compost (Compost) | 1.41 | 0.44 | 1.34 | 68.1 | 1.37 | 0.33 | 1.33 | 69.8 |
| 2. Comp.+ 5% biochar | 1.48 | 0.46 | 1.47 | 64.1 | 1.45 | 0.35 | 1.25 | 65.0 |
| 3. Comp.+ 25% biochar | 1.29 | 0.55 | 1.26 | 62.0 | 1.18 | 0.38 | 1.20 | 61.3 |
| CV% | 4.43 | 5.87 | 5.20 | | 5.36 | 6.52 | 7.05 | |
| LSD 0.05 | 0.14 | 0.06 | 0.16 | | 0.16 | 0.05 | 0.20 | |

**Table 6.** Properties of the study soils for rice experiments at study sites before experiment

| Parameter | Thai Nguyen | Thanh Hoa | Parameter | Thai Nguyen | Thanh Hoa |
|---|---|---|---|---|---|
| $pH_{KCl}$(1/5) | 4.40 | 5.10 | Available $P_2O_5$ (mg/100g soil) | 6.79 | 2.32 |
| Total OC, (%) | 1.70 | 2.70 | Available $K_2O$, (mg/100g soil) | 19.52 | 27.72 |
| Total N, (%) | 0.17 | 0.31 | Exch. $Ca^{2+}$, (cmol/100g soil) | 2.31 | 6.21 |
| Total $P_2O_5$, (%) | 0.07 | 0.07 | Exch. $Mg^{2+}$, (cmol/100g soil) | 0.94 | 0.76 |
| Total $K_2O$, (%) | 0.66 | 2.01 | Exch. $Al^{3+}$, (cmol/100g soil) | 0.35 | 0.18 |
| - | - | - | CEC, (cmol/100g soil) | 11.70 | 17.60 |
| Clay content, (%) | 17.2 | 25.7 | Fine sand, (%) | 41.3 | 40.2 |
| Silt content, (%) | 38.3 | 31.1 | Coarse sand, (%) | 3.2 | 3.0 |

Vegetable experiments ware set up on in home garden. Soil properties are presented in Table 7.

Soils are acidic with pH values of 4.5 and 4.72. Total soil organic carbon is low, and total N is medium rates.

Total phosphorus is 0.05-0.08%. Total potassium is 0.53-68%$K_2O$. Available phosphate and potassium is low, 2.13-3.28mg/100g, $K_2O$ is 0.71-1.54 mg/100g. Cation Exchange Capacity of soil (CEC) is low in Thanh Hoa soil (9.34cmol/kg soil) and medium in Thai Nguyen soil (11.35 cmol/kg soil).

## Effects of biochar to rice

### Effect of biochar application on the nutrient concentration of rice

leaves were used for analysis. 20 hills were selected in each plot; 3 rice plants were selected in each hill; 4 leaves including flag leave were selected and 3 leaves below flag leaf Analysis results indicate that effects of biochar to the nutrient uptake of rice.

In Thai Nguyen: In comparison, application of 2.5 tons /ha biochar (T2) content of N in rice leaves was less significant less when biochar was applied alone at 2.5 tons/ha (T2) (2.03%), than when NPK was applied on its own (the control, T1, 2.27%). . There was no significant increase in N uptake with both NPK + 0.5 t/ha BC (2.35%) and NPK + 2.5 t/ha BC (2.36%) compared to field without biochar application. The best results were obtained when NPK + 10 tons compost (made with BC, see above) were added to the soil (2.49%).

Adding 0.5 t/ha biochar to NPK did not change P uptake. BC on its own and the compost mixture, however, increased the phosphorus content by small but significant amounts. Potassium concentrations did not change.

In Thanh Hoa site, the addition of BC alone at 2.5 t/ha did not change the N content of leaves. Both treatments with biochar and NPK, significantly increased the nitrogen uptake to 3.57% for NPK + 0.5 t/ha BC and 3.33% for NPK + 2.5 t/ha BC, compared with the control (2.80%). The highest N content was for NPK + 0.5 t/ha BC and similar was NPK + 10 t compost at 3.50%. For phosphorus uptake, there is very little difference between any of the treatments; they range from 0.42% to 0. 48% with the control being 0.46%. Only the compost-biochar mixture increased the foliar K concentrations. Table 8

### Effects of biochar on rice yield (Table 9)

Results of initial rice experiment indicate that in Thai Nguyen, spring rice yield using treatments 0.5 ton biochar and 2.5 tons biochar with NPK are not statically different, changing between 6.60-7.10 tons/ha. The highest yield was obtained in treatment in which NPK+

**Table 7.** Properties of soil at the home garden before vegetable experiments

| Sites | pH | Total content, (%) | | | | Available, (mg/100g) | | CEC, (cmol/kg) |
|---|---|---|---|---|---|---|---|---|
| | | OC | N | $P_2O_5$ | $K_2O$ | $P_2O_5$ | $K_2O$ | |
| Thanh Hoa | 4.50 | 1.65 | 0.12 | 0.05 | 0.68 | 3.28 | 0.71 | 9.34 |
| Thai Nguyen | 4.72 | 1.73 | 0.16 | 0.08 | 0.53 | 2.13 | 1.54 | 11.35 |

**Table 8**. Nutrient content in the rice leaves at flowering stage (%), (Spring rice)

| Treatment | In Thai Nguyen | | | In Thanh Hoa | | |
|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| 1. NPK | 2.27b | 0.28a | 2.76bc | 2.80b | 0.46b | 2.32b |
| 2. Biochar. (2.5tons./ha) | 2.03a | 0.33bc | 2.63ab | 2.66ab | 0.42b | 2.40b |
| 3: NPK+0.5 tons biochar | 2.35b | 0.26a | 2.46ab | 3.57d | 0.48b | 2.33b |
| 4: NPK+2.5 tons biochar | 2.36b | 0.31ab | 3.02c | 3.33c | 0.45b | 2.50bc |
| 5: NPK+10 tons compost | 2.49c | 0.39c | 2.48ab | 3.50d | 0.48b | 2.77c |
| CV,% | 2.8 | 9.40 | 6.80 | 2,7 | 8,1 | 6,7 |
| LSD, 5% | 0.12 | - | 0.32 | 0.15 | | 0,29 |

**Table 9.** Effect of biochar to rice yield in Thai Nguyen (tons/ha)

| Treatment | Spring rice | Summer rice | Mean (tons/ha) | (%) |
|---|---|---|---|---|
| 1: NPK | 6.23bc | 4.85ab | 5.54 | 100 |
| 2: 2.5 tons biochar | 4.69a | 3.98a | 4.34 | 78.2 |
| 3: NPK + 0.5 tons biochar | 6.60bc | 5.27b | 5.94 | 107.1 |
| 4: NPK + 2.5 tons biochar | 7.10cd | 6.45c | 6.78 | 122.3 |
| 5: NPK + 10 tons compost | 7.87d | 6.53c | 7.20 | 130.0 |
| LSD, 5% | 0.98 | 0.90 | | |
| CV, % | 8.40 | 9.20 | | |

10 tons of compost were applied for rice. In summer rice (second season), rice yield in treatment with 2.5 tons biochar/ha was significant higher than 0.5 tons biochar/ha and control treatment (NPK). The lonely application of 2.5 tons biochar/ha, grain yield was reduced by 24.7% in spring rice and but unchanged for summer rice.

However, when biochar is composted with manure at the rate of 5% and using at the rate of 10 tons compost with NPK, it reaches the highest yield, reaching 7.87 tons/ha. As for previous rice crop, rate of spraying 2.5 ton biochar + NPK and 10 tons compost (5% biochar) + NPK is the same in yield with yield changing between 6.45-6.53 tons/ha and with significant difference compared with treatment 0.5 ton biochar + NPK that only yields 5.27 ton/ha in summer rice. Table 10.

In Thanh Hoa, the situation is similar to in Thai Nguyen. In spring rice, lowest yield was obtained with biochar alone at rate 2.5 tons/ha. Yields in treatments 4 and 56 were significant different, compared with treatment 2, but were not statistically different between treatments, with yield changing 7.50-8.47 tons/ha, an increase of 9.3-23.4% compared with control plots in spring season. In treatment 4 and 5, rice yield was significant higher than that in treatment 3 and control plot.

For summer rice, yield of rice applying treatments 5 and 6 are the same with yield changing within 5.39-5.67 tons/ha, a significant difference in comparison with treatment 4. However, application of 0.5 ton biochar + NPK, rice yield of 2 seasons is not different from adding only NPK. The lonely application of 2.5 tons biochar/ha, grain yield was reduced by 25.5% in spring rice and 12.5% in summer rice.

In the both seasons and sites, application of 2.5 tons/ha biochar without NPK was lower rice yield than that in treatment with NPK applied (treatment 1).

**Table 10.** Effect of biochar to rice yield in Thanh Hoa

| Treatment | Spring rice | Summer rice | Mean (tons/ha) | (%) |
|---|---|---|---|---|
| 1: NPK | 7.02b | 4.43b | 5.73 | 100 |
| 2: 2.5 tons biochar | 5.09a | 3.85a | 4.47 | 78.1 |
| 3: NPK + 0.5 tons biochar | 7.50bc | 4.62b | 6.06 | 105.9 |
| 4: NPK + 2.5 tons biochar | 8.14bc | 5.39c | 6.77 | 118.2 |
| 5: NPK + 10 tons compost | 8.47c | 5.67c | 7.07 | 123.5 |
| LSD, 5% | 1.29 | 0.42 | | |
| CV, % | 9.90 | 4.9 | | |

**Table 11.** Effects of biochar on vegetable yields on 2 study sites

| Treatment | Thai Nguyen (*Basella alba* L.) | | Thanh Hoa (*Ipomoea aquatic* Fossk) | |
|---|---|---|---|---|
| | ton/ha | % | ton/ha | % |
| 1. Farmers' practice | 14.33 a | 100 | 16.83 a | 100 |
| 2. Compost without biochar + NPK | 17.67 b | 123.3 | 22.43 b | 133.3 |
| 3. Compost with 5% biochar + NPK | 17.50 b | 122.1 | 22.80 b | 135.5 |
| 4. Compost with 25% biochar + NPK | 15.00 ab | 104.7 | 17.88 a | 106.2 |
| CV,% | 8.3 | | 11.0 | |
| LSD, 5% | 2.66 | | 3.52 | |

However, the effectiveness trends to increase from spring to summer season.

### Effect of biochar application on vegetable yield

Results of vegetable experiment indicate that at both sites, addition of compost with or without 5% biochar increased vegetable yields compared to farmer practice, but not with 25% biochar. Table 11.

## CONCLUSION

Improvements of crop yields with biochar additions under flooded rice conditions increased over time. Future research should clarify whether this is a seasonal effect or in fact rooted in improved efficiency with time. However, vegetable yields could not be improved, despite likely mitigation of acid soil conditions by the biochar. The effect of biochar on composting and the quality of the compost product remains unclear.

## ACKNOWLEDGEMENTS

This study was funded by Denmark Care through "Energy and Environment Partnership– EEP", International CARE – Vietnam, Soil and Fertilizer Research Institute and Centre of Population Environment Development implemented project "*The Piloting Pyrolytic Cookstoves and Sustainable Biochar Soil Enrichment in Northern Vietnam Uplands project"; Reference code- 3-V-048.*

## REFERENCE

Hartemink AE (2005). Poor soils make poor people and poor people make the soil worse. Workshop on "Management of tropical sandy soils for sustainable agriculture. A holistic approach for sustainable development of problem soils in the tropic. 27th Nov. -2nd Dec. Khonken, Thailand.

Lehmann J, da Silva Jr JP, Rondon M, Cravo MS, Greenwood J, Nehls T, Steiner C, Glaser B (2002). Slash-and-char- a feasible alternative for soil fertility management in the central Amazon? 17th World Congress of Soil Science, Bangkok, Thailand. CD-ROM Paper no. 449, p. 1-12.

Lehmann J, Rondon M (2006). Bio-char soil management on highly weathered soils in the humid tropics. In Uphoff N et al. (ed.) Biological Approaches to Sustainable Soil Systems. CRC Press, Boca Raton, FL. pp.517-530.S

President of Thai Nguyen province (2011). Decision No.04/2011/QD-UBND, dated January 28, 2011 by the People's Committee of Thai Nguyen province on approval of census on poor households and near poor households in Thai Nguyen for 2011-2015 periods.

The Minister of Labour – War Invalids – Social Affairs (MOLISA) (2012). Approving the results of investigation and check of poor

household, near poor households in 2011. Decision No. 375/QĐ-LĐTBXH dated March 28.
The Prime Minister (2011).Decision No. 9/2011/QD-TTG by the Prime Minister: on issuance of applicable standards for poor ad poor households for 2011 – 2015 periods, dated January 30.
Vietnam Society of Soil Science (2000). Vietnam soils. Agricultural publishing house. Hanoi.

Vinh N C, HIen N V, Anh M T L, Lohan L, Stephen J (2014). Biochar Treatment and its Effects on Rice and Vegetable Yields in Mountainous Areas of the Northern Vietnam. Int. J. Agric. Soil Sci. Vol. 2(1):5-13