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Research Article

EFFECT OF BIOCHAR, BOILER ASH AND CATTLE MANURE ON NITROGEN LEACHING IN SANDY SOIL ASEMBAGUS, SITUBONDO

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Abstract: Sandy soil has macropores which caused the difficulty of water and soil nutrient retained in soil layer resulting nutrient leaching. This research used a leaching tube conducted in Ekofisiology Laboratory of Indonesian Sweetener and Fiber Crops Research Institute (ISFCRI), Malang, arranged in Completely Randomized Design with six treatments and three replications. Treatments is: without soil amendment (control soil), sugarcane trash biochar 10 t/ha, boiler ash 10 t/ha, cattle manure10 t/ha, combination of biochar 5 t/ha + cattle manure 5 t/ha, and combination of boiler ash 5 t/ha + cattle manure 5 t/ha. Tubes were poured with water equivalent to rainfall in Asembagus. The leachate observed every 2 weeks until 10 weeks after incubation. The results showed that application of biochar 10 t/ha can reduced leaching of total nitrogen stably than the other. It was always decreased from week 2 until week 10, ranged from 0.10 to 0.29 ppm. On the other treatment and control, the leaching ranged from 0.07 to 0.77ppm and 0.18 to 1.08 ppm and then increased at week 10. The percentage of leachate volume in biochar 10 t/ha treatment was lowest than the other, ranged from 51.45 to 82.46%.

Keywords: *biochar, nitrogen, leaching of nitrogen, sandy soil*

Introduction

Asembagus in Situbondo district is an area dominated by sandy soil and the region to cultivate of sugarcane (*Saccharum officinarum* L.). Sandy soil has many macropores, low aggregate stability and fast permeability, caused the water and the air is out and only a few retained in the planting medium (Jamilah, 2003). Elfiati and Devian (2010) research resulted that the sandy loam soils with sand fraction of 74.56% and that stands of eucalyptus on slope of 8-15% in the first minute had the infiltration rate of 144 cm/hour. High rainfall on sandy soil could cause the leaching of mobile nutrients such as nitrogen so that necessary to minimize the leaching. One of the alternative ways is to give soil amendment such as biochar, boiler ash and cattle manure.

Biochar and cow manure has the ability to retain water in the soil, helping to prevent loss of nutrients due to leaching (leaching) (Ferizal 2011; Hartatik and Widowati, 2006). Masulili *et al*. (2010) result that giving of rice hull biochar of 10 t/ha increased soil porosity, available soil water at 15.47% from control of 11.34%. Adijaya and Yasa (2014) stated that cow manure 10 t/ha could improved soil water content of 35.17% from 31.11% (without cow manure). Besides biochar, sugar industrial waste that can be used as a source of organic material is boiler ash, residue of burning bagasse, provided approximately 0.3% - 0.6% of the total cane milled (Almazan *et al.*, 1998; Gartner, 2012). Research by Latuponu et al. (2011) showed that the highest soil buffering capacity to N leaching achieved in treatmentof biochar pyrolized by 400^{o}C temperature of 33.65%. The percentage of N leached in biochar treatment of about 33-45%, whereas in the control soil and soil with N fertilization without accompanied by biochar percentage leached N reached 76-81%.

The higher cation exchange capacity in cattle manure has indirect effect on the nitrogen leaching. Supriyadi (2007) states that the cation exchange capacity indicates the soil's ability to exchange the number of cations such as K^+ that could bind to nitrate NO_3^- formed a compound that could reduced nitrogen leaching. Moreover, Santi and Goenadi (2010) stated that biochar pore size varies between 2-5 µm, it can adsorb nitrogen that has covalent radius 71 pm (71 x 10^{-6}µm). Ding *et al*. (2010) states that the specific surface area of biochar reached 330 m^2/g causes biochar has a high adsorption capacity

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of the nutrient. Research by Laird *et al*. (2010) also showed that the application of biochar 20 g/kg was able to absorb ammonium and microbial biomass that can inhibit mineralization and nitrification of organic N-NH_4^+, further decreased nitrogen leaching by 11%. Nevertheless, in the long term biochar application did not disturbed nitrogen balance (Gani 2009).

Biochar is soil amendment that decomposed in a long time, it needs to be combined with manure. This study aims to determine the effect of biochar, boiler ash and cattle manure application on nitrogen leaching in sandy soils from Asembagus, Situbondo, Indonesia. This research is expected to produce technology to reduce nitrogen leaching in sandy soils so that the availability of nitrogen in the soil can be improved.

Materials and Methods

This research was conducted at Ecophysiology Laboratory of the Indonesian Sweetener and Fiber Crops Research Institute (ISFCRI), Karangploso, Malang, Indonesia. Analysis of soil and soil amendment scarried in Soil Chemistry Laboratory, University of Brawijaya Malang. This research was conducted in April to August 2015.

The materials used in this study included samples of sandy soil, biochar, boiler ash, cow manure. Soil taken from Asembagus, Situbondo. Biochar is processed from sugarcane trash by combustion process with minimum oxygen conditions in the drum kiln. Boiler ash obtained from burning bagasse in Asembagus Sugar Factory. While cattle obtained from farmers in Karangploso. In addition there is the addition of nitrogen derived from NPK fertilizer (Phonska).

This experiment used a completely randomized design with 6 treatments and 3 replications. The treatments used include: without soil amendment (control soil), biochar 10 t/ha, boiler ash 10 t/ha, cattle manure 10 t/ha, the combination of biochar 5 t/ha + manure 5 t/ha, and the combination of boiler ash 5 t/ha + cattle manure 5 t/ha.

This experiment was using a leaching tube. Leaching experimental tools consist of PVC pipe with a diameter of 14.40 cm and 60 cm high, glass woll, marbles, and the bottle as a leachate container. The tubes were made from PVC pipe filled with 3.5 kg dried-aired soil up to 50 cm. The bottom of the column tube was coated with glass wool and spread 24 pieces of marbles on top to facilitate the leaching process. Bottle installed on the bottom of the tube to collectthe leachate.

Leaching tool that has been filled with soil and amendment treatment in order to obtain further saturated with aquadest. Aquadest gave in tubes carried out in interval of every week. Water is poured to the experimental tools adapted to the amount of rainfall in the field based on the rainfall data Asembagus Experimental Station, Situbondo 2013. It refered to a previous study carried out in Asembagus, Situbondo. Daily rainfall in the fieldcummulated for one week as weekly rainfall, and then converted into a water volume (mL) added to the leaching experiment.

The supply of water to the instrument experiments were conducted in a way poured slowly to comply with the conditions of rain on the field, and not to damage the soil conditions on yube that had been treated. At 3 weeks after incubation (MSI), NPK fertilizer Phonska added at a dose of 2.23 g/tube (equivalent to 600 kg/ha). Furthermore, water leachate were collected in a bottle per two weeks, which were then measured in volume and analyzed the content of total-N in the laboratory.

Observations conducted destructively on soil and leachate. Parameter observations of soil included cation exchange capacity, levels of total-N, pH, bulk density, particle density, total porosity, while observation of leachate were total-N content and the volume of leachate. Analysis of the soil carried out at the beginning and end of the study, while the leachate analysis conducted at 2, 4, 6, 8 and 10 weeks after incubation. Data were analyzed statistically by ANOVA and continued with Duncan test in 5%level.

Results and Discussion

Soil Bulk Density

Giving of biochar 10 t/ha had significant effect on soil bulk density at 10 MSI (Figure 1). It could decreased soil bulk density from 1.498 g/cm^3(control) become 1.416 g/cm^3 at 10 MSI. The presence of biochar in the soil can be a good medium for soil microbial and support the decomposition process that produced organic acids that could improve soil aggregates. The improved of soil aggregates so could be increased soil porosity, there by decreased the weight of the soil. Application of cocoa skin biochar 5 t/ha can reduced soil bulk density compared to the control soil is 1.31 to 1.24 g/cm^3 at Typic Kanhapludults in Taman Bogo, Lampung (Zhaeittun, 2016).

Total Soil Porosity

Givingof biochar 10 t/ha could increase soil porosity from the initial conditions 40.40% to 41.76%. Santi and Goenadi (2010) stated that biochar had a high total pore space and available water capacity. Micro structure of biochar with 10,000 times magnification showed that porous so that it could improve soil porosity. Research of Masulili *et al*. (2010) showed that giving of rice hull biochar 10 t/ha increased soil porosity followed by increased in available soil water at 15.47% from 11.34% in soil control (Figure 2).

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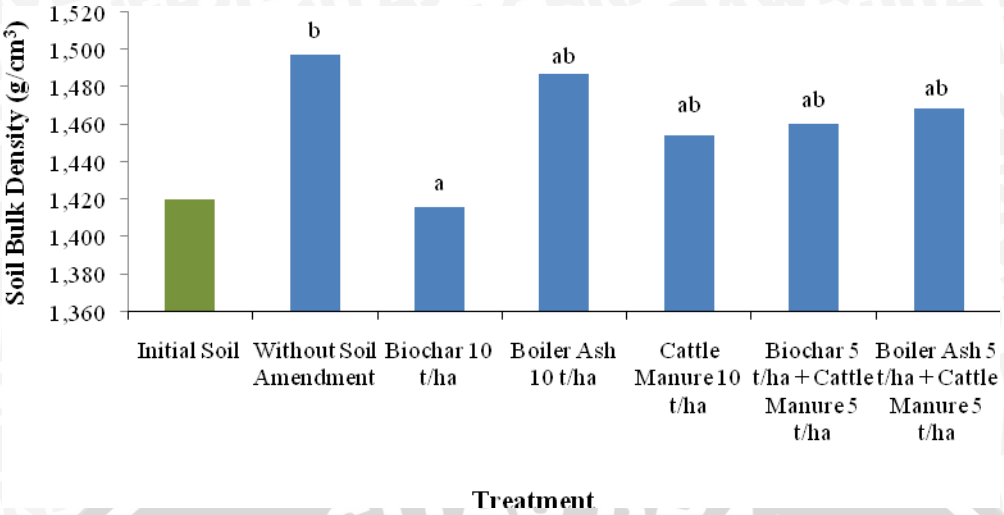

Figure 1. Soil bulk density at 10 weeks after incubation
Note: Numbers followed by same letter are not significant different at Duncan test (p = 5%).

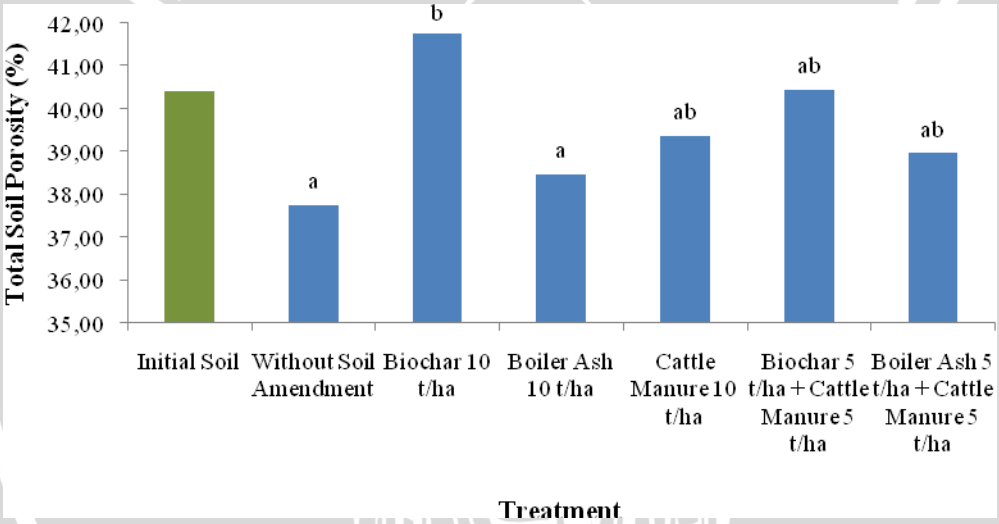

Figure 2. Total soil porosity at 10 weeks after incubation
Note: Numbers followed by same letter are not significant different at Duncan test (p = 5%).

Soil pH

Figures 3 showed that giving a combination of biochar 5 t/ha with manure 5 t/ha could improved soil pH from initial soil of 5.51 become 5.90. This treatment could increase the soil pH higher than other treatments. Sevindrajuta study (2013) showed that the application of 10 t/ha of cow manure increased soil pH from 4.73 to 4.95 in inceptisol Tanjung Tower IV Koto Nan, Payakumbuh. Increased in soil pH occured if the organic matter added to the soil was completed decomposed (mature), because it had been mineralized to release minerals such as cations. Jamilah and Safridar (2012) also stated that the application of biochar in the soil couldraise the pH to 1 unit.

Soil Cation Exchange Capasity (CEC)

Giving of cattle manure 10 t/ha could improved the CEC from 18.02 cmol/kg of the initial conditions to 23.10 cmol/kg at 10 MSI (Figure 4). Research by Mustoyo *et al.* (2013) showed that the application of 10 t/ha manure improved soil CEC from 17.77 to 19.22 cmol/kg in Andisol Cisarua, Bogor. Other studies also demonstrated that the application of 10 t/ha cattle manure fermented with EM-4 bioactifator and local microorganisms improved soil CEC from 18.72 to 21.56 cmol/kg (Ariyanto, 2011). Sevindrajuta (2013) explained that the application of 10 t/ha of ca cattle manure could increase soil CEC from 16.33 to 24.05 cmol/kg in Inceptisol Tanjung Tower IV Koto Nan, Payakumbuh.

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Giving combination of biochar 5 t/ha with manure 5 t/ha could increase soil CEC become 21.99 cmol/kg. Giving biochar 10 t/ha could improve soil CEC become 20.16 cmol/kg. The average value of the CEC on treatment without NPK fertilizer with biochar residue of 10 t/ha increased the CEC of the initial conditions of research from 39.92 to 40.60 cmol/kg, increased of 1.67% (Mawardiana *et al.*, 2013). Anggono (2015) also showed that giving of biochar 10 t/ha were able to increase the CEC of 8.25 cmol/kg at a depth of 0-20 cm and 11.36 cmol/kg at a depth of 20-40 cm compared to CEC soil without biochar of 8.16 and 10.18 cmol/kg. Although the giving of boiler ash 10 t/ha and combination boiler ash 5 t/ha with manure 5 t/ha had no significant effect on the CEC but might increased soil CEC of 18.38% and 18.86% from the initial soil CEC of 15.68%.

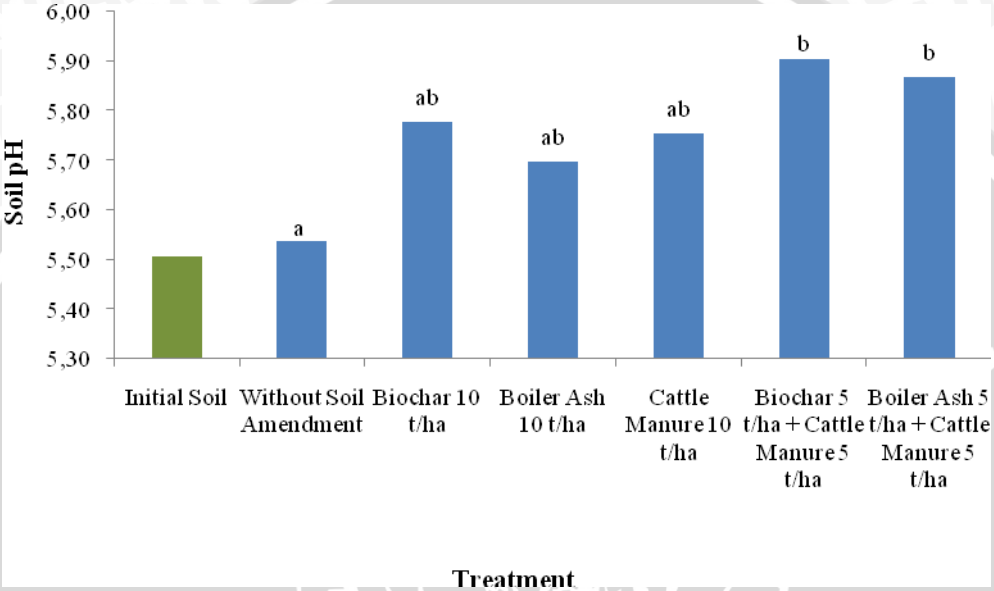

Figure 3. Soil pH at 10 weeks after incubation
Note: Numbers followed by same letter are not significant different at Duncan test (p = 5%).

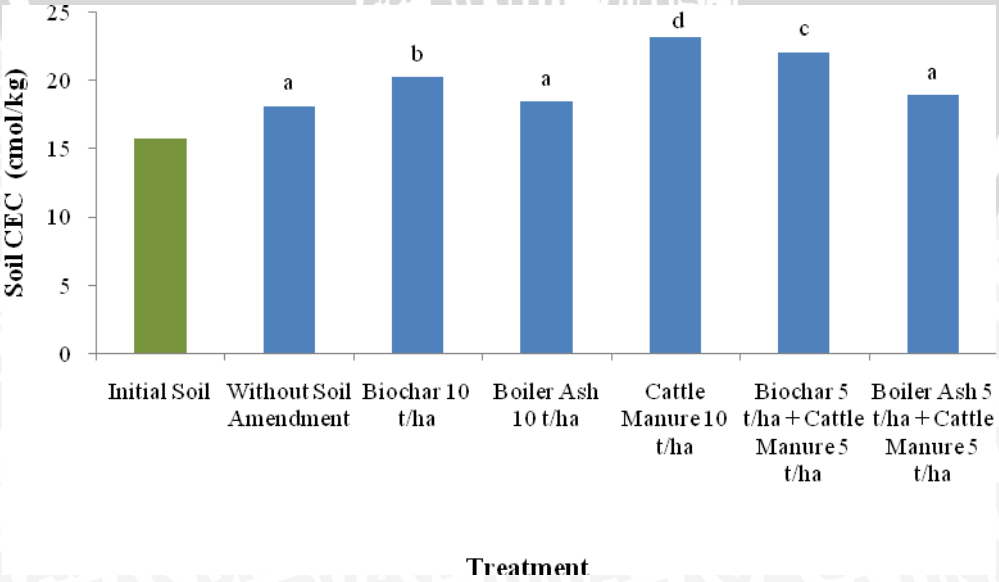

Figure 4. Soil CEC at 10 weeks after incubation
Note: Numbers followed by same letter are not significant different at Duncan test (p = 5%).

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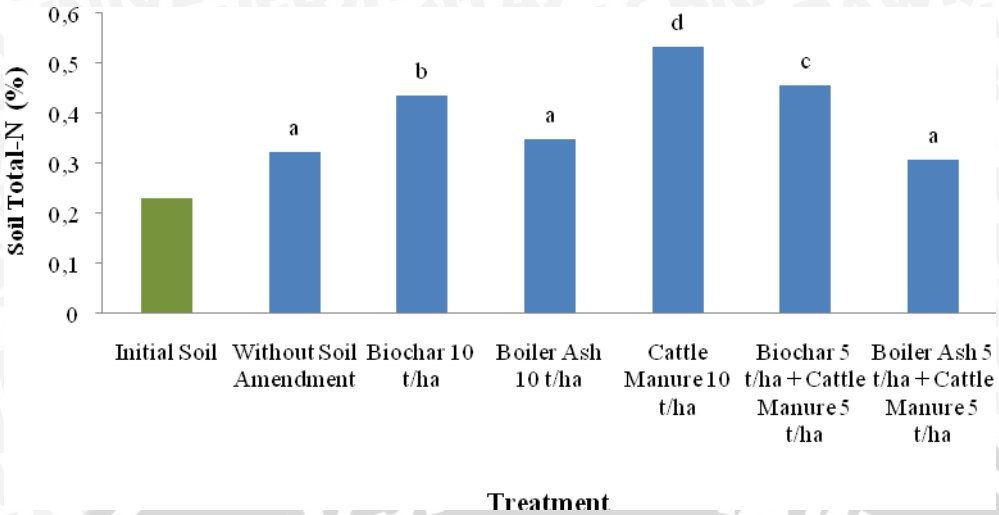

Figure 5. Soil total-N at 10 weeks after incubation
Note: Numbers followed by same letter are not significant different at Duncan test (p = 5%).

Table 1. Total-N Leachate Content

Treatment	Total-N Leachate(ppm)										Total-N Leachate Cummulative	
	2 WAI		4 WAI		6 WAI		8 WAI		10 WAI			
Without soil amendment	1.08	b	1.08	c	0.24	a	0.18	b	0.18	ab	2.77	b
Biochar 10 t/ha	0.29	a	0.29	a	0.20	a	0.13	ab	0.10	a	1.02	a
Boiler ash 10 t/ha	0.66	ab	0.29	a	0.17	a	0.09	ab	0.20	ab	1.41	b
Cattle manure 10 t/ha	0.40	a	0.35	ab	0.33	a	0.07	a	0.31	ab	1.47	b
Biochar 5 t/ha + Cattle manure 5 t/ha	0.57	a	0.40	ab	0.18	a	0.18	b	0.24	ab	1.58	b
Boiler ash 5 t/ha + Cattle manure 5 t/ha	0.77	ab	0.68	b	0.42	a	0.09	ab	0.37	b	2.33	b

Note: Numbers followed by same letter in column are not significant different at Duncan test (p = 5%).
WAI = weeks after incubation

Soil total-Nitrogen

Giving of cattle manure 10 t/ha increasedsoil total-N to 0.53% from control of 0.32% at 10 MSI (Figure 5). Manure was an organic material that quickly decomposed and produced nitrogen. Cattle manure 10 t/ha could increase soil total-N from 0.26% in the initial soil to 0.29% (Sevindrajuta, 2013). In Aryana (2014) research conducted on sandy soil in Asembagus Situbondo also showed that the best treatment in increasing levels of soil total-N at 16 weeks after planting was cattle manure 10 t/ha of 0.08%, increased of 15.9% compared to the control soil

N-total *Leachate*

In 10 weeks after incubation, leaching of total-N in treatment of biochar 10 t/ha ranged from 0.10 to 0.29 ppm/2 weeks (Table 1). While on the control total-N ranged from 0.18 to 1.08 ppm. Accumulation of N-total leachate for 10 weeks after incubation in treatment of biochar 10 t/ha was lower than other treatment that is equal to 1.02 ppm. On the control and other treatments, the accumulation of total-N leachate for 10 weeks after incubation ranged from 1.41 to 2.77 ppm. Latuponu *et al.* (2011) stated that the percentage of N leached in biochar treatment were about 33-45%, whereas in the control and soil only fertilized N without accompanied by biochar the percentage leached N reached 76-81%. Giving biochar pyrolyzed with 400^{o}C temperature had N content in the leachate of 10.87 mg/L lower than biochar pyrolyzed with 200^{o}C and 600^{o}C.

Giving of biochar 10 t/ha could reduced total-N leaching stably than other (Figure 6). Leaching of the total-N in the biochar treatment of 10 t/ha always decreased from week 2 to week 10 after incubation, whereas on the other treatment and control total-N leaching increased at week 10 after incubation. Biochar has single and double pore holes with size ranged of 2-5 µm, and specific surface area reached 330 m^2/g cause biochar has a

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high adsorption capacity of the nutrients and water (Ding *et al.*, 2010). Latuponu *et al.* (2011) states that the giving of biochar pyrolyzed with 400°C temperature has low N content in the leachate of 10.87 mg/L than biochar pyrolyzed with 200°C and 600°C. Application of biochar 20 g/kg in the soil could reduce nitrogen leaching by 11% (Laird *et al.*, 2010).

Percentage of LeachateVolume

Giving biochar 10 t/ha were able to reduce the percentage volume of leachate better than the other treatments (Table 2). Accumulated volume of leachate at treatment biochar 10 t/ha was 78.74% during 10 weeks, while for control and other treatments ranged from 81.90% to 82.22%. The specific surface area of biochar reached 330 m^2/g caused biochar has a high adsorption capacity of the nutrients and water (Ding *et al.*, 2010). Increased soil porosity showed that there was improvement in the soil micropores so that it could retain water for not easily flow into the bottom layer of the soil. Research of Masulili *et al.* (2010) showed that giving of rice hull biochar of 10 t/ha increased soil porosity followed by an increase in available soil water at 15.47% from 11.34% in the control soil.

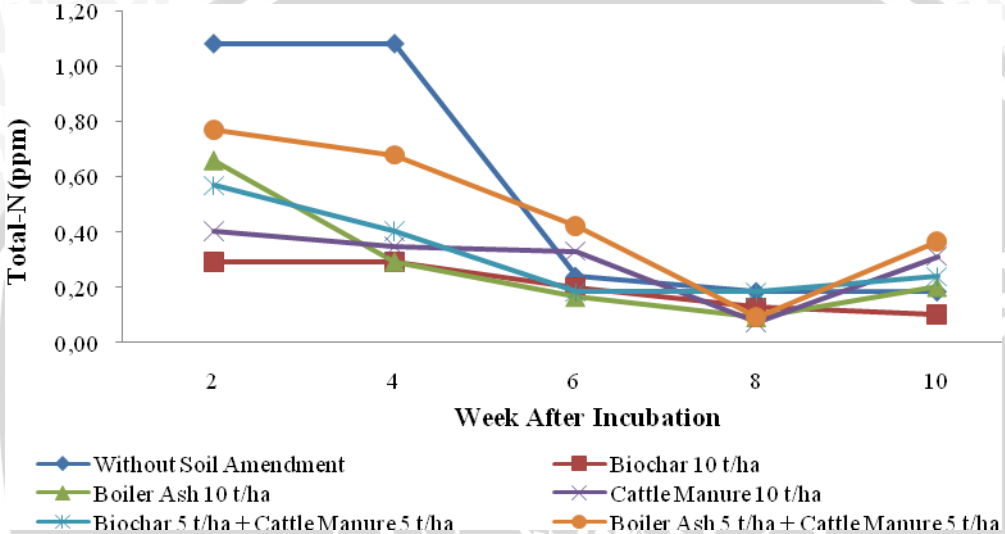

Figure 6. Dynamics of Total-N Leachate

Tabel 2. Percentage of Leachate Volume

Treatment	Percentage of Leachate Volume (%)										Leachate Volume Cummulative	
	2 WAI		4 WAI		6 WAI		8 WAI		10 WAI			
Without soil amendment	81.56	b	52.38	a	86.35	b	83.56	a	74.87	a	82.22	b
Biochar 10 t/ha	79.02	a	51.45	a	81.37	a	82.46	a	73.74	a	78.74	a
Boiler ash 10 t/ha	79.61	a	54.47	a	85.55	b	84.90	a	74.61	a	81.90	b
Cattle manure 10 t/ha	82.11	b	54.01	a	86.53	b	82.78	a	76.22	b	82.56	b
Biochar 5 t/ha + Cattle manure 5 t/ha	82.32	b	54.01	a	86.41	b	84.07	a	74.48	a	82.45	b
Boiler ash 5 t/ha + Cattle manure 5 t/ha	78.89	a	54.01	a	86.79	b	84.44	a	74.22	a	82.22	b

Note: Numbers followed by same letter in column are not significant different at Duncan test (p = 5%).
WAI = weeks after incubation

Conclusion

The best treatment to minimize the leaching of total-N as well as efforts to hold water in the soil was biochar 10 t/ha. Giving biochar 10 t/ha couldreduce total-N leaching stably than the other. Leaching of total-N in the biochar 10 t/ha treatment always decreased from week 2 to week 10 after incubation and ranged from 0.10 to 0.29 ppm, whereas in other treatment and control soil total-N leaching ranged from 0.07 to 0.77 ppm and 0.18 to 1.08 ppm, and increased at week 10 after incubation. The percentage of leachate at biochar 10 t/ha treatment was the lowest compared with control and other treatments that ranged from 51.45 to 82.46%, while in control and other treatments ranged from 52.38 to 86.79%.

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Further research needs to be done to determine the effect of biochar, boiler ash and manure as well as combinations on the nitrogen leaching in sandy soils and nutrient availability and the ability to hold water in the long term.

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