Biochar and biodigester effluent increase the yield of Yardlong bean (*Vigna unguiculata*) and improve soil properties

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ບົດຄັດຫຍໍ້

ການນຳໃຊ້ຖ່ານຊີວະພາບເຂົ້າໃນການປັບປຸງຄວາມອຸດົມສົມບູນຂອງດິນ ແລະ ຍົກສະມັດຕະພາບຂອງຜົນຜະລິດພືດກຳລັງເປັນທີ່ໄດ້ຮັບຄວາມສົນໃຈຈາກທົ່ວໂລກ ໂດຍມີຈຸດປະສົງເພື່ອຫຼຸດຜ່ອນການເສື່ອມຄຸນນະພາບຂອງດິນໃນຂະນະດຽວກັນ ທັງເປັນການຫຼຸດຜ່ອນບັນດາທາດອາຍເຮືອນແກ້ວອີກດ້ວຍ. ເຖິງຢ່າງໃດກໍຕາມ, ຂໍ້ມູນທີ່ໄດ້ຮັບຈາກການສຶກສາພາຍໃຕ້ຫົວຂໍ້ດັ່ງກ່າວຍັງມີລັກສະນະຈຳກັດ ໂດຍສະເພາະແມ່ນການນຳໃຊ້ຖ່ານຊີວະພາບກັບພືດຜັກ. ການທົດລອງຄັ້ງນີ້ໄດ້ຈັດຕັ້ງປະຕິບັດຂຶ້ນທີ່ ສູນທົດລອງກະສິກຳແບບປະສົມປະສານ, ມະຫາວິທະຍາໄລຈຳປາສັກ, ສປປ ລາວ ເພື່ອສຶກສາເຖິງຜົນຈາກການນຳໃຊ້ຖ່ານຊີວະພາບຮ່ວມກັບນ້ຳເສດເຫຼືອຈາກບໍ່ໝັກຂີ້ໝູເພື່ອຜະລິດແກັສຊີວະພາບຕໍ່ກັບຄຸນສົມບັດຂອງດິນ ແລະ ຜົນຜະລິດຂອງໝາກຖົ່ວຝັກຍາວ. ການທົດລອງຄັ້ງນີ້ ໄດ້ຈັດເຂົ້າໃນຮູບແບບການທົດລອງແບບສຸ່ມສົມບູນພາຍໃນບລັອກ (RCBD) ລວມມີທັງໝົດ 6 ຈຸທົດລອງ ແລະ 4 ຊ□້າ ທີ່ມາຈາກ 2 ປັດໄຈການທົດລອງຄື: 1). ການນຳໃຊ້ຖ່ານຊີວະພາບໃນ 2 ລະດັບ: 0 ແລະ 40 ໂຕນ/ຮຕ ແລະ 2). ແມ່ນການນຳໃຊ້ນ້ຳເສດເຫຼືອຈາກບໍ່ໝັກຂີ້ໝູເພື່ອຜະລິດແກັສຊີວະພາບໃນ 3 ລະດັບແຕກຕ່າງກັນຄື: 0, 50, ຫຼື 100 ກລ N/ຮຕ. ຂໍ້ມູນທີ່ໄດ້ເກັບກຳຈາກການທົດລອງຄັ້ງນີ້ປະກອບມີຄຸນສົມບັດທາງດ້ານຟີຊິກຂອງດິນ, ອົງປະກອບຂອງຜົນຜະລິດ ແລະ ຜົນຜະລິດຂອງໝາກຖົ່ວຝັກຍາວ.

ການນຳໃຊ້ຖ່ານຊີວະພາບ ແລະ ນ້ຳເສດເຫຼືອຈາກບໍ່ໝັກຂີ້ໝູສາມາດເພີ່ມຜົນຜະລິດຂອງໝາກຖົ່ວຝັກຍາວຂຶ້ນເຖິງ 50% ເມື່ອສົມທຽບກັບຈຸທົດລອງທີ່ບໍ່ໄດ້ໃສ່ຫຍັງ. ຈຳນວນຝັກລີບຂອງໝາກຖົ່ວຫຼຸດລົງເຖິງ 2 ເທົ່າໃນຈຸທົດລອງທີ່ນຳໃຊ້ຖ່ານຊີວະພາບ 40 ໂຕນ/ຮຕ. pH ຂອງດິນໄດ້ຮັບການປັບປຸງໃຫ້ດີຂຶ້ນພາຍຫຼັງການນຳໃຊ້ຖ່ານຊີວະພາບ. ຄວາມສາມາດໃນການອຸ້ມນ້ຳຂອງດິນມີລັກສະນະເພີ່ມຂຶ້ນຢ່າງເຫັນໄດ້ຈະແຈ້ງພາຍຫຼັງທີ່ນຳໃຊ້ຖ່ານຊີວະພາບລົງໃນດິໃນທຸກຈຸທົດລອງທີ່ນຳໃຊ້ນ້ຳເສດເຫຼືອຈາກບໍ່ໝັກຂີ້ໝູ ເຊິ່ງຂໍ້ມູນດັ່ງກ່າວເປັນສັນຍານທີ່ດີເພື່ອຊ່ວຍເຂົ້າໃນການນຳໃຊ້ນ້ຳໃນການປູກຝັງໃຫ້ມີປະສິດທິຜົນສູງ.

ຄຳສຳຄັນ: ຖ່ານຊີວະພາບຈາກແກບເຂົ້າ, ຄຸນສົມບັດຂອງດິນ, ຄວາມສາມາດອຸ້ມນ້ຳຂອງດິນ

Abstract

Biochar application to improve soils fertility and crop yield has been increasingly concerned worldwide to combat soils degradation while mitigating the greenhouse gases. However, the effects have not been determined in a wider range of crops especially vegetables. This experiment was carried out at the Integrated Farming Demonstration Centre, Champasack University, Lao PDR to determine the effects of biochar and biodigester effluent on soil properties and yield of Yardlong bean. Six treatments were arranged in a randomized complete block design (RCBD) as a 2*3 factorial with 4 replications. The factors were: 1) biochar application rate at 0 or 40t/ha; and 2) level of biodigester effluent: 0, 50 or 100 kg N/ha. Biochar was obtained from rice husk in the Top Lid Updraft (TLUD) gasifier stove, and effluent was collected from a "plug-flow" tubular polyethylene biodigester. Measurement of soil physical properties, yield component, and yield ofYardlong bean were performed.

Application of biochar and effluent increased the yield of Yardlong bean by 50% compared to the control treatment. Empty pods of the bean were reduced 2 fold when biochar was applied at 40t/ha. Soil pH was improved due to biochar amendment. Water holding capacity of the soil was significantly increased when biochar was applied at all levels of effluent which could be a good sign for water efficiency usage.

Keywords: rice husk biochar, soil properties, and water holding capacity

Introduction

The world is faced with major global changes i.e. resource depletion and climate change (global warming), all of which are undermining world food economy while the world population is increasing considerably. In order to tackle these challenges, there is an urgent need to produce and deliver food to maintain the present world population (Leng 2009).

At the same time, soil deterioration from depletion of organic matter is an increasingly serious global problem that contributes to hunger and malnutrition. The soil organic matter is quickly decomposed into carbon dioxide by soil microbes and then it released into the atmosphere when the soil is intensively cultivated with high levels of chemical fertilization leaving the soil compacted and nutrient-poor as well as adding to global warming (Guo, 2008).

The Lao PDR is primarily an agricultural economy, with this sector contributing 51 percent of the GDP. Approximately 1,880,000 individuals are involved in agricultural work. The basic staple of such farmers is the production of sticky rice for local consumption. In terms of tons of agricultural production, the top 5 crops in Laos in order of importance are rice, vegetables and beans, sugarcane, starchy roots, and tobacco. Yardlong bean is a kind of vegetables that have been grown and eaten by the Lao people for many years and spread nationwide. It can be eaten raw (fresh) or as part of the ingredient for cooking such as salad (Tam mak thua) and another kind of soup.

The fertility of soils is important in agriculture particularly in making decisions on planting of crops. To promote the production of the agricultural sector, the improvement of soil fertility is considered to be the key to enhanced crop yield. Biochar is the by-product from processes such as gasification and pyrolysis where biomass is heated to high temperatures in situations where the supply of oxygen is limited. Biochar is composed of the residual mineral matter from the original biomass and carbon resulting from the incomplete combustion of the biomass. Because of the high temperatures (from 600 to 1000°C) reached in the gasification and pyrolysis processes, the physical and chemical properties of the carbon-rich residue in biochar are changed. According to Glaser (2007, p.188) the carbon in biochar is intimately associated with "poly-condensed aromatic moieties are the backbone of charcoal (black carbon) and assumed to be responsible for its chemical and biological recalcitrance in the environment". Glaser (2007) also emphasized the importance of the highly porous structure of biochar as responsible for its high capacity to adsorb organic molecules. When added to soil it can significantly improve soil fertility and also act as a sink for carbon (Lehmann, 2007).

The agronomic benefits of biochar have usually been shown to be greater in dry, sandy and nutrient poor soils. There are many such soils in the developing world, and there are also large numbers of people whose main source of food and income is small scale agriculture. In these types of environment it is hoped that biochar could improve crop productivity and soil quality, which will only become more important as the effect of climate change become more marked. The increment in crop yield with biochar application has been reported in many kind of crops such as cowpea (Yamato et al., 2006), soybean (Tagoe et al., 2008), maize (Yamato et al., 2006; Rodríguez et al., 2009), water spinach (Southavong et al., 2012a), upland rice (Asai et al., 2009), paddy rice (Zhang et al., 2012).

Biodigester effluent is a nutrient-rich fertilizer derived from anaerobic biodigestion of excreta from livestock; it contains a high proportion of the nitrogenous constituents as ammonium salts. Pedraza et al (2002) observed that the proportion of ammonia-N in the effluent from plug-flow, tubular plastic biodigesters was in the range of 0.65 to 0.75. Similar findings were reported by San Thy and Phen Buntha (2005). In their study, the proportion of ammonia-N to total-N increased from 0.077 to 0.12 in fresh pig manure to 0.46 to 0.65 in the effluent. The combination of biodigester effluent and biochar therefore should be synergistic in improving soil fertility and plant growth. When applied to crops, it can lead to increases in biomass yield and a higher content of crude protein, as seen in Chinese cabbage (San Thy and Pheng Buntha 2005), water spinach (Kean Sophea and Preston 2001; Ho Bunyeth and Preston 2004; Nguyen Van Hiep and Preston 2006), mulberry (Phiny et al 2009), cassava (Le Ha Chau 1998), maize (Rodríguez et al 2009; Sokchea and Preston 2011; Southavong et al 2012b) and rice (Southavong and Preston 2011), taro (Vivasane et al 2012) and French beans (Saxena et al 2013).

Objectives

Objectives of the study are two-hold. First of all, the study determines the effects of biochar and level of biodigester effluent on growth and yield of yardlong bean. Second, the study investigates the effect of biochar on soil physical properties (water holding capacity and soil pH).

Materials and Methods

Location and duration

The trial was conducted at the Integrated Farming Demonstration Centre, Champasack University, about 15 km far from Pakse City, Champasack province, Laos. The experiment covered a period of 6 months from Nov 2013 to May. The climate in this area is tropical monsoon with a rainy season between May and October and a dry season from November to April. The mean air temperature is 28.2°C. Average annual rainfall is 2,000mm/year.

Experimental design

Six treatments were arranged in a randomized complete block design (RCBD) as a 2*3 factorials with 4 replications (24 experimental units in total).

The factors were:

- Biochar application rate: with or without at $4kg/m^2$
- Level of effluent: 0, 50 or 100 kg N/ha

Individual treatments were:

- B0E0: Biochar at $0kg/m^2$ + Effluent at 0 kg N/ha
- B0E50: Biochar at $0kg/m^2$ + Effluent at 50 kg N/ha
- B0E100: Biochar at $0kg/m^2$ + Effluent at 100 kg N/ha
- B4E0: Biochar at $4kg/m^2$ + Effluent at 0 kg N/ha
- B4E50: Biochar at $4kg/m^2$ + Effluent at 50 kg N/ha
- B4E100: Biochar at $4kg/m^2$ + Effluent at 100 kg N/ha

Table 1 Experimental layout

Rep I	B0E0	B4E0	B0E50	B4E100	B0E100	B4E50
Rep II	B4E0	B0E50	B4E100	B0E100	B0E0	B4E50
Rep III	B0E0	B4E100	B4E0	B4E50	B0E100	B0E50
Rep IV	B4E0	B4E50	B0E100	B4E100	B0E50	B0E0

Model

The model of this research was:

- $Y_{ij} = \mu + b_i + \tau_j + \varepsilon_{ij}$

Where:

Yij = i^{th} observation in treatment j block i, j = 1…t, i = 1…n
μ = population mean
b_i = effect of block i
τ_j = difference in response for the j^{th} treatment relative to the population mean
ε_{ij} = deviation from treatment j population mean for observation i of that treatment

Experimental materials

Biochar (Photo 1) was produced locally by burning rice husk in the Top Lid Updraft (TLUD) gasifier stove (Photo 2). The effluent was taken from biodigester of a “plug-flow” tubular polyethylene with UV filter (5 m^3 liquid volumes) (Photo 3) charged daily with washing (1.5 m^3) from pig pen holding on average 20 pigs of 50 kg mean live weight. The pigs are mainly fed by local available feed i.e. rice bran and taro silage. Yardlong bean seeds were bought locally from the market.

Figure. 1. Biochar produced from gasifier stove

Figure. 2. The TLUDgasifier stove developed in Vietnam (Olivier, 2010)

Figure. 3. The plug-flow tubular polyethylene biodigester

Land preparation and planting

Land was ploughed (15-20cm depth) using two wheels tractor and dried out under sunlight for 7 days to eliminate weeds. Biochar was applied to the soil before planting at the rate of 4kg/m^2. The spacing between plants was 0.3m and 0.6m between rows, the plot size was 2.5*3.6m (9m^2) plants and the total area was 274.55m^2. Seeds were sowed directly into the holes about 3 seeds/hole. After 7 days of germination 1 or 2 plant(s) was removed to keep only one plant for further data collection.

Staking

Yard-long bean is a climbing plant and requires support for best production. Bamboo poles of about 150-175 cm high were set about 10 cm apart from the plant (Photo 4).


Figure. 4 .Yardlong bean staking

Fertilizing

The biodigester effluent was applied at the beginning and every 7 days interval after planting until 42 days of age (7 times in total). The quantities was calculated according to the N content of the effluent to give the equivalent of 50 or 100 kg N/ha or (5 or 10 g N/m^2). Effluent was analysed for N before application to the plot each time.

Data collection

The yardlong bean was harvested at the maturing stage and weighing for fresh yield for 4 times. Numbers of pods per plant, length of pods, pod circumstance, the percentage of filled and empty pods have also been measured. Water holding capacity and pH of the soil was determined at the beginning and at the end of the trial.

Chemical analysis

The DM content of soil samples and biochar were determined using the micro-wave radiation method of Undersander et al (1993). Organic matter (OM) and N of soil and effluent was determined by AOAC (1990) methods. The pH of the soil, biochar and biodigester effluent was determined using digital pH meter.

Statistical analysis

The data was analyzed according to the General Linear Model option in the ANOVA programme of the Minitab (2000) software. Sources of variation were biochar, level of effluent, interaction biochar*level of effluent, block and error. Tukey test in the Minitab software was used to separate mean values that differ when the F-test is significant at $P<0.05$.

Results and Discussion

Chemical composition of experimental materials

The pH content of the biochar and effluent (Table 2) was similar to that reported by Southavong and Preston (2011). The OM content of biochar (Table 2) was similar to that reported by Vivasane et al (2012). The N content of the effluent was much lower compared to the result reported by Rodríguez et al (2009), Southavong and Preston (2011) and Sokchea and Preston (2011). The reason for this may have been the more dilute influent to the biodigester as a result of washing the pens frequently, the lower number of pigs and the concentration of the N in the pigs' feed.

Table 2: Chemical composition of experimental materials

Composition	DM, %	N, mg/litre	OM, % in DM	pH
Soil	88.9	200	NA	4.68
Biochar	87.8	-	15.8	9.54
Effluent	NA	390	NA	6.81

NA: Not analysed

Effect of biochar and effluent on yield and yield component of yardlong bean

The increment in yield and yield components of Yardlong bean due to the application of biochar in combination with biodigester effluent are presented (Table 3; Figure 1). The the results clearly show that the increase of yield was due to the increment of the yield components; for instance, pod length, pod circumference, percentage of filled and empty pods when biochar and biodigester effluent were applied especially at the level of 4 kg/m^2 and 100 kg/ha respectively. The improvements of the Yardlong bean production from this experiment are similar to those reported in the literature by Southavong et al (2012a) with water spinach (*Ipomoea aquatica*) when effluent was applied at 5 different levels (0, 25, 50, 75 and 100, N kg/ha) in combination with biochar at 0 or 4 kg/m^2; and Chhay Ty et al (2013) with mustard green (*Brassica juncea*) where biochar was applied at 0 or 4 kg/m^2 together with effluent from biodigester at 0, 2.5, 5.0, 7.5 and 10 kg N/ha, respectively. This effect of biochar is in agreement with reports by Glaser et al (2002), Sombroek et al (2003), Lehmann et al (2003), Lehmann and Rondon (2005), Lehmann (2007) and Lehmann and Joseph (2009) that when biochar is applied to soil it helps to retain the nutrients which remain available to plants thus increasing the plant growth and yield. The increment in CEC of the soils was also described by Liang et al (2006) which is one of the most important processes regarding the improvement of the soil fertility hence it increases the crop yield.

Table 3: Effects of biochar and effluent on yield and yield component of Yardlong bean

	Pod's length, cm	Pod's circum-stance, cm	Pod/plant	Fresh weight/ plant	% filled pod	% empty pod	Yield kg/ 9m²	Yield kg/ha
Biochar application rate, kg/m²								
B0	33.4[b]	2.2[b]	16	14.0[b]	82.1[b]	17.9[b]	4.18[b]	4,639[b]
B4	38.4[a]	2.5[a]	17	16.9[a]	92.0[a]	8.16[a]	5.59[a]	6,213[a]
Prob	0.0001	0.0001	0.56	0.0001	0.0001	0.0001	o.018	0.018
SEM	0.74	0.05	0.11	0.52	1.51	1.51	0.46	511
Effluent application, kg N/ha								
0	31.1[b]	2.21[b]	3.28	11.6[c]	77.7[b]	22.3[b]	3.70	4,107[b]
50	37.4[a]	2.36[b]	3.53	16.2[b]	91.3[a]	8.59[a]	4.72	5,248[b]
100	39.2[a]	2.51[a]	3.27	18.5[a]	92.1[a]	8.20[a]	6.23	6,924[a]
Prob	0.0001	0.003	0.39	0.0001	0.0001	0.0001	0.005	0.005
SEM	0.9	0.06	0.14	0.63	1.51	1.85	0.65	723
Prob (interactions)								
B*E	0.097	0.0001	0.026	0.071	0.004	0.004	0.624	0.624
SEM	1.27	0.08	1.52	0.89	2.61	2.62	0.53	509

B: Biochar, E: Effluent level, Prob: Probability

Means in the same column without common letters are significantly different (P<0.05)

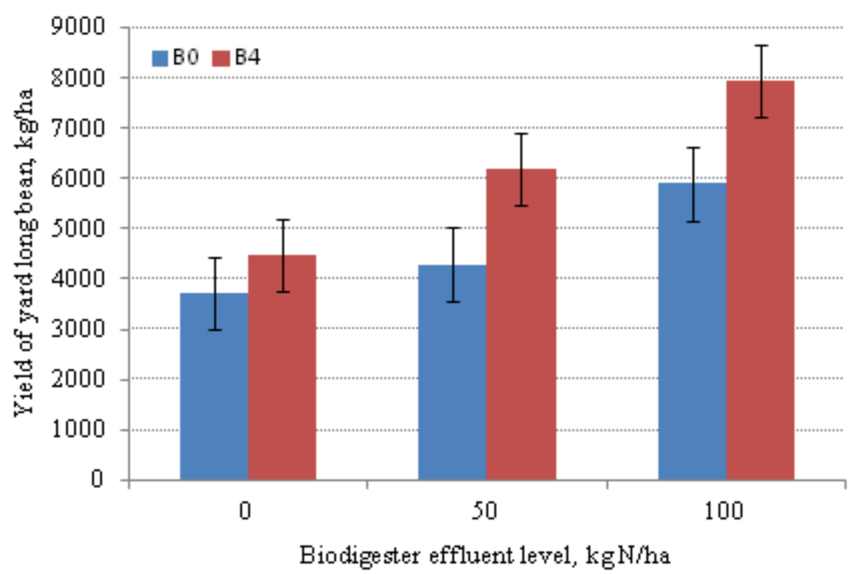

Figure. 5. Effects of biochar and effluent on yield of yardlong bean (B0 = no biochar; B4 = 4 kg biochar/m^2)

Effects of biochar and effluent on water-holding capacity and soil pH

Water holding capacity of the soil was increased by 20% (Table 4 and Figure 3) when biochar was added to the soil. There was also an improvement in WHC when effluent was increased to 100 kg N/ha. The level of improvement with biochar was similar to that reported by Vivasane et al (2012) but it was considerably lower than the value reported by Southavong et al (2012b) when 4% (by weight) biochar was added to the soil. Chan et al (2007) showed that biochar application improved some physical properties of soils, such as increased soil aggregation and water holding capacity. The process of the improvement of the water holding capacity with biochar amendment was also described by Asai et al (2009). Sun and Lu 2014 reported that there was a positive improvement on physical quality and pore-space status of clay soil when straw biochar and/or wastewater-sludge biochar were added.

The data obtained from our study show that there was an improvement in soil pH when biochar was added to acid soil at 4 kg per m^2 or 40 tonnes per ha (Table 4; Figure 2). This result is also in agreement with what has been reported by Southavong et al (2012a) and Vivasane et al (2012). It has been identified that biochar applied to soil improves the availability of phosphorus, total nitrogen and major cations (Glaser et al 2002; Lehmann et al 2003). Furthermore, biochar has positive liming effect when added to low pH soils (Van Zwieten et al 2007), thereby the application of biochar to acidic soils increases the soil pH and therefore improves nutrient use efficiency by decreasing exchangeable aluminium in soil to alleviate the possible toxic effects (Van Zwieten et al 2010; Alling et al 2014).

Table 4: Mean values for effects of biochar and level of effluent on soil pH and water holding capacity after third harvest (140 days after planting)

	Soil pH	**WHC, %**
Biochar application, kg/m²		
B4	6.20[a]	30.0[a]
B0	5.24[b]	26.2[b]
Prob.	0.0001	0.001
SEM	0.13	0.35
Effluent level, kg N/ha		
0	5.34[b]	27.2[b]
50	5.81[a]	27.8[b]
100	5.99[a]	29.3[a]
Prob.	0.02	0.01
SEM	0.15	0.42
Prob. (interactions)		
S*E	0.26	0.51
SEM	0.22	0.60

S: Soil amender, E: Effluent level, Prob: Probability

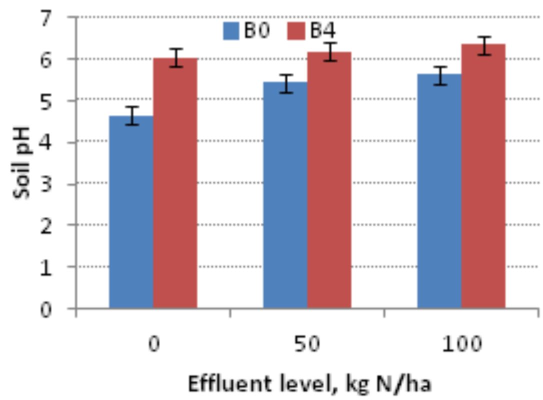

Figure. 6. Effects of biochar and effluent on soil pH (B0 = no biochar; B4 = 4 kg biochar/m^2)

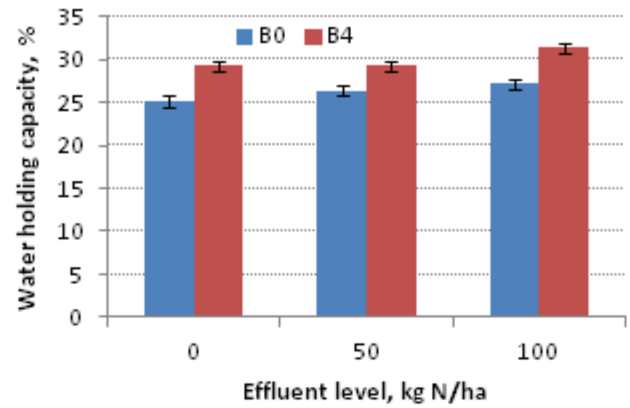

Figure. 7. Effects of biochar and effluent on soil water holding capacity (B0 = no biochar; B4 = 4 kg biochar/m^2)

Conclusion

Biochar and effluent increased the yield of the yardlong bean by 50% compared to the control treatment. Empty pod of the bean was reduced by 2 fold when biochar was applied at 4 kg/m^2. Soil pH was improved due to biochar amendment. Water holding capacity of the soil was significantly increased when biochar was applied at all level of effluent.

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