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Effect of biochar on the Release and Loss of Nitrogen from Urea Fertilization

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ABSTRACT

Laboratory experiments were carried out to study the pattern of nitrogen release from urea fertilizer with biochar application. The soil or soil mixture was put in in soil column of 30 cm length, fertilized with 300 ha^{-1} urea, and then treated with: (1) without organic amendments; (2) 30 Mg ha^{-1} Chicken manure (CM); (3) 30 Mg ha^{-1} organic city waste compost (CW); (4) 15 Mg ha^{-1} CM biochar; and (4) 15 Mg ha^{-1} CW biochar. The results show that application of biochar could impede the transformation of N-NH_4 to N-NO_3. After 28 days of incubation, there was 60 mg kg-1 N-NH_4 (CM biochar) and 52 mg kg-1 (CW biochar), compare to 40 mg kg-1 N-NH_4 (CM) and 12 mg kg-1 N-NH_4 (untreated soil).In addition to the high CEC, this high N-NH_4 in biochar treated soil one of the mechanism by which biochar decrease nitrogen loss due to leaching. The nitrogen loss due to leaching from biochar treated soil was 470 – 510 mg, whereas that of from untreated soil 641 mg.
Keywords: organic amendment, organic manure, poultry litter, leaching.

1. INTRODUCTION

With the limitation of organic material resources and the negative effect of organic farming, by the end of 20th century agricultural experts are searching for more resistant organic material resources. Looking the experiences of the traditional farmers in the Amazon of South America, there was some idea to use “char” for agricultural purposes (1). This idea arises because of the sustainability of crop production in the Amazon black soil which was then known contains “char” material. This material is now known as “agrichar” or “biochar”.

Biochar is organic-C rich black materials resulted from burning of organic maters with no or limited oxygen. With it aromatic C-compound, biochar is very resistant to decomposition, so that its effect will last for a longer time. Research results have shown that biochar is a very prospective soil amendment (2). Biochar application has been shown able to increase the chemical, as well as the physical properties of the soil (1, 3). The chemicals properties influenced by biochar application include soil pH, and CEC (4), and the physical properties include soil aggregation, soil water holding capacity and soil strength (5). In the long term, biochar application increase plant nutrient availability (1, 3, 6), either due to the improvement of soil properties or addition of some plant nutrient in the biochar. Biochar application has also been reported to increase soil biology population and activity (6, 7), and increase the efficiency of nitrogen fertilization (8).

The increase in crop yield with biochar application has also been reported by many workers, such as for maize (9, 10), soybean (11), and cassava (12). In addition, with its recalcitrant properties, it is believed that biochar is a good carbon sink (13), and hence could help to reduce the rate of global warming due to methane gas emission (14).

A lot of research on the effect of biochar application on soil properties and crops yield has been done. Although still limited, there was already some data showed the effect of biochar application on the efficiency of fertilizer application. However, information on the effect of biochar application on the mechanism by which bochar influence nitrogen fertilization is still rare. Therefore, the research described here was aimed to investigate the pattern of nitrogen released from urea fertilizer. The loss of nitrogen due to leaching was also studied.

2. MATERIALS AND METHODS

The research was carried out in Soil Science Laboratorium of Brawijaya University, Malang. Indonesia. Biochar was made from chicken manure (CM biochar) and organic city waste (CM biochar), and was prepared according to the method described by Masulili et al. (15). Chicken manure was collected from poultry litter (consist of sawdust materials and chicken manure) of P.T. Charoen Pokhan, and city waste (mostly consist of plant materials) was collected from city waste collector of Malang city, Indonesia. These materials were sun dried to reach water content of about 17 % and then heated in the pyrolysis reactor (15) at temperature of 500^{o} C for 2 hours 30 minutes (CM biochar) and 2 hours 5 minutes (CW biochar).

Biochar pH was determined by the method of Amedna (16), total C by ASTM method (17),, and for N, P, K, Ca, Mg was employed the method described by Masulili et al. (15). To study the chemical surface of biochar, FT-IR analysis was performed using spektrometer FT-IR 8400 Shimatzu..The characteristics

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of chicken manure, city waste, CM biochar and CW biochar are presented in Table 1.

Table 1. Characteristics of soils and organic amendments used in the experiment

Characteristics	Soil	Chicken manure	City waste Compost	CM biochar	CW biochar
pH H_2O	6,37	7,10	7,9	9,00	9,60
Organic -C (%)	1,46	17,61	21,43	20,13	31,41
N Total (%)	0,19	2,02	1,81	1,90	1,67
C/N	7	8	11	10	18
P (%)		2,77	0,35	3,77	0,72
P Bray 1 (mg kg^{-1})	24,38				
K (%)		2,44	0,82	1,48	0,93
K (cmol kg^{-1})	0,75				
CEC (cmol kg^{-1})	14,02			17,48	23,87
Mg (%)		1,29	0,16	0,99	0,61
Mg (cmol kg^{-1})	3,81				
Ca (%)		6,78	1,76	1,02	1,08
Ca (cmol kg^{-1})	4,49				
Sand (%)	21,00				
Silt (%)	55,33				
clay (%)	23,67				

The release of nitrogen from Urea followed the method developed by Handayanto et al. (18). 100 g of soil sample mixed thoroughly with quartz (2mm diameter) which has been washed with acid. This soil-quartz mixture was put in a plastic cylinder of 4.0 cm diameter and 25.0 cm length, and then 300.0 kg Urea/ha was put in to the mixture. The treatments tested were: (1) without organic amendments (without OM); (2) 30 Mg ha^{-1} Chicken manure (CM); (3) 30 Mg ha^{-1} organic city waste compost (CW); (4) 15 Mg ha^{-1} CM biochar; and (4) 15 Mg ha^{-1} CW biochar. Soil water content in the mixture was maintained about 70 % of its water holding capacity. These treatments were arranged in a Complete Randomized Block with 3 replications. To prevent dispersion and compaction during watering the cylinder was clogged with glass wool. To minimize microorganism activity and evaporation, the cylinder was then put in a dark room at room temperature (20^o C)

After 1; 2; 4; and 8 weeks after incubation the cylinder was leached with 100 ml of solution containing 1 mmol $MgSO_4$; 1 mmol $CaCl_2$; 1 mmol KH_2PO_4). During leaching water content in the mixture was maintained at 70 % WHC, and low pressure was employed to help a leaching. The leachate was put in a freezer (to minimize nitrification), and after which it was determined its NH_4^+ and NO_3^- with Kjeldahl methods.

Leaching experiment was done in PVC cylinder of 14.40 cm diameter and 40 cm height. The cylinder was filled with 3.5 kg dry soil (the height of soil sample in the cylinder was about 20 cm) and treated similar to the nitrogen release experiment. Pores of 3,0 mm was made at the bottom of the cylinder (4 pore cm-^{2}), and to facilitate leaching 24 marbles (about 2.0 cm diameter) were put on the bottom of the cylinder, after which the cylinder was clogged with glass wool, and the leachate was collected in erlenmeyer bottle connected with glass funnel to the bottom part of the cylinder. The soil was watered thoroughly with deionized water until water content at about field capacity, after which it was allowed to equilibrium for 3 days. The experiment was done in in dark room with temperature of 20^o C.

On the following day, the cylinder was watered every day with deionized water to maintain water height of about 10 cm and allowed leaching to proceed. After 30 days, the leachate was analyzed for its nitrogen content by Kjeldahl method.

3. RESULTS AND DISCUSSION

The results presented in Table 1 show that biochars had a higher pH, C, P, K, Ca and CEC but less N compared to their feedstuffs. The difference in biochar characteristics presented in Table 1 is logic consequence of the different feedstuff characteristics (13). The FT-IR analysis result (Fig 1) shows the occurrence of aromatic structure in both biochar (spectra of 1464 to 1606 for CM biochar and 1634 for CW biochar). The occurrence of this aromatic structure had been suggested as one of the reason for the recalcitrant property of biochar (6).

After 30 days of incubation, except nitrogen, there was an improvement of soil properties with biocahr application (Table 2). The higher organic-C and some plant nutrient in biochar treated soil could be explained by the data given in Table 1 which show that both biochars have a higher organic –C, and some plant nutrient such as P, K, Ca and Mg. With this phenomena, it can be suggested that in addition as a soil amendments as has been discussed by many workers (2), biochar from chicken manure and organic city waste are potential materials to be used as supplement for increasing plant nutrient availability.

The higher pH in soil treated with biochar can be understood, because both biochar had alkaline properties (pH more than 9.0, see Table 1). The data presented in Table 1 also show that CEC of the chicken manure and city waste increased as these materials transformed to be "biochar". This would contribute to the higher CEC of biochar treated soil. The increase in CEC of a soil treated with biochar has also been shown by many workers (5, 17). This increase is suggested originated from phenolic and carboxyl compound in biochar.

Table 2 Soil characteristics after 30 days of organic amendments

Soil characteristics	Before incubation	After incubation				
		Without OM	Chicken manure	City waste compost	CM biochar	CW biochar
pH H_2O	6.37	6.35 a	6.87 ab	6.73 ab	7.67 b	7.70 b
C organik (%)	1.46	1.39 a	2.78 b	2.85 b	3.37 c	3.36 c
N total (%)	0.19	0.19 a	0.65 c	0.35 b	0.26 ab	0.19 a
P Bray (1 mg kg^{-1})	24.38	22.41 a	62.01 bc	53.28 b	70.59 c	69.31 c
K (cmol kg^{-1})	0.75	0.69 a	1.81 b	2.02 b	2.16 b	2.93 c
Na (cmol kg^{-1})	0.28	0.38 a	2.07 b	2.33 b	2.80 b	2.88 b
Ca (cmol kg^{-1})	4.49	4.36	6.86	7.83	5.76	6.61 NS
Mg (cmol kg^{-1})	3.81	3.92	3.92 a	4.62 b	4.51 a	5.87 NS
CEC(cmol kg^{-1})	14.02	14.02	19.64	18.90	18.96	19.60

1)Means followed by the same letters in the same line are not significantly different (p=0,05)

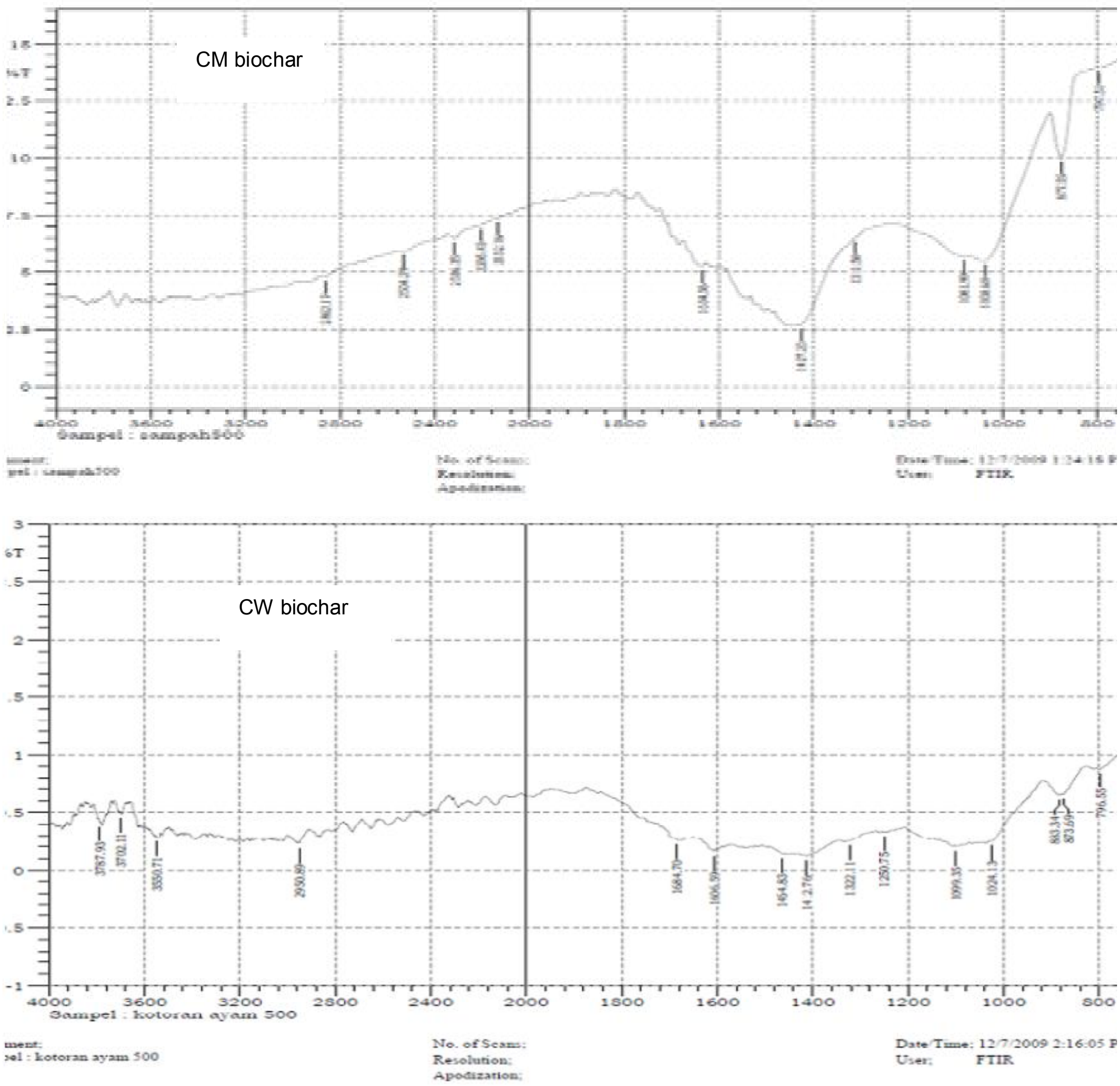
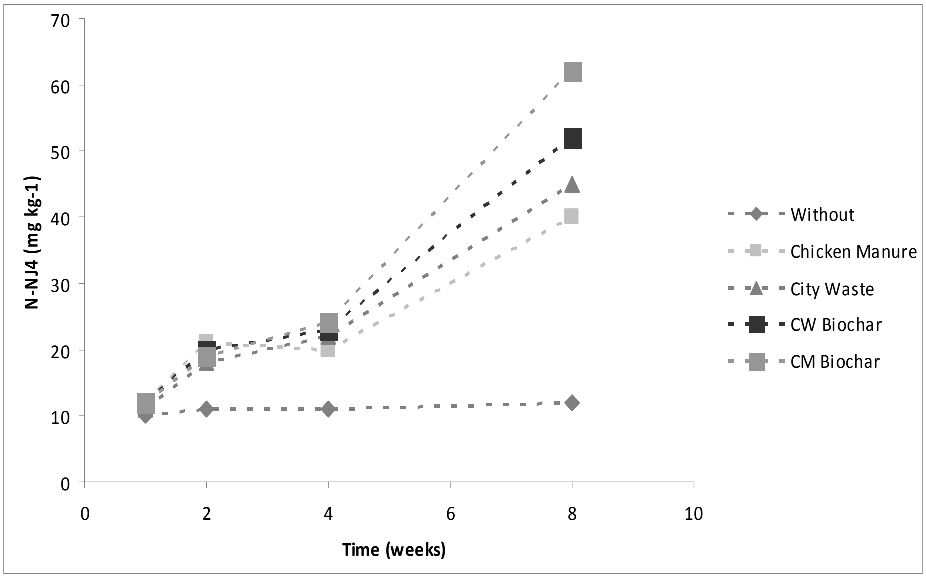


Fig 2. FTIR spectra of CM biochar (above) and CW biochar (below)

At the early stage of incubation, biochar application did not influence the pattern of nitrogen release from urea fertilizer. The data presented in Fig 2 show that until one week of incubation, biochar treated soil released about the same amount of N-NH_4 and N-NO_3 with the other treatments. However, after 2 weeks of incubation the amount of N-NH4 in soil treated with organic amendment was higher compared to that of untreated soil. In contrast with N-NH_4, the amount of N-NO_3 in biochar soil trated soil was much lower compared to that of other treatments.



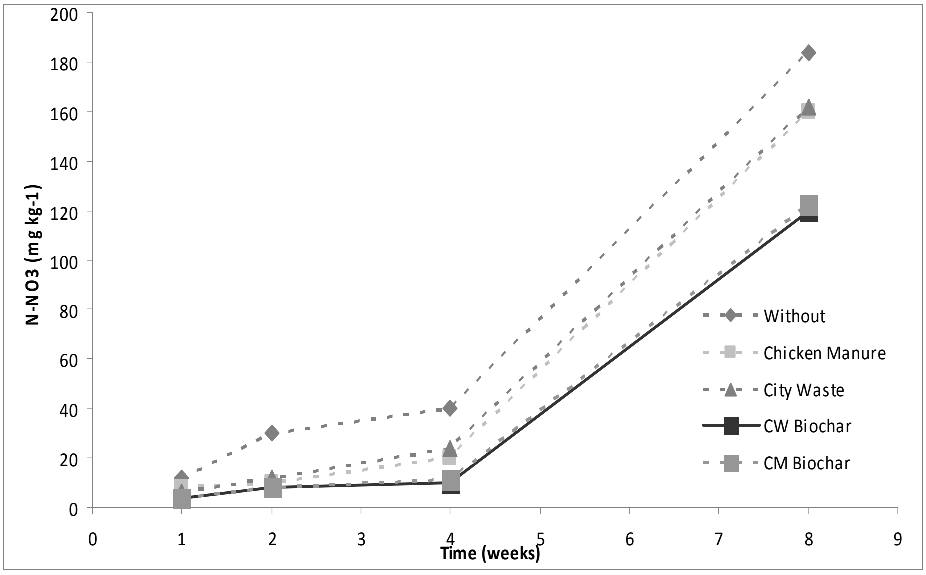


Figure 3. The release of N-NH_4 (above) and N-NO_3 (below) from urea fertilizer as influenced by organic amendments

Furthermore, the data in Fig 2 show that after 8 weeks of incubation the amount of N-NH_4 in biochar treated soil was higher compared to that of untreated and chicken manure or city waste compost treated soil. At this time, the amount of N-NH_4 was $_{62}$ mg kg-1, this is much higher compared to that of in chicken manure treated soil (52 mg kg^{-1}) or city waste compost treated soil (40 mg kg^{-1}). This result indicated that biochar was able to minimize the transformation of N-NH_4 release from urea to N-NO_3. Ding et al. (8) also showed a higher N-NH4 concentration in the upper layer of his multi-layer experiment. However, he explained that addition biochar to the surface soil layer retarded the downward transport of N-NH_4..

Until 30 days of incubation, application of biochar did not significantly influence the volume of leachate (Table 3). It seems that until 30 days of incubation there was no changes in soil physical properties that influence soil water movement. However, in term of nitrogen concentration, the result in Table 3 show that the loss of N-NH4 in biochar treated soil is much lower (95.26 mg l-^{1}) compared to that without organic amendment (142,74 mg l^{-1}) or chicken manure treated soil (150 mg l^{-1}). These phenomena can be understood. Although the biochar treated soil had a high concentration of N-NH_4, with the high CEC of the soil, N-NH_4 will be absorbed by the negative charge resulting from carboxyl and phenolic group of biochar.

The data in Table 3 also show that application of biochar decrease the loss of total nitrogen from the fertilizer due to leaching.. The total nitrogen loss from untreated soil was 641. 47 mg, decreased to 510.13 mg with application of organic city waste biochar, and to

470,13 mg with application of chicken manure biochar. The higher CEC of the soil treated with biochar (Table 2) would also have significant effect to this low total nitrogen loss. With the higher CEC, there would be more N-NH_4^+ absorbed by these negative charges, and therefore there would be less nitrogen loss with downward water movement (9).

Table 3. Effect of biochar on N-NH_4 and N-NO_3 concentration in the leachate and total nitrogen loss

Treatments	Leachate characteristics			
	Conc of N-NO_3 (mg l^{-1})	Conc. of N-NH_4 (mg l^{-1})	Leachate vol (ml)	Total N loss (mg)
Without OM	474.54 b	142.74 c	1038.61	641,97 c
Chicken manure	405.65 ab	150.52 c	1030.09	572,85 b
CW compost	386.72 ab	124.60 b	989.84	506,10 a
CM biochar	360.60 b	105.48 a	1010.39	470,73 a
CW biochar	405.36 ab	95.26 a	1019.49	510,13 a
			Ns	

1) Means followed by the same letters in the same column are not significantly different (p=0.05); Ns = not significantly different (p=0,05)

4. CONCLUSION

The experimental results presented and discussed in section 3 show that application of biochar influence the pattern of nitrogen release from urea fertilizer. Biochar slow down the transformation of N-NH_4 to N-NO_3.. After 28 days of incubation, there was 62 mg kg-1 N-NH_4 in CM biochar treated soil and 52 mg kg-1 in CW biochar treated soil. These are higher compare to that of untreated soil (12 mg kg-1 N-NH_4), or even in CM treated soil (40 mg kg-1 N-NH_4).

The high N-NH_4 in biochar treated soil made they were absorbed by negative charge arise from carboxyl and phenolic group in biochar, and hence decrease nitrogen loss due to leaching. The nitrogen loss due to leaching in biochar treated soil was 470 – 510 mg, whereas that of from untreated soil was 641 mg.

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