



(RESEARCH ARTICLE)



Effect of biochar and biodigester effluent on growth of maize (*Zea mays*) and on soil physical properties

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Abstract

This study investigates the effects of different levels of biochar and biodigester effluent on growth of maize (*Zea mays*) and on soil physical properties, in this experiment was done at Animal Science Farm of Faculty of Agriculture and Forest Resource, Souphanouvong University, Lao PDR, the experimental was designed in Complete Randomized Design and was to compared in a 5*2 factorial arrangement. The factors were: first factor: five levels of biochar at 0; 20; 30; 40 and 50kg/tonne; and second factor: with or without biodigester effluent 50kg/ha, there were 10 treatments and with 10 replications of each treatment. The biomass growth of maize showed a curvilinear increase as the level of biochar was raised from 0, 20, 30, 40 and 50kg/tonne, and was higher when supplemented with effluent than non-effluent. Soil properties as pH, % of organic matter (OM), % of nitrogen (N) and % of water holding capacity (WHC) were increased by increasing the levels of biochar and was higher with effluent than non-effluent.

Keywords: Soil Properties; Biochar; Biodigester Effluent; Biomass

1. Introduction

The soil is a very crucial factor in food production. The most important problem of tropical agriculture is the inability of the land to sustain annual food crop for more than a few years at a time. Since animals, in turn, depend on plants, it becomes obvious that all agricultural activities directly or indirectly depend on the soil (Akinrinde, 2006). At best, common renewable energy strategies can only offset fossil fuel emissions of CO₂ - they cannot reverse climate change. One promising approach to lowering CO₂ in the atmosphere, while producing energy and biochar, is by pyrolysis and gasification of biomass (Lehmann, 2007). This technology relies on capturing the off-gases from thermal decomposition of wood or grasses to produce heat, electricity, or biofuels. Biochar is produced by so-called thermal decomposition of organic material under limited supply of oxygen (O₂). This process often mirrors the production of charcoal, which is one of the most ancient industrial technologies developed by mankind - if not the oldest (Harris, 1999). In soil, biochar was shown to persist longer and to retain cations better than other forms of soil organic matter. Furthermore, the cation retention of fresh biochar is relatively low compared to aged biochar in soil, and it is not clear under what conditions, and over what period of time, biochar develops its adsorbing properties (Lehmann, 2007). Sisomphone et al., 2012 a,b showed that there were effects on growth of water spinach from combining biochar with biodigester effluent, as additives to an acid soil (pH 4.6). It was therefore hypothesized that applying similar method in a field trial would also increase biomass yield of water spinach. In this experiment will be investigated the effect of biochar and biodigester effluent for increasing of the maize yield and soil fertility.

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Objectives

To compare different levels of biochar and biodigester effluent on growth of maize (*Zea mays*) and on soil physical properties

2. Material and methods

2.1. Location of the study area

The experiment was conducted in the Animal Science Farm and Laboratory of the Faculty of Agriculture and Forest Resource, Souphanouvong University, LuangPrabang Province, Lao PDR. The site is located 7.5 km from LuangPrabang city to the South-west, at an altitude of 385m above sea level. The experiment was conducted from October 2023 to January 2024.

2.2. Treatments and experimental design

Ten treatments were arranged in a complete randomized design (CRD) as a 5*2 factorial with 10 replications.

2.2.1. The factors were:

- Application of biochar: different levels at 0; 20; 30; 40 and 50 tones/ha
- Addition of biodigester effluent: with or without at 50 kg/ha

2.2.2. The treatments were:

- 0B-NBE (0-Non Biodigester Effluent)
- 0B-BE (0-Biodigester Effluent)
- 20B-NBE (20-Non Biodigester Effluent)
- 20B-BE (20-Biodigester Effluent)
- 30B-NBE (30-Non Biodigester Effluent)
- 30B-BE (30-Biodigester Effluent)
- 40B-NBE (40-Non Biodigester Effluent)
- 40B-BE (40-Biodigester Effluent)
- 50B-NBE (50-Non Biodigester Effluent)
- 50B-BE (50-Biodigester Effluent)

Note: B: biochar, BE:biodigester effluent

2.3. Materials

The biochar was derived from rice husk, produced locally in an updraft (TLUD) gasifier stove (Olivier, 2010) (Photo 3). The effluent was taken from a "plug-flow" biodigester (5 m³ liquid volume) made from tubular polyethylene with UV filter (Photo 4) and charged daily with washing (1 m³) from pig pens holding on average 5 pigs of 50kg mean live weight. maize seeds were bought locally from the market.



Figure 1 Biochar



Figure 2 Rice husk



Figure 3 The updraft gasifier stove



Figure 4 Effluent from the plug-flow tubular polyethylene biogas digester

2.4. Procedure and data collection

500 kg of acid soil (pH 4.5) with or without soil amender (biochar or biodigester effluent) was put into plastic baskets (18*25cm, 10kg capacity) and each plastic basket were filled with 10 kg of Acid soil (pH 4.5) according to the experimental design. Maize seeds (n=2) were planted in each bag. After germination, some plants were eliminated leaving only 1 plant for the rest of the experiment. Distance of each bags were spacing between of 80cm and between replications were 120cm. Biochar was applied to the soil in the plastic bags at 0; 2; 3; 4 and 5% by weight of biochar on DM basis. The water was applied uniformly to all plastic baskets every morning and evening. In raining day additional water was not applied.



Figure 5 The Acid soil

2.5. Fertilizing and irrigation

The fertilizer (biodigester effluent) was applied at the beginning and then 10-day interval (total of 4 times) during the growing period. The quantities were calculated according to the Nitrogen content of the effluent based on the experimental design. The staggered application was 10; 20; 30 and 40% of the total specified quantity applied at days 1; 10; 20 and 30 respectively.

2.6. Measurements

The height of the plants and number of the leaves were measured every 10 days over a total period of 40 days, at the end of the trial, the whole plants were removed from bags, washed free of soil, and was weighted for fresh biomass. The roots length also measured. The green aerial parts (Leaves and stems) and the roots were separated and analyzed immediately for DM. Samples of soil and biochar was analyzed at the beginning and at the end of the trial for DM and pH. The forages were analyzed for DM, N and Ash content. Samples of soil were analysed at the beginning and end of the trial for pH, OM, WHC and N. Biochar were analysed for DM, pH and ash content.



Figures 6 Height, roots length and fresh biomass measured of the plants

2.7. Chemical analysis

The N, water holding capacity (WHC), DM, OM and Ash were determined by AOAC (1990) methods. pH of soil was determined by using digital pH metre by adding 5g of ground sample (DM basis) into a breaker with 25ml of distilled water and was kept over-night before measure pH in the next morning. Water holding capacity was measured by weighing 5g of soil (DM basis) into a glass funnel fitted with filter paper and then saturating the soil with water. After 24 h the soil was weighed to determine the quantity of water that had been retained.

2.8. Statistical analysis

Collected data were statistically analyzed using ANOVA with Minitab version 16.2.0 (2010). Comparison of significant differences in mean values was assessed at the probability level of $p < 0.05$. The statistical model used is as follows:

$$Y_{ijk} = \mu + P_i + A_j + P_i * A_j + e_{ijk}$$

Where: Y_{ijk} is dependent variables

μ is overall mean

P_i is the effect of level of biochar

A_j is the effect of biodigester effluent source

$(P * A)_{ij}$ is the interaction between source of biodigester effluent and source of level of biochar, e_{ijk} is random error.

3. Results and Discussion

The nitrogen and pH content were higher for effluent than soil (Table 1).

Table 1 Chemical composition of experimental materials

No	Items	pH	N	OM	WHC
1	Soil	4.65	1.12	6.81	19.57
2	Biochar	10	NA	37.85	NA
3	Effluent	6.81	5.92	NA	NA

Notes: pH: percentage of hydrogen ion, OM: organic matter, WHC: water holding capacity, N: nitrogen, NA: Not analysed

pH, % OM, % N and % WHC were increased by increasing the level of biochar and were high when supplemented with effluent than non-supplementation (Table 2).

Table 2 Mean value for pH, % OM, % N and % WHC by increasing level of biochar or source of effluent

No	Items	Level of biochar										SEM	p
		0		20		30		40		50			
		NBE	BE	NBE	BE	NBE	BE	NBE	BE	NBE	BE		
1	pH	5.25 ⁱ	5.37 ^h	5.49 ^g	5.75 ^f	6.37 ^e	6.42 ^{de}	6.45 ^{cd}	6.49 ^c	6.81 ^b	6.88 ^a	0.012	<0.001
2	OM (%)	5.51 ^j	23.67 ^e	15.53 ⁱ	27.01 ^d	17.41 ^h	29.77 ^c	17.82 ^g	32.22 ^b	19.33 ^f	35.37 ^a	0.045	<0.001
3	N (%)	1.13 ^f	3.65 ^d	1.15 ^f	3.73 ^c	1.17 ^f	3.75 ^c	1.22 ^e	3.80 ^b	1.25 ^e	3.85 ^a	0.009	<0.001
4	WHC (%)	19.9 ^h	39.83 ^d	23.5 ^g	41.7 ^c	27.6 ^f	43.7 ^b	30.6 ^e	43.9 ^b	30.9 ^e	45.6 ^a	0.166	<0.001

Note: ^{abc} Mean values without common superscript differ at p<0.05, N-E: Non-effluent, W-E: With-effluent.

DM of root, leaves and stem were decreased by increasing the level of biochar and were lower when supplemented with effluent than non-supplementation (Table 3).

Table 3 Mean value for DM of root, leaves and stem by increasing level of biochar or source of effluent

No	Items	Level of biochar										SEM	p
		0		20		30		40		50			
		N-E	W-E	N-E	W-E	N-E	W-E	N-E	W-E	N-E	W-E		
1	Root	20.5a	18.3d	20.1b	18.2d	19.6c	17.8e	19.5c	17.5f	19.5c	17.3g	0.030	<0.001
2	Leaves	17.3a	15.8d	17.3a	15.3e	17.1ab	15.2e	16.9bc	15.2e	16.7c	14.7f	0.052	<0.001
3	Stem	11.2a	10.5c	11.2a	10.3d	11.1a	10.2d	11.1ab	9.7e	10.9b	9.7e	0.036	<0.001

Note: ^{abc} Mean values without common superscript differ at p<0.05, N-E: Non-effluent, W-E: With-effluent.

The amount of leaves were non-effect by increased the level of biochar and source of effluent from day 10-day 20, and day 40, but was affect when day 30 (Table 4).

Table 4 Mean value for amount of leaves by increasing level of biochar or source of effluent

No	Items	Level of biochar										SEM	p
		0		20		30		40		50			
		N-E	W-E	N-E	W-E	N-E	W-E	N-E	W-E	N-E	W-E		
1	D-10	3.9	4.1c	4.1	4.0	4.2	4.7	4.4	4.8	4.7	4.7	0.13	0.101
2	D-20	7.4	7.8	7.7	8.0	8.4	8.3	8.2	8.3	8.3	7.5	0.23	0.089
3	D-30	11.2c	12.5abc	11.3bc	11.8abc	11.2a	12.2a	12.4a	12.2a	12ab	11.4abc	0.30	0.009
4	D-40	12.6	14.5	13.2	13.8	13.6	14.3	14.7	14	13.9	13.3	0.33	0.296

Note: ^{abc} Mean values without common superscript differ at p<0.05, N-E: Non-effluent, W-E: With-effluent, D: day

Height of foliage were increased by increasing the level of biochar and were high when supplemented with effluent than non-supplementation from 0-40kg/tonne of biochar levels, but while 50kg/tonne was decreased (Table 5).

Table 5 Mean value for height by increasing level of biochar or source of effluent

No	Items	Level of biochar										SEM	p
		0		20		30		40		50			
		N-E	W-E	N-E	W-E	N-E	W-E	N-E	W-E	N-E	W-E		
1	D-10	30.3 ^{bcd}	24.7 ^e	28.9 ^{bcd}	27.8 ^{cd}	37.5 ^a	29 ^{bcd}	33.4 ^{abc}	34.6 ^{abc}	32.7 ^{abc}	34.7 ^{ab}	1.49	0.002
2	D-20	69 ^c	81 ^{abc}	79 ^{bc}	79 ^{bc}	84 ^{abc}	94 ^a	93 ^{ab}	89 ^{ab}	95 ^a	89 ^{ab}	3.23	0.014
3	D-30	118	127	121	125	140	138	141	140	136	134	3.73	0.472
4	D-40	149 ^c	167 ^{ab}	145 ^c	157 ^{bc}	161 ^{abc}	176 ^a	170 ^{ab}	170 ^{ab}	166 ^{ab}	159 ^{bc}	3.64	0.003

Note: ^{abc} Mean values without common superscript differ at $p < 0.05$, N-E: Non-effluent, W-E: With-effluent, D: day

The weight of maize was increased when increasing the level of biochar and were high when supplemented with effluent than non-supplementation, but for the length of root were increased by levels of biochar from 0-30kg/tonne, and were high when supplemented with effluent, while 40 and 50kg/tonne of biochar levels were decreased (Table 6).

Table 6 Mean value for weight and length of root by increasing level of biochar or source of effluent

No	Items	Level of biochar										SEM	p
		0		20		30		40		50			
		N-E	W-E										
1	Weight, g	83 ^g	132 ^e	100 ^f	162 ^d	130 ^e	288 ^b	167 ^d	324 ^a	199 ^c	338 ^a	3.38	<0.001
2	Length of root, cm	40 ^h	70 ^g	89 ^d	100 ^b	96 ^c	110 ^a	74 ^f	82 ^e	87 ^d	71 ^{fg}	0.86	<0.001

Note: ^{abc} Mean values without common superscript differ at $p < 0.05$, N-E: Non-effluent, W-E: With-effluent

4. Discussion

The results were agreed by reported of Sombroek et al (2003); Glaser et al (2002), Lehmann and Glaser (2003); Lehmann and Rondon (2005) reported 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 and Rondon et al (2007) reported when biochar was made by pyrolysis of eucalyptus logs and contained only 0.3% of ash the data showed an increase in soil pH from 5.0 to 5.4 after applying 40g biochar per 1kg of soil, much less than the increase from 4.7 to 6.6

5. Conclusion

The biomass growth of maize (over 30 days period from planting) showed a curvilinear increase as the level of biochar was raised from 0, 20, 30, 40 and 50kg/tonne and was higher for effluent than non-effluent

The DM of foliage as root, leaves and stem were lower when increasing levels of biochar and were lower when supplemented with effluent than non-effluent

Biochar raised soil pH from 5.25 to 6.88 by increasing the levels from 0, 20, 30, 40 and 50kg/tonne % OM, % N and % WHC were increased by increasing the levels of biochar and was higher when supplemented with effluent than non-effluent.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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